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AGRONOMY AND HORTICULTURE | ORIGINAL ARTICLE

Medicinal Plants as a Potential Strategy to Reduce Greenhouse Gas Concentration Under Egyptian Conditions

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ABSTRACT

The earth's climate is changing because of the increase in greenhouse gas (GHG) concentration. Carbon dioxide (CO_2) is the primary greenhouse gas contributing to recent climate change. The study was carried out in 2019 and 2020 on six-year-old trees of moringa (*M. oleifera*) and pecan (*C. illinoinensis*) in two governorates of Egypt (Al-Dakahlia and El-Bihera) to investigate the potential effect of *M. oleifera* and *C. illinoinensis* trees on reducing greenhouse gas such as carbon dioxide. The results indicate that growth performance [plant height (m), diameter (m), volume (m3), and biomass (kg/tree)]; carbon content (kg/tree), and carbon dioxide sequestration/tree (kg/tree) of *M. oleifera* was significantly higher ($P \leq 0.05$) as compared to *C. illinoinensis*. Similarly, the maximum sequestration of CO_2 was recorded (97.60 and 111.70 Kg/tree) for *M. oleifera* in 2019 and 2020, respectively. *M. oleifera* was the dominant tree in growth, carbon stock, and carbon sequestration than the other species (*C. illinoensis*). Therefore, *M. oleifera* can be recommended as a potential crop to mitigate global warming.

1. Introduction

Climate change is considered one of the most serious global problems, affecting many sectors of economic growth in the world (Lema and Majule, 2009). It is defined as the shift in climate patterns mainly caused by greenhouse gas emissions (GHG) from natural systems and human activities (IPCC, 2007). Excessive concentration of carbon dioxide (CO_2) in the upper atmosphere is the main cause of the greenhouse effect and the increase in atmospheric temperature (IPCC, 2014; Nunes et al., 2019). Carbon dioxide accounts for 72 % of all anthropogenic greenhouse gases, causing 9 – 26 % of the global warming climate (Ugle et al., 2010). The total annual global CO_2 emission for 2022 increased by 5.5% relative to 2019, reaching 37.55 billion metric tons worldwide (Liu et al., 2023). CO_2 emissions impact is continually rising. In Egypt, it rose to 275 million ($MTCO_2e$) in 2010 and is projected to be above 550 $MTCO_2e$ by 2030 (Hamza, 2021). The increasing CO_2 emissions are of major concerns for entire world as well addressed in Kyoto protocol (Chavan and Rasal, 2011). Therefore, it is necessary to develop innovative strategies that can reduce CO_2 emissions to tackle climate change. Carbon sequestration is a critical strategy in the fight against climate change.

Carbon capture and sequestration (CCS) through trees is considered one of the most cost-effective strategies for mitigation of global warming and global climatic change. This process is closely related to the CO_2 emissions reduction order, which was imposed by the Kyoto Protocol established in 2004 (Takimoto et al., 2008; Aggangan, 2001; FAO, 2010; Chavan and Rasal, 2012).

Several studies have demonstrated the capacity of trees to sequester atmospheric carbon and convert it into biomass through photosynthesis, making them beneficial in mitigating climate change by lowering atmospheric CO_2 concentrations (Bealey et al., 2007 Afzal and Akhtar, 2013; Kabisch et al., 2016; Kiran and Kinnary, 2011; Smaje, 2015; Hurd et al., 2022). Tak and Kakde (2020) reported that, the carbon sequestration was highest in *Azadirachta indica*, 3289 kg/tree, followed by *Ficus benghalensis* (2375 kg/tree), *Tamarindius indica* (1666

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kg/tree), *Casurina equisetifolia* (1530 kg/tree) and *Pongamia pinnata* (865.9 kg/tree).

Moringa (*M. oleifera*) and pecan (*C. illinoinensis*) trees can play a crucial role in the atmospheric carbon sequestration by efficiently converting the CO_2 into huge biomass (Mohammed, 2015; Salih et al., 2017; Pieterse, 2020; Chauhan et al., 2021; Jat et al., 2022; Zermeno et al., 2023). However, very limited studies have been conducted on *M. oleifera* and pecan *C. illinoinensis* related to evaluation of their carbon sequestration potential (Chauhan et al., 2021; Jat et al., 2022; Zermeno et al., 2023).

