



Comparative study of the growth and carbon sequestration potential of Bermuda grass in industrial and urban areas

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Abstract

Climate change is a global phenomenon occurring throughout the world. Greenhouse gases (GHGs) especially carbon dioxide (CO₂) considered to be the major culprit to bring these changes. So, carbon (C) sequestration by any mean could be useful to reduce the CO₂ level in atmosphere. Turf grasses have the ability to sequester C and minimize the effects of GHGs on the environment. In order to study that how turf grasses can help in C sequestration, Bermuda grass (*Cynodon dactylon*) was grown both at industrial and urban location and its effect on C storage were assessed by soil and plant analysis. Dry deposition of ammonium and nitrate was maximum at both locations through the year. However wet deposition was highest during the months of high rainfall. It was examined through soil analysis that soil organic matter, soil C and nitrogen in both locations increased after second mowing of grass. However, soil pH 6.68 in urban and 7.00 in industrial area and EC 1.86 dS/m in urban and 1.90 dS/m in industrial area decreased as the grass growth continue. Soil fresh weight (27.6 g) in urban and (27.28 g) industrial area also decreased after first and second mowing of grass. The C levels in plant dry biomass also increased which showed improved ability of plant to uptake C from the soil and store it. Similarly, chlorophyll contents were more in industrial area compared to urban area indicates the positive impact of high C concentration. Whereas stomatal conductance was reduced in high C environment to slow down respiration process. Hence, from present study it can be concluded that the Bermuda grass could be grown in areas with high C concentration in atmosphere for sequestering C in soil.

Keywords: Carbon sequestration, bermuda grass, nitrogen, soil, mowing, organic matter, EC

Introduction

Greenhouse gases (GHGs) emission in 250 years created the issue of global warming. Human activities, especially the excessive burning of fossil fuels such as coal, oil and gas have resulted in an excessive increase in atmospheric carbon dioxide (CO₂) level. (Bi *et al.*, 2004). The impact of global warming triggered rise sea-level, higher frequency of fires in forests, climate change and occurrence of disasters (flooding and drought). High atmospheric CO₂ might have also resulted in increment of absorption of CO₂ by sea water, making the ocean more acidic, with potential disastrous impact on marine vegetation, fish, animals and coral reefs. Thus, technically and economically feasible strategies are needed to mitigate the consequences of increased atmospheric CO₂ (Zhang *et al.* (2012).

Various strategies could be used to capture the C in oceans, soils, vegetation along with geologic formations for extended period of time. Although oceans store much of the C in atmosphere, soil also contributes about 75% of the C

sink on land; almost three times more than the amount consumed and accommodated by living plants and animals. Therefore, soils have a major contribution in maintaining balanced global C cycle (Ecological Society of America, 2002). C storage depends on the ability of agricultural lands and forests to minimize CO₂ from the atmosphere. Trees, plants and crops reduce CO₂ by absorption through photosynthesis along with storage of carbon as biomass in various parts of tree and soil (EPA, 2008). Grasses are more unique than trees because they have an ability to store more C in the soil rather than in themselves unlike trees. When a fire comes, most C that has been stored in the soil stays there. But with trees, a fire that burns those trees release C into the atmosphere. Bermuda grass is the best turf grass which is used for C sequestration than the other agriculture plant/crops. Grasslands are called as C sinks because of their ability to store large amounts of C in them for longer periods of time. Land stores about 12%–29% of the overall soil C reserves (Eswaran *et al.*, 1993). As C storage in ground is safer than plant parts, C storage in graze lands helps and can act as a long term proposed solution to

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decrease atmospheric CO₂. Several factors result in enhanced soil C concentration in pastures as compared to agricultural lands, including thickening of roots, root exudation and minimum physical soil disturbance (Schuman *et al.*, 2001).

Bermuda grass (*Cynodon dactylon*) is a hot season turf grass for lawns, parks, and sport fields. It is well distributed in arid, semi-arid, warm and humid areas (Shi *et al.*, 2013). Turf grasses have the ability to sequester C and minimize the effects of GHGs on the environment. Thus present research was conducted to study the role of Bermuda grass on C sequestration by changing various physicochemical, physiological, mineralogical and ecological processes in soil. This study also aimed to assess the C sequestration in industrial and urban areas by the cultivation of Bermuda grass in different location and to estimate hidden anthropogenic C costs, related to the turf grass maintenance.

