INFLUENCE OF DIFFERENT ORGANIC MANURES AND BIOCHAR ON GROWTH AND YIELD OF CELERY (*Apium graveolens*)

NUR FATAMA SATU

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DEPARTMENT OF HORTICULTURE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

JUNE, 2021

INFLUENCE OF DIFFERENT ORGANIC MANURES AND BIOCHAR ON GROWTH AND YIELD OF CELERY (*Apium graveolens*)

BY

NUR FATAMA SATU

REGISTRATION NO. 14-06092

A Thesis Submitted to

The Department of Horticulture, Faculty of Agriculture

Sher-e-Bangla Agricultural University, Dhaka-1207

In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (MS)

IN HORTICULTURE

SEMESTER: JANUARY – JUNE, 2021

Approved by:

Dr. Abul Hasnat M. Solaiman
Professor
Dept. of Horticulture
SAU, Dhaka
Supervisor

Dr. Jasim Uddain
Professor
Dept. of Horticulture
SAU, Dhaka
Co-Supervisor

Dr. Khaleda Khatun
Professor
Chairman
Dept. of Horticulture
SAU, Dhaka

DEPARTMENT OF HORTICULTURE
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled **"INFLUENCE OF DIFFERENT ORGANIC MANURES AND BIOCHAR ON GROWTH AND YIELD OF CELERY** (*Apium graveolens*)" submitted to the Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE**, embodies the result of a piece of bona fide research work carried out by **NUR FATAMA SATU,** Registration No. **14-06092,** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

I further certify that such help or sources of information as has been availed of during the course of this investigation have been duly acknowledged.

Dr. Abul Hasnat M Solaiman
Professor
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka-1207
Supervisor

Dated: ______________
Place: Dhaka, Bangladesh

DEDICATED TO

BELOVED PARENTS

ACKNOWLEDGEMENTS

Authoress is prostrated before Almighty Allah, most merciful, beneficent and the lord of the Day of Judgment for giving the strength and courage to successfully complete the research work.

This thesis owes its existence to the help, support and inspiration of several people. Firstly, I would like to express my sincere appreciation and gratitude to my supervisor, Prof. Dr. Abul Hasnat M. Solaiman, Department of Horticulture, Shere-Bangla Agricultural University (SAU), Dhaka, for his guidance and constant encouragement during my research. His support and inspiring suggestions have been precious for the development of this thesis content.

Then I would like to express heartfelt thanks to my co-supervisor, Prof. Dr. Jasim Uddain, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, for his utmost co-operation and constructive suggestions to conduct the research work.

I express my sincere respect to the Chairman, Prof. Dr. Khaleda Khatun, Department of Horticulture and all the teachers of Department of Horticulture, Sher-e-Bangla Agricultural University, who have been a constant source of encouragement and enthusiasm during the two years of my Master's program. II

My deepest gratitude goes to my family for their unflagging love, unconditional support, ever ending prayer, encouragement, sacrifice and dedicated efforts throughout my life and my studies.

Finally, I wish to thank my friends especially Afroza Khatun, Sajia Tasnim, Khairun Nahar and Joy for their direct and indirect help in the endeavor to complete this thesis.

\- Authoress

INFLUENCE OF DIFFERENT ORGANIC MANURES AND BIOCHAR ON GROWTH AND YIELD OF CELERY (*Apium graveolens*)

ABSTRACT

An experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November, 2019 to January, 2020 to evaluate the effect of organic manures and biochar on growth and yield of celery. The experiment consisted of two factors: Factor A: Organic Manures (four levels) as OM_0: Control i.e., no manure, OM_1: Vermi-compost @3.5 t/ha, OM_2: Cowdung @10 t/ha, OM_3: Trichocompost ((@1.5t/ha) trichoderma treated with Vermi-compost Factor B- Biochar (three levels) B_0: Control, B_1: Biochar @4 t/ha, B_2: Biochar @2 t/ha. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Significant variation was found with the treatments. In case of combined effect of organic manures and biochar, maximum fresh weight of leaves was achieved from OM_3B_1 treatment (154.90 g) and marketable number of leaves at 55 DAT was highest at OM_3B_1 treatment (23.22). For combined effect of organic manures and biochar, length of celery leaves was highest at OM_3B_1 which was statistically similar with OM_3B_2. Economic analysis revealed that OM_3B_1 gave the maximum gross return and net return with significant benefit cost ratio (**2.51**). So, considering all, it can be concluded that, OM_3 treatment Trichocompost@ 1.5 t/ha) combined with B_1 Biochar@ 4 t/ha) provided the best result for growth and yield of celery for commercial cultivation in Bangladesh.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