Therefore, the present study aimed to evaluate the potential of carbon sequestration of moringa (*M. oleifera*) and pecan (*C. illinoinensis*) in two governorates of Egypt (El-Bihera and Al-Dakahlia).

2. Materials and Methods

2.1. Study area

The present study was conducted in 2019 and 2020 on moringa (*Moringa oleifera* L) and pecan (*Carya illinoensis* Wang. K. koch) trees grown in private orchards located at Al-Dakahlia and El-Bihera governorate, Egypt. The trees were approximately six years old at the experiment's beginning and were planted 5×5 m apart. Soil physical and chemical analyses of experimental areas are shown in Table 1.

Table 1. Soil physical and chemical analyses of experimental areas at the beginning of experiment 2019

Properties	Al-Dakahlia	El-Bihera
Particle size distribution %		
Sand	92.76	90.0
Salt	5.86	5.0
Clay	1.38	5.0
Texture class	Sandy	Sandy
Bulk Density (g/cm^{-3})	31.06	1.68
Organic matter %	0.32	0.06
$CaCO_3$	10.22	17.50
pH	7.88	8.20
E.C. (dS/m)	2.67	1.50
Soluble cations (meq/L)		
N	0.14	0.10
P	0.03	0.44
Ca^{2+}	0.15	8.88
K^{+}	0.21	0.98
Mg^{2+}	0.04	7.65

2.2. Data collection

2.2.1. N, P and K leaf contents of M. oleifera and C. illinoinensis.

At harvest, leaf samples were collected to measure nitrogen (N), phosphorus (P) potassium (K) concentration. Nitrogen percentage was determined by the Microkjeldahl methods described by Pregl (1945). Phosphorus percentage was determined colorimetrically according to Murphy and Riley (1962). Potassium was determined according to Jackson (1973) by flame photometer.

2.2.2. Tree height (H) and diameter at breast height (DBH)

The biomass (aboveground and belowground biomass) of *M. oleifera* and *C. illinoinensis* were estimated using an Allometric model developed by Amoah et al. (2020). All trees were measured for height and diameter at breast height (DBH) using a clinometer and measuring tape, respectively. Each tree was measured for total height and DBH at 1.37 m from the ground (Nizami et al. 2009; Tagupa et al., 2010; Nizami, 2012; Liu et al., 2018).

2.2.3. Tree volume (V)

It was calculated using the following equation:

$$\text{Tree volume } (\mathrm{m}^3) = \mathrm{a} \times \mathrm{DBH} \times \mathrm{H}$$

Where, a is the stem form factor; DBH is the diameter at breast height; and H is the total height.

The value of “a” was set to 0.4 and 0.61 for moringa and pecan, respectively (Pandya et al., 2013 and Yadav et al., 2017).

2.2.4. Aboveground (AGB) and belowground biomass (BGB)

Aboveground biomass (kg/tree) was calculated by multiplying wood density with volume, volume calculation based on diameter at breast height (DBH), and tree height using the following equation (Pandya et al., 2013):

$$\mathrm{AGB} = \text{Wood volume } (\mathrm{m}^3) \text{ x wood density } (\mathrm{kg/m}^3)$$

Belowground Biomass (kg/tree) has been obtained by multiplying Above-Ground (AGB) with 0.20 as the root shoot ratio (Mohammed, 2015).

2.2.5. Total biomass (TB)

Total biomass (kg/tree) was calculated by adding aboveground and belowground biomass (Sheikh et al., 2011).

2.2.6. Total carbon content (TCC)

Generally, carbon of any species is usually considered to be as 50% of its total biomass (TB) (Eggleston et al., 2006). It was expressed as kg/tree.

2.2.7. Carbon dioxide sequestered/tree

It was calculated using the following equation (Kauffman and Donato, 2012):

$$CO_2 \text{ sequestered (kg/tree)} \\ = \mathrm{TCC} \times \text{ Atomic weight of Carbon (ATWC; 3.6663)}$$

2.2.8. Carbon dioxide sequestered/tree/year

It was calculated by dividing the weight of CO_2 sequestered in the tree by the age of the tree.

2.3. Statistical analysis

The experimental design was completely randomized with three replications (three trees per replication). Data was analyzed using the SPSS 17.0 (Statistical Packages for the Social Sciences, released 23 August 2008). The mean comparison was carried out using the Least Significant Difference (LSD) Test for p≤0.05.