Materials and Methods

Plant material

Common Bermuda grass (*Cynodon dactylon*) was selected from two locations such as PMAS Arid Agriculture University lawn (Urban area) and Industrial area I-9 Islamabad-Pakistan. Existing Bermuda grass at both locations was managed through different practices (mowing, weeding and watering) to ensure uniform growth. In selected plots, planting of grass was done through sprigs and weeding, removing of insects, pests and irrigation was done according to crop demand. Urea (@ 20 kg/acre) was used as source of nitrogen on each plot to avoid damage to grasses. The study area was located at 33.6492° N, 73.0815° E (Urban area) and 33.6547° N, 73.0553° E (Industrial area). Each experiment was performed in triplicate.

Determination of dry and wet deposition of ammonium and nitrate

Wet deposition was monitored by installing rain gauges and dry deposition was configured by washing of tree leaves which was dip in water for few minutes and analyzed for ammonium and nitrate.

Rain water was collected every month (March 2016 to February 2017) in clean polythene bags with water collecting gauges installed at selected sites. The volume of rainwater was measured, and the water was analyzed calorimetrically to determine the ammonium-N and nitrate-N content (Keeney & Nelson, 1987).

Physicochemical characterization of soil

Soil analysis was done to check the level of organic matter, nitrate-N, ammonium-N, total nitrogen (N), pH, EC and soil saturation percentage at 4 different growth stages. First sampling was done before planting grass, second after establishment of grass, third one month after first mowing, fourth after one month of 2nd mowing.

Soil samples were analyzed by following procedures;

Organic matter contents

One gram air dried soil was weighed, then soil sample were transferred to 500 ml conical flask, afterwards 5 ml of K₂Cr₂O₇ and mixed well. 10 ml sulphuric acid was added and mixed. The flask was allowed to stand for 30 minutes to cool. Then 100-150 ml distilled water was added. 3 ml phosphoric acid or 0.5 g NaF was also added, 5-10 drops of indicator and it was finally be titrated against standardized ferrous sulphate to sharp green end point. In the end it runs blank and sample reading was subtracted from blank to get the actual volume of ferrous sulphate which was used to reduce potassium dichromate (Bhatti *et al.*, 2013).

Electrical Conductivity

The electrical conductivity of soil was measured with EC meter (Model CrisonMM40+, Spain) (Bhatti *et al.*, 2013).

Carbon Percentage

Determine the C Percentage out by multiplying organic matter with 0.05 (Kjeldahl, 1883).

$$C \% = \text{Organic Matter (O.M)} \times 0.05$$

Nitrogen percentage

Percentage of nitrogen (N) was found out by dividing organic matter with 1.72 (Kjeldahl, 1883).

$$N \% = \text{Organic Matter (O.M)} / 1.72$$

Nitrate-N and Ammonium-N

The extract was then analyzed by (Alpkem) continuous-flow colorimetry. Standard curve was drawn and results were compared with unknown samples. The calculations were done by following formula for nitrate-N and Ammonium-N:

$$\mu\text{g analyte per g dry soil} = (\text{mg/L}) \times \frac{1000\mu\text{g}}{1 \text{ mg soil}} \times \frac{0.021}{\text{dry weight(gm)}}$$



The dry weight value of the soil sample was based on percent moisture data for each sample, obtained separately (Keeney& Nelson, 1987).

pH

pH of soil was measured by pH meter (Bhatti *et al.*, 2013).

Table 1: Wet and dry deposition of ammonium (mg kg⁻¹) in soils of urban and industrial areas

Month	Wet Deposition		Dry Deposition		Mean
	Urban Area	Industrial Area	Urban Area	Industrial Area	
March 2016	0.31qr	0.41 kl	0.28 s	0.34 o	0.33 I
April 2016	0.36 n	0.38 m	0.33 p	0.36 n	0.35 H
May 2016	0.30 r	0.32 q	0.26 t	0.40 l	0.32 J
June 2016	0.27 t	0.36 n	0.24 u	0.42jk	0.32 J
July 2016	0.40 l	0.46 h	0.34 op	0.38 m	0.39 F
August 2016	0.44 i	0.51 f	0.38 m	0.41 kl	0.43 D
September 2016	0.42j	0.46 h	0.33 op	0.30 r	0.38 G
October 2016	0.43 j	0.48 g	0.38 m	0.38 m	0.42 E
November 2016	0.53 e	0.54 de	0.41 kl	0.45 i	0.48 C
December 2016	0.56bc	0.59 a	0.43 j	0.49 g	0.52 A
January 2017	0.49 g	0.55 cd	0.42jk	0.51 f	0.49 B
February 2017	0.51 f	0.56 bc	0.45 i	0.57 b	0.52 A
Mean	0.42 B	0.47 A	0.35 C	0.42 B	