Abbreviation	Full Word
@	At the rate of
AEZ	Agro-Ecological Zone
Agric.	Agricultural
Anon.	Anonymous
cm	Centimeter
CV	Coefficient of variation
cv.	Cultivar
DAT	Days After Transplanting
°C	Degree Celsius
et.al.	And others
Expt.	Experiment
g	Gram
ha	Hectare (10000 meter square)
Hort.	Horticulture
i.e.	That is
J.	Journal
kg	kilogram
LSD	Least Significance difference
ppm	parts per million
Res.	Research
Sci.	Science
t	Ton
Tk.	Taka
UK	United Kingdom
Viz.	Namely

CHAPTER 1

INTRODUCTION

CHAPTER 1

1 INTRODUCTION

Celery (*Apium graveolens*) is a popular vegetable crop that is now grown all over the world. It's a wetland plant from the Apiaceae family that thrives in the winter and early spring. It requires warm days and cool nights, low humidity and least six hours of full sunlight, as well as a pH of 6.0-7.5 and soil have large number of organic fertilizers (Ryder, 1979). It is a biennial or annual crop that is commonly planted for its fresh leafstalks, which are used as a vegetable and seeds which yield essential oil and contain 2-3% essential oil. Organic manures are strongly recommended in agriculture to provide soils with plant nutrients and to enhance soil chemical, physical, and biological qualities (Brandy & Weil, 2001). Its stalks, leaves, or hypocotyl are consumed and used in cooking, depending on locality and cultivar. Celery seeds are also a spice, and its extracts are utilized in herbal remedies.

The cultivar known as Pascal celery dominates commercial celery farming in North America. They are divided into two categories: white and red. The stalks grow in a compact, straight, parallel cluster, which is how they're usually sold fresh. They are sold without roots and with only a small bit of green leaves. The stems usually eaten, used in salads or added to soups, stews, and pot roasts as a seasoning. Celeriac, sometimes called as celery root in Europe, is another popular variation (*Apium graveolens var. rapaceum*). In the winter, the bulb can be stored for months and is typically used as a key element in soup. It's also shred able and can be used in salad (Newman & Jacqueline 2006). It's a biannual or annual erect herb. Roots are plentiful, delicious, and well-developed. The stem branches are angular or fistular in shape and jointed prominently. Celery is a herbaceous plant that grows 60 to 90 centimeters tall. It has a shallow tap root system and a succulent, branching, and ridged stem (Asif *et al.*, 2011). Leaves of celery have moisture 88.0%, protein 6.3%, fat 0.6% minerals 2.1%, fiber 1.4% and carbohydrates 1.6% respectively. Calcium, phosphorus, iron, carotene, riboflavin, niacin, and vitamin C were among the minerals and vitamins present (Khalil *et al.* 2019).

Carbohydrates, flavonoids, alkaloids, and steroids are the phytochemical components found in celery. Celery plants are a rich source of natural active compounds that varies on mechanism and biological features. Plants' free radical scavenging and antioxidant capabilities are attributed to a variety of phytochemical substances, particularly polyphenols (such as flavonoids, phenolic acids, and tansipropanoids) (Nickavar *et al.*, 2007). Many researchers have examined into the antioxidant properties of celery (*Yildiz et al.*, 2008). According to a recent study, celery can be employed as a therapeutic herb for the fight against SARS-CoV-2 (Rupasinghe, 2020; *Shawky et al.*, 2020; Thakur et al., 2020).

As a result, celery will be a promising crop to produce fertilization is a method of increasing the amount of nutrients availability for the plants. The plant receives two forms of fertilizer: inorganic fertilizers and organic fertilizers. Organic fertilizer comes in two forms: organic solid fertilizer and organic liquid fertilizer. By considering environmental and agricultural economic aspects, irrigation and nitrogen levels may be optimized to improve crop quality (Mateo-Sagasta, 2017).