3. Results and Discussion

3.1. N, P and K leaf contents

The study revealed significant (P ≤ 0.05) differences for N, P and K leaf contents among different tree species tree species (*M. oleifera* and *C. illinoinensis*). Based on the data presented in Figure 1, it was observed that *M. oleifera* showed the maximum N (5.21 and 5.44 %), P (0.77 and 0.82 %) and K (2.11 and 2.33%) in 2019 and 2020, respectively. On other hand, *C. illinoinensis* showed the minimum N (3.22 and 4.02 %), P (0.47 and 0.57 %), and K (1.33 and 1.41 %) in 2019 and 2020, respectively.

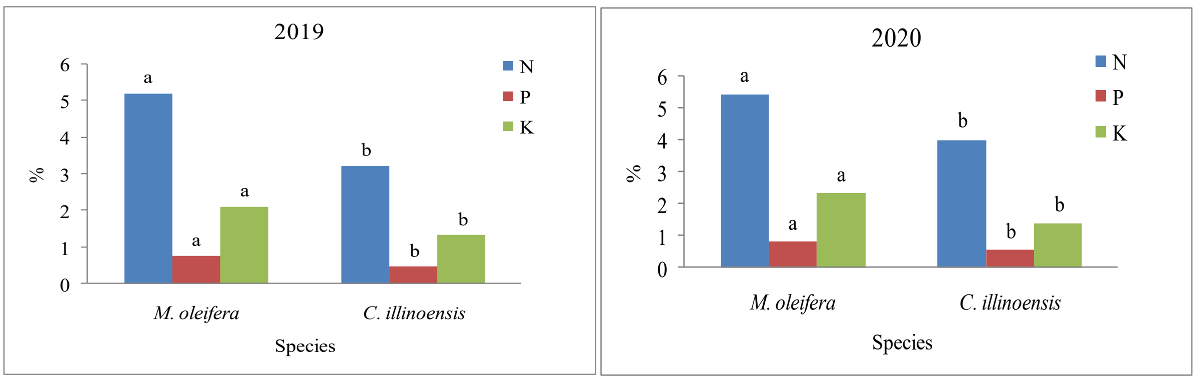


Figure 1. Concentration of nitrogen (N), phosphorus (P), and potassium (K) as a percentage of dry matter in leaves of *M. oleifera* and *C. illinoinensis* in 2019 and 2020. Means in the same bar followed by the same letter(s) are not significantly (p≥ 0.05) different.

3.2. Growth parameters

The study revealed significant (P≤0.05) variations in growth performance (height (H), diameter at breast height (DBH), and volume) for tree species (*M. oleifera* and *C. illinoinensis*) in 2019 and 2020. Based on the data presented in figure 2, it was observed that *M. oleifera* exhibited the maximum averages of height (7.35 and 7.63 m), diameter at breast height (0.24 and 0.25 m), and volume (0.17and 0.19 m^3) in 2019 and 2020, respectively. On other hand, *C. illinoinensis* exhibited the minimum averages of height (4.98 and 5.53 m), diameter at breast height (0.09 and 0.1 m), and volume (0.02 and 0.03 m^3) in 2019 and 2020, respectively. In the present study, the increase in growth performance of *M. oleifera* may be attributed to an improved uptake of N, P, and K (Zayed, 2012). Increased uptake of nitrogen might have resulted in vigorous growth and higher photosynthetic rate (Gnanasundari et al., 2019).

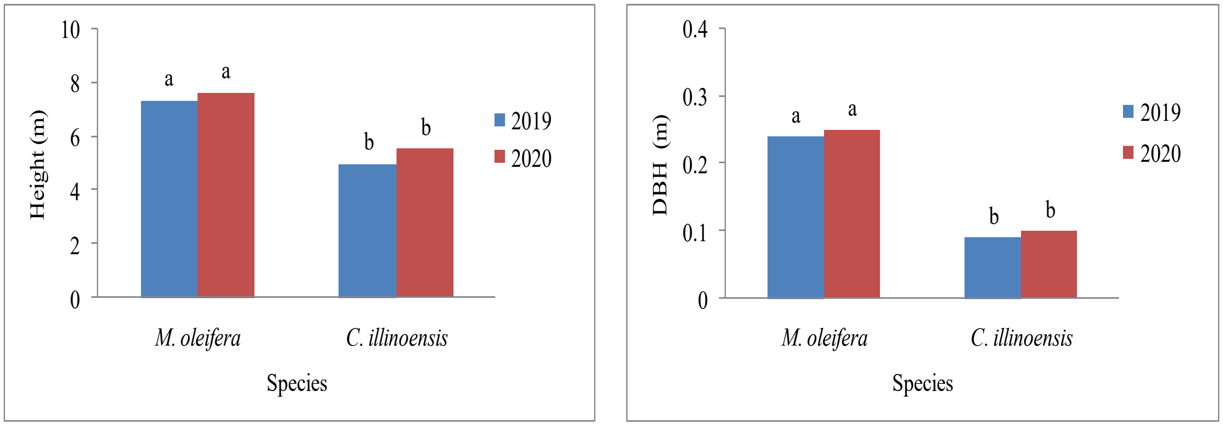
3.3. Aboveground and belowground biomass