Means having same letter are not significantly different by the LSD at 0.05 probability level

Table 2: Wet and dry deposition of nitrate (mg kg⁻¹) in urban and industrial areas

Month	Wet Deposition		Dry Deposition		Mean
	Urban Area	Industrial Area	Urban Area	Industrial Area	
March 2016	0.42 yz	0.48 x	0.43 yz	0.62 op	0.49 J
April 2016	0.33 z	0.42 yz	0.47 x	0.58 rs	0.45 K
May 2016	0.50 vw	0.59 qr	0.52 v	0.59 qr	0.55 H
June 2016	0.44 y	0.50 w	0.51 vw	0.58 rs	0.51 I
July 2016	0.55 tu	0.62 op	0.56 tu	0.65 jkl	0.60 G
August 2016	0.61 pq	0.65 jkl	0.64 lmn	0.66 hij	0.64 E
September 2016	0.56 tu	0.61 pq	0.62 nop	0.66 ijk	0.61 F
October 2016	0.58 rs	0.64 klm	0.68 gh	0.71 de	0.65 D
November 2016	0.65 jkl	0.68 ghi	0.70 ef	0.81 a	0.71 B
December 2016	0.62 op	0.67 hij	0.67 ghi	0.76 bc	0.68 C
January 2017	0.63 mno	0.69 fg	0.76 c	0.80 a	0.72 A
February 2017	0.55 u	0.57 st	0.72 d	0.78 b	0.65 D
Mean	0.54 D	0.59 C	0.61 B	0.68 A	

Means having same letter are not significantly different by the LSD at 0.05 probability level

Table 3: Effect of different growth stages of Bermuda grass on physicochemical characteristics of soil

Parameter	Urban area				Industrial area			
	BP	GE	FM	SM	BP	GE	FM	SM
Soil organic matter (%)	0.76 d	0.80 c	0.86 b	0.91 a	0.72 d	0.75 c	0.79 b	0.83 a
EC (dS m ⁻¹)	1.99 a	1.96 ab	1.90 ab	1.86 b	1.97 a	1.97 a	1.93 b	1.90 b
Carbon (%)	0.44 d	0.46 c	0.49 b	0.53 a	0.41 d	0.43 c	0.45 b	0.48 a
Nitrogen (%)	0.038 d	0.040 c	0.043 b	0.045 a	0.036 d	0.037 c	0.039 b	0.041 a
Nitrate N (mg kg ⁻¹)	14.78 c	14.91 c	16.66 b	18.52 a	14.79 b	14.90 b	16.74 a	17.86 a
Ammonical-N (mg kg ⁻¹)	9.73 c	9.87 c	11.04 b	11.97 a	9.75 c	9.82 c	11.19 b	11.87 a
pH	7.49 a	7.48 a	7.15 b	6.68 c	7.72 a	7.55 a	7.35 b	7.00 c
Soil moisture (%)	70.33 c	70.40 c	74.66 b	75.83 a	70.23 b	70.36 b	74.16 a	75.90 a

BP = Before planting of grass, GE = After grass establishment, FM = First mowing, SM = Second mowing



Moisture percentage of soil

For measuring soil moisture 10 ± 0.01 g sub-samples of soil from each replicate was weighed into pre-weighed aluminum foil dishes and dried for 24 h at 105°C in a pre-heated oven, then it was cooled in desiccators. After drying, the dishes of dry soil was reweighed and the difference in weight was recorded to determine the moisture contents from the loss of mass, expressed on an oven dry weight basis (Riaz *et al.*, 2008, Bhatti *et al.*, 2013).
 Mass of dry soil after incubation = (mass of soil + mass of dish) – mass of dish

Soil moisture percentage = $100 \text{ (mass of water/mass of dry soil)}$

Studying the physiological variation in Bermuda grass

Chlorophyll content of plant was measured through chlorophyll meter (Riaz *et al.*, 2008).