Biochar is made from the thermochemical reaction of biomass. It is one kind of charcoal which is used as a ameliorant of soil for both carbon sequestration and development of soil health. It is produced due to the biomass pyrolysis in absence of oxygen. It is a carbon-riching stable solid that can last for thousands of years in soil. Biochar has the potential to help combat against global warming and climate change. It is produced through pyrogenic carbon capture and storage (PyCCS) processes and improves soil fertility in acidic soils, increases agricultural production, and protects against several foliar and soil-borne diseases (Constanze et al., 2018). The physical and chemical features of biochars are essential for their use in industry and the ecosystem. Biochars are subjected to several characterization tests in order to establish their performance in a specific application. The proximate and elemental composition, pH value, and porosity, all of which correspond with different biochar properties, can be used to characterize the qualities of biochar. The atomic ratios of biochar, such as H/C and O/C, are related to biochar features such as polarity and aromaticity, which are significant to the organic content (Crombie *et al.*, 2012). Because functional groups containing hydrogen and oxygen are released during the carbonization process, both the H/C and O/C ratios decrease (Weber and Peter 2018). Biochar is a source of biomass previously heated in the absence or low concentration of oxygen with the purpose of application to the soil this process is called pyrolysis (Maia *et al.*, 2001). So, Biochar may enhance the agricultural productivity & combat land degradation by improving soil health (Kokana *et al*, 2001). The research could contribute new utilizations of celery & to development of new markets for celery producers in the long term.

Objectives of the Research Work:

- To find out the effect of organic manures on the growth and yield of celery
- To find out the optimum level of biochar on the growth and yield of celery
- To investigate the suitable combination of organic manures and biochar on the growth and yield of celery.

CHAPTER 2

REVIEW OF LITERATURE

CHAPTER 2

2 REVIEW OF LITERATURE

Despite the fact that celery is grown in numerous nations, the United States remains the leading producer, followed by Mexico. Celeriac, often known as root celery, is more commonly grown in Europe than stalk celery. Chinese or leaf celery is more often grown in the Orient than either of the other varieties. Celery is also grown for its seeds, which are used as a flavoring agent in several countries.

2.1 Influence of Different Organic Manures

Liu *et al.* (2015) carried out an experiment to find out the effect of different kinds and dosage of organic manure on the yield and quality of celery by field test. The result showed, the growth, physiological activity, yield and quality of celery were improved by chicken excrement and pig dung significantly. On the increasing of yield, the chicken excrement > oil cake > pig dung. Vitamin C and soluble sugar of celery were increased by the three kinds of organic manure, its followed: chicken excrement>pig dung>oil cake. The nitrate content of celery was reduced significantly by the organic manure, it rang reached 7.1%-53.1%. The effect on nitrate content followed this order: chicken excrement>pig dung>oil cake. The nitrate content of celery increased followed the fertilized level of oil cake and chicken excrement, but the pig dung followed the contrary rule. Under these levels of the organic manure, the heavy metal elements of Pb, Cd, Cu, Zn in leaf and petiole of celery were significantly lowered the national standard. But the heavy metal elements of Cu, Zn in leaf were increased significantly with the increase of application of pig dung. These results suggested that the heavy metal elements of Cu, Zn would contaminate celery under the condition that application of abundant pig dung for long time.

GAO *et al.* (2011) conducted a study to determine the effects of combined application of organic manure and chemical fertilizers on yield and quality of celery, and accumulation and leaching of soil nitrate under greenhouse condition. The results show that compared with the conventional fertilization with much higher rates of N, P_2O_5 and K_2O, there are not significant differences of celery yields under the different combined application patterns of organic manure and chemical fertilizers with proper rates of N,P_2O_5 and K_2O.The average output of the combined application patterns of organic manure and chemical fertilizers is significantly increased by 22306 RMB Yuan/ha, with the highest income for the combined application pattern of 3/4 N in chemical fertilizer and 1/4 N in organic manure. Compared with the chemical fertilizer application pattern and the conventional fertilization, the nitrate contents in edible celery parts are decreased by 16.7% and 26.1%, while the Vc contents in edible celery parts are increased by 36.8% and 112.2% under the combined application patterns of organic manure and chemical fertilizers. There are significant accumulations of soil nitrate at depths of 60-80 and 80-100 cm after celery harvest under the conventional fertilization, whereas no significant accumulations of soil nitrate at depths of 60-80 and 80-100 cm after celery harvest are observed for the combined application patterns of organic manure and