Variations in aboveground (AGB), belowground (BGB) and total biomass (TB) is evident among tree species (*M. oleifera* and *C. illinoinensis*) in 2019 and 2020, as highlighted in Figure 3. Among two species, *M. oleifera* exhibited the highest AGB (44.37 and 50.78 kg/tree), BGB (8.87 and 10.16 kg/tree) and TB (53.24 and 60.94 kg/tree) in 2019 and 2020, respectively. In contrast, *C. illinoensis* demonstrated the lowest AGB (19.05 and 26.12 kg/tree), BGB (3.81 and 5.22 kg/tree) and TB (22.86 and 31.34 kg/tree) in 2019 and 2020, respectively.

3.4. Carbon stock and CO_2 sequestration

Observation from Table 2 revealed significant (p ≤ 0.05) variations in carbon stock, CO_2 sequestration/tree and CO_2 sequestered/tree/year by *M. oleifera* and *C. illinoensis* in 2019 and 2020. Among the species studied, *M. oleifera* showed that maximum amount of carbon stock (26.62 and 30.47 kg/tree), CO_2 sequestration/tree (97.60 and 111.70 kg/ tree) and CO_2 sequestered/tree/year (8.13 and 8.59 kg/tree/year) in 2019 and 2020, respectively. On other hand, the lowest amount of carbon stock (11.43 and 15.67 kg/tree), CO_2 sequestration/tree (41.91 and 57.46 kg/ tree) and CO_2 sequestered/tree/year (6.99 and 8.21 kg/tree/year) in 2019 and 2020, respectively. *M. oleifera* had higher height, diameter at breast height, and volume, resulting in an enhanced growth parameters and biomass and carbon accumulation.

In this study, the differences in biomass and carbon accumulation among the two species could be largely due to differences in the growth parameters (height, diameter at breast height and volume) of trees as indicated by Afzal and Akhtar, (2013), Chauhan et al (2021), Darmawan et al (2022) and Ali et al (2023). Moreover, it was found that the trees with lager diameter breast height stored greater amount of carbon. Measured tree height and tree DBH indicates positive correlation, i.e., with increase in tree



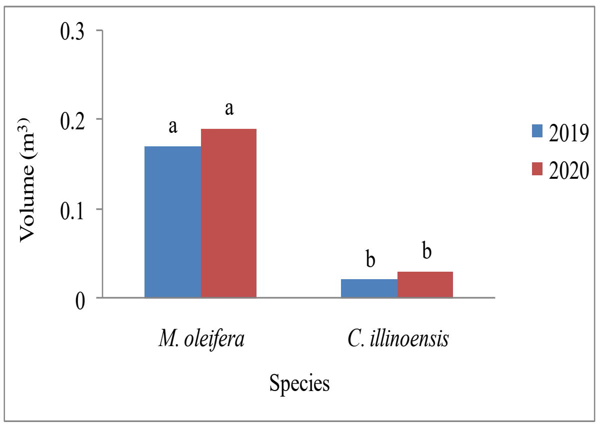
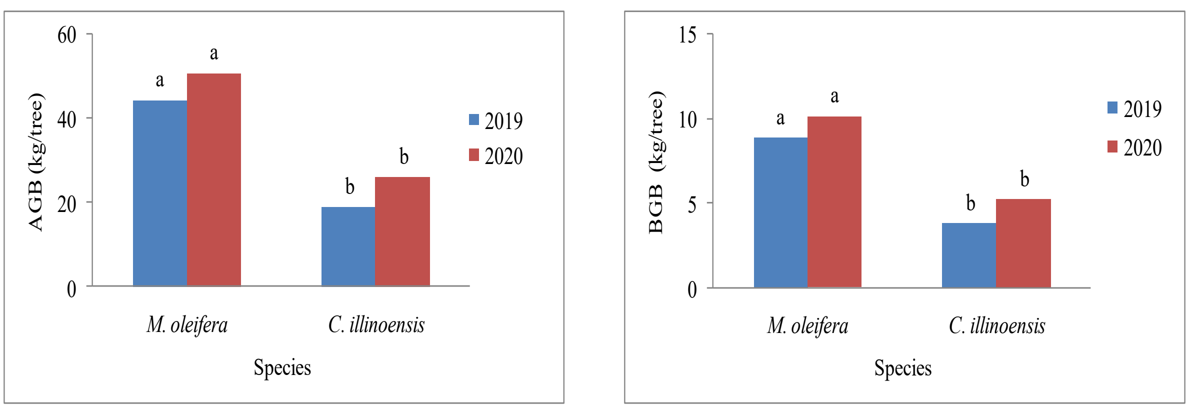