Grass samples were also analyzed for the leaf conductance by using a leaf porometer.

Electrolyte leakage was measured by using EC meter (Riaz *et al.*, 2008).

Fresh and Dry weight of above and below Ground Biomass

First of all weight of thin brown paper bags were carefully found out by using weighing balance. Collected grass samples were kept in brown paper bags and weighed again. The weight of brown paper bag + fresh plant biomass was noted down. Weighed grass samples were kept in hot air oven for 24 hour for drying at 65°C . Weight of dry plant biomass was found out by employing following formula:

Dry weight of grass shoots = (Dry Wt. of grass shoots with brown paper bags – Wt. of brown paper bags)

Dry weight of grass roots = (Dry Wt. of grass roots with brown paper bags – Wt. of brown paper bags).

Carbon in dry Biomass (mg kg⁻¹)

The value of dry shoot and root was multiplied by the factor of 0.5 to obtain the value of C in dry biomass of grass
 Carbon in dry biomass = (dry weight of Roots + dry weight of Shoots) / 0.05.

Statistical analysis

The data were analyzed by using the Analysis of Variance (ANOVA) to determine the differences in both locations and LSD was used for determining significant difference among the mean (Steel *et al.*, 1997). Statistix 8.1 software was used for analyzing the data.

Results

Dry and wet deposition of nitrogen compounds

Wet and dry deposition of nitrogen compounds (ammonia and nitrate) at both locations during different months is shown in (Table 1 & 2). It was observed that dry deposition was more than wet deposition at both urban lawn area and industrial area. Nitrate deposition was more than ammonium deposition. In urban area during summer (March-June), wet deposition of nitrate was in a range of $0.33\text{-}0.55 \text{ mg kg}^{-1}$ and dry deposition was $0.43\text{-}0.56 \text{ mg kg}^{-1}$. Similar in industrial area, where wet deposition was $0.42\text{-}0.62 \text{ mg kg}^{-1}$ and dry deposition was $0.58\text{-}0.65 \text{ mg kg}^{-1}$. For ammonium, in urban area wet deposition ranges from $0.27\text{-}0.40 \text{ mg kg}^{-1}$ and dry was $0.24\text{-}0.34 \text{ mg kg}^{-1}$ and in industrial area, low wet ($0.32\text{-}0.46 \text{ mg kg}^{-1}$) and dry deposition ($0.34\text{-}0.42 \text{ mg kg}^{-1}$) was observed. In July-September period, heavy rainfall gives maximum value of ammonia and nitrate wet and dry deposition values. But as the winter approaches (October-January) deposition values increase significantly ($p < 0.05$) at both location and gives highest values as compared to other months.

Effect of different growth stages of Bermuda grass on soil parameters

Data regarding effect of different growth stages of Bermuda grass on soil parameters is shown in Table 3. Results showed that different growth stages of Bermuda grass has positive effect on soil organic matter and it significantly changes at different growth stages. Minimum soil organic matter (%) was determined at before planting stage in urban (0.76 %) and industrial location (0.72 %). Soil organic matter starts increasing after grass mowing and highest after second mowing of Bermuda grass and it was 0.91 % at urban and 0.83 % at industrial location. Similarly, soil C (%) also changes with different growth stages of Bermuda grass, it was minimum before planting of Bermuda grass in both urban (0.44 %) and industrial area (0.41 %). However, after second mowing of Bermuda grass highest soil C percentage was examined at urban (0.53 %) and at industrial location (0.48 %). Soil nitrogen percentage (%) decreases significantly before planting of grass. In urban growing area it was 0.036 % and in industrial growing area it was 0.035%. But when mowing of grass were started, it was maximum after second mowing in both urban (0.045 %) and industrial (0.041 %) growing area respectively. The amount of nitrogen compounds in Bermuda grass was significantly increased as the growth continuously enhanced. Level of nitrate (mg kg^{-1}) and ammonium (mg kg^{-1}) was minimum before planting of grass in urban (14.78 and 9.73 mg kg^{-1}) and in industrial



growing area (14.79 and 9.75 mg kg⁻¹). However after second mowing of Bermuda grass, maximum value of nitrate (mg kg⁻¹) and ammonium (mg kg⁻¹) was observed at urban (18.52 and 11.97 mg kg⁻¹) and industrial (17.86 and 11.87 mg kg⁻¹) location. The soil moisture percentage changes at different growth stages of Bermuda grass, before planting of grass minimum soil percentage in urban (70.3 %) and in industrial (70.2 %) were recorded. But it starts increasing and after second mowing of grass it was maximum. After second mowing, soil moisture percentage was 75.8 % in urban area and 75.9 % in industrial area.

In contrast to these parameters, soil pH and EC significantly decreases with Bermuda grass growth. Highest EC value was observed before planting of grass in urban (1.99 dS m⁻¹) and in industrial area (1.97 dS m⁻¹). But after second mowing of Bermuda grass, EC value was significantly decreased in both urban (1.86 dS m⁻¹) and industrial (1.90 dS m⁻¹) area. Similarly, soil pH at before grass planting and after grass establishment was same and it was alkaline. Soil pH before grass planting was 7.49 in urban and 7.72 in industrial area. After grass establishment stage, it was 7.5 at urban and 7.55 at industrial location. But after first and second mowing decrease in pH was observed and it was minimum after second mowing stage in urban (6.68) and industrial area (7.00). Soil fresh weight (g) also depicted the same trend and it was highest at before planting stage in urban and industrial location. In urban location, 33.61 g soil fresh weight was observed while it was 32.8 g at industrial location. However fresh weight starts decreasing after first moving and it was minimum after the second mowing of Bermuda grass. Lowest fresh weight was studied in urban (27.6 g) and industrial area (27.28 g) after second mowing.

Effect of different CO₂ levels in urban and industrial areas on plant parameters of Bermuda grass at different time intervals

Effect of different CO₂ levels in urban and industrial areas on plant parameters of Bermuda grass at different

time intervals is presented in Table 4. Data related to chlorophyll content of Bermuda grass under environmental pollution showed the chlorophyll content increases as the growth continuous. Chlorophyll content was minimum at T₁ time (10 days after grass establishment) in urban (36 SPAD readings) and industrial area location (40.6 SPAD readings). But as the grass continue its growth and development rate of chlorophyll content also increases. At T₄ (75 days after grass establishment) highest chlorophyll contents were observed in leaves of Bermuda grass growing in urban area (52 SPAD readings) and industrial area (54.66 SPAD readings). Leaf conductance under high atmospheric CO₂ changes significantly at different time interval. Minimum leaf conductance was observed in both urban (0.36 cm s⁻¹) and industrial area (0.33 cm s⁻¹) at T₁ treatment (10 days after grass establishment). However, it increases with the time and maximum leaf conductance was examined in urban area (0.50 cm s⁻¹) and in industrial are (0.51 cm s⁻¹) at T₄ treatment (75 days after grass establishment). Effect of different CO₂ levels in urban and industrial areas on fresh and dry weight of above ground part (shoot) increased significantly. After 10 days of grass establishment, fresh weight of shoot was 2.75 g in urban and 2.78 g in industrial area. However, after 75 days of grass establishment as the grass grows older, shoot fresh weight was maximum. Shoot fresh weight was 7.9 g at both urban and industrial location. Similarly shoot dry weight was lowest at 10 days after grass establishment in urban (1.76 g) and industrial area (1.74 g) and highest value of shoot dry weight after 75 days of grass establishment was 4.06 g in urban and 3.92 g in industrial area. For fresh weight of below ground part (roots), Bermuda grass after 10 days of establishment yield minimum rate in urban (1.53 g) and in industrial area (1.49 g) but increases after 75 days of grass establishment in urban (3.94 g) and industrial area (3.61 g). Similar trend was observed for root dry weight, in which lowest value was observed in urban (0.73 g) and industrial area (0.69 g) after 10 days of establishment whereas it was highest at 75 days after grass establishment

Table 4: Effect of different CO₂ levels in urban and industrial areas on physiological and morphological characteristics of Bermuda grass in different time intervals