Figure 2. Growth performance of *M. oleifera* and *C. illinoensis* trees during 2019- 2020. DBH diameter at breast height. Means in the same bar followed by the same letter(s) are not significantly (p≥ 0.05) different.



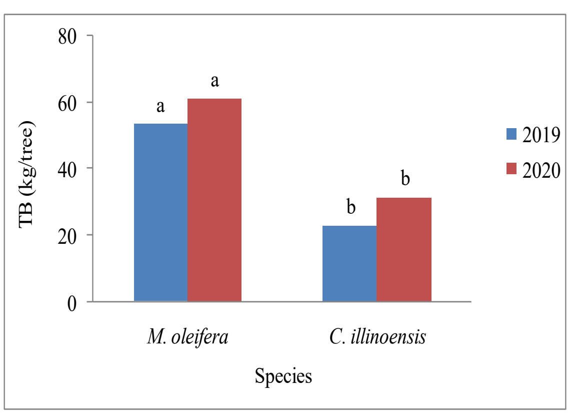


Figure 3. Biomass accumulation of *M. oleifera* and *C. illinoensis* during 2019- 2020. AGB = aboveground biomass, BGB = belowground biomass and TB = Total Biomass. Means in the same bar followed by the same letter(s) are not significantly (p≥ 0.05) different.

Table 2. Carbon sequestration of *M. oleifera* and *C. illinoensis* during 2019- 2020

Species	*Total carbon stock per tree (kg)		*Carbon dioxide sequestered per tree (kg)		*Carbon dioxide sequestered per tree per year (kg)	
	2019	2020	2019	2020	2019	2020
M. oleifera	26.62 a	30.47 a	97.60 a	111.70 a	8.13 a	8.59 a
C. illinoensis	11.43 b	15.67 b	41.91 b	57.46 b	6.99 b	8.21 b

*Means in the same column followed by the same letter(s) are not significantly ($p \geq 0.05$) different.

height, DBH increases and vice versa. Similarly, tree height and tree DBH were positively correlated with AGB. These findings are agreed with those of Guiabao, (2010), Vishnu and Patil (2016), Jithila and Prasadan (2018) and Pascua et al. (2021) who reported that trees with maximum DBH have higher aboveground (AGB), belowground (BGB) and carbon stock.

The above results followed a similar trend with the carbon sequestration levels Ramswaroop et al (2022) experimented on *M. oleifera*, *Terminalia arjuna*, *Azadirachta indica*, *Acacia nilotica*, *Millettia pinnata*, *Albizia lebbeck*, *Gmelina arborea*, *Dalbergia sissoo* and *Justicia adhatoda*. Moreover, Mabapa et al (2018) evaluated the physiological parameters of three tree species (*M. oleifera*, *Colophospermum mopane* and *Sclerocarya birrea*) for their comparative capability to mitigate climate change through carbon sequestration under semi-arid conditions and concluded in their study that *M. oleifera* was superior in carbon sequestration among the three species.

4. Conclusion

The present study shows a promising capability of the *M. oleifera* and *C. illinoensis* species in seizing the atmospheric CO_2. Results revealed that the specie *M. oleifera* has the highest amount of carbon sequestered (26.62 and 30.47 kg/tree) in 2019 and 2020, respectively. The investigation data will be helpful to evaluate the role of *M. oleifera* and *C. illinoensis* trees in reducing atmospheric the carbon dioxide

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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