Parameter	Urban area				Industrial area			
	T1	T2	T3	T4	T1	T2	T3	T4
Chlorophyll content	36 c	43.33 b	49.33 a	52 a	40.66 c	46 b	49 a	54.66 a
Leaf conductance (cm s ⁻¹)	0.36 d	0.41 c	0.45 b	0.50 a	0.33 d	0.41 c	0.45 b	0.51 a
Shoot fresh weight (g)	2.75 d	4.78 c	6.19 b	7.99 a	2.78 d	4.73 c	6.14 b	7.9 a
Shoot oven dry weight (g)	1.76 d	2.42 c	3.12 b	4.06 a	1.74 d	2.40 c	2.94 b	3.92 a
Root fresh weight (g)	1.53 d	2.71 c	3.08 b	3.94 a	1.49 d	2.65 c	3.01 b	3.61 a
Root oven dry weight (g)	0.73 d	1.34 c	1.52 b	1.93 a	0.69 d	1.29 c	1.47 b	1.77 a
Carbon in dry biomass (mg kg ⁻¹)	50.07 d	74 c	92.87 b	119.87 a	42.73 d	75.53 c	88.33 b	112.6 a

T₁ = 10 days after grass establishment, T₂ = 25 days after grass establishment, T₃ = 50 days after grass establishment, T₄ = 75 days after grass establishment.



in urban (1.93 g) and industrial area (1.77 g). Analysis of data showed that C in dry biomass of Bermuda grass was minimum after 10 days of grass establishment. At urban location, C in dry biomass was 50.07 mg kg⁻¹ whereas at industrial it was 42.73 mg kg⁻¹. But after 75 days of grass establishment a significant increase in C in dry biomass was observed. It was 119.87 mg kg⁻¹ in dry biomass of Bermuda grass growing in urban area whereas it was 112.6 mg kg⁻¹ in dry matter of grass growing in industrial area

Effect of different CO₂ levels in urban and industrial areas on electrolyte leakage of Bermuda grass

Electrolyte leakage of Bermuda grass under different CO₂ levels in urban and industrial areas was measured in ionized and boiled deionized water. Results showed that electrolyte leakage was maximum in ionized water both in Bermuda grass leaves planted in urban area and in industrial area. In urban area, electrolyte leakage value in ionized water was 2.77 dS m⁻¹ while in industrial area; it was slightly higher (2.94 dS m⁻¹). However, in boiled deionized water, minimum electrolyte leakage was observed in urban (2.19 dS m⁻¹) and industrial location (2.21 dS m⁻¹) (Table 5).

Table 5: Effect of different CO₂ levels in urban and industrial area on electrolyte leakage from Bermuda grass

	Electrolyte leakage (dS m ⁻¹)	
	Urban area	Industrial area
IW	2.77 a	2.19 a
BW	2.19 b	2.21 b

Discussion

Statistical analysis showed that dry deposition of nitrate and ammonium was higher than wet deposition throughout the year because of drier surface that attract more pollutants due to electrostatic charges (Anderson *et al.*, 2006). The nitrate and ammonia major source of emission is vehicle, exhaust, coal combustion, fertilizer manufacturing, industrial process and burning of biomass (Li *et al.*, 2013; Sutton *et al.*, 2014). So deposition of both compounds were highest in industrial location. Maximum wet deposition of ammonium and nitrate during high rainfall period obscured. Although lighter rain cleans the pollutants but heavy rainfall results in greater amount of deposit pollutants (Anderson *et al.*, 2006). Significant increase of wet and dry deposition of nitrate was due to domestic heating, dry weather, low temperature and wind speed which led to more deposition of pollutants as these environmental condition does not allow the pollutants to transform into different compounds and diffuse (Li *et al.*, 2013). Ammonium deposition was lower than nitrate,

ammonia in atmosphere reacts with sulfate and nitrate to form ammonium sulfate and ammonium nitrate aerosols which were transported 500 km from the source before they were removed from atmosphere through rain or dry deposition (Berner and Berner, 2012).

Results related to the effect of Bermuda grass on different soil parameters depict that increase in soil organic C after first and second mowing was due to addition of grass clippings to the soil. These grass clippings after decomposing increase the organic content of soil which increase the productivity of soil by providing available nutrients and improves the microbial activity (Tahar and Keltoum, 2011). Soil organic matter consists of dead plant, animal matter and microbial biomass that contain nutrients, minerals, C and N that is mineralized and added into the soil (Campbell, 2012; Law, 2014). From the results increase in soil C was caused by the fertilizer application and irrigation. Zirkle, (2010) reported that about 7-8% dry biomass was produced in grass which is fertilized compared to unfertilized grass lawn. Through irrigation, an increase of 50.00 - 100.0 kg C ha⁻¹ yr⁻¹ soil organic C was observed. Addition of mowed grass clippings into the soil and their decomposition increases the activity of soil microorganisms for 1-7 days and increase the storage of C up to 11-59 % (Canadell *et al.*, 2007). It was observed from the statistical analysis that nitrogen content of soil increases after grass mowing which was due to the decomposition of plant residue in soil which increases the soil organic matter thus increases microbial activity which changes atmospheric nitrogen into usable form for the plants. Also, the addition of mowed grass clippings increases nitrogen concentration both in plants and in soil (Law, 2014).

Similarly, higher organic content in soil, increases the microbial activity which enhance the organic nitrogen mineralization through, decomposition of animal and plant matter, ammonification (conversion of nitrogen into ammonia through nitrogen fixing bacteria) and nitrification (conversion of ammonia to nitrate) thus increasing nitrate and ammonium level in soil (Ratsep, 1996; Plant *et al.*, 2012). The application of nitrogenous fertilizer plays an important role in increasing nitrate and ammonium level in soil. In present result, ammonium level was lower than nitrate level because of nitrification process or uptake of ammonia by the growing plants from the soil (Kaiser *et al.*, 2012). Presently Increase in fresh weight of soil at before planting stage was due to accumulation of various pollutants in soil that affects its organic matter and microbial growth which makes the soil compacted. Turf grasses improve the soil properties and its structure like soil aggregation, tilth, reduce erosion, increase water and nutrient retention and filter pollutants from the soil (Zarkile, 2010). This resulted into change of soil texture from



compacted to loose form. As loose soil is lighter than compacted form so decrease in soil fresh weight at first and sowing mowing showed that soil was porous and well aerated as compared to compacted soil. After first and second mowing, grass clippings were added into soil as dead plant material which work as a mulch. As the mulch start decomposing, it increases the soil organic matter, reduce water loss and retain moisture. Decrease in soil pH after management practices (mowing) were due to the addition of organic matter in soil. As grass clippings decompose in soils it turns into organic matter which results in lowering of soil pH (Childers, 2006). EC (electrical conductivity) is a measurement of salt level. EC is correlated with pH. As pH of soil decreases and at 6.8 range which means that soil has low level of salts accumulation. Also the increase in soil organic matter which prevents the movement of salt to the soil surface through evaporating water and increases the leaching down of salts from the root zone. Thus removing salts from the soil causes a decrease in soil EC value (Ramachandra, 2006).

Increase in chlorophyll content in industrial area improves the photosynthesis rate that causes an increase in assimilation of CO₂ which ultimately resulted in increase in plant growth and production of biomass (Bhatt *et al.*, 2010). Decrease in leaf conductance is one of the common responses of the plants under high atmospheric CO₂ to reduce the transpiration loss (water loss) through stomata closing and opening (Lammerstma *et al.*, 2011). However, as the grass growth continuous, leaf conductance increases because of increase in storage of C and nitrogen in plant and soil which ultimately increases the plant growth. As highest nitrogen value under atmospheric CO₂ increases the leaf conductance. Although leaf conductance was reduced but it increases the photosynthesis rate and improves the plant water use efficiency (Karnosky, 2011).

Increase in fresh and dry weight of roots and shoots were due to lawn management practices such as mowing, fertilizer application (urea and DAP) and irrigation that increases the plant biomass by increasing the soil organic content which ultimately improves the nutrient availability and increases the plant growth (Zirkle, 2010). Increase in plant biomass in industrial area is also proved the adaptability of plant to the pollutant environment (Bhatt *et al.*, 2010). An increase of C in dry biomass become older was due to the elevated atmospheric CO₂ in industrial area which increases the photosynthetic rates that enhance the plant growth and development by increasing the C assimilation (Gautier, 2008). Increase in electrolyte leakage occurred due to stress conditions. Elevated atmospheric CO₂ increases the acidification of cells, which increases the production of reactive oxygen species (ROS). These reactive oxygen species (ROS) alter different compositional

and physical properties of cell membranes which results in change in lipid composition, separation of membrane phase and increase in leakage of electrolytes from the cell (Richardson, 2002; Omasa *et al.*, 2012).

It was concluded from the results that Bermuda grass was effective in sequestering of C and nitrogen in both soil and plants with the help of different management practices (irrigation, fertilizer application and mowing). Thus, this grass can be used as an environmental cleaner and can be grow in highly polluted areas.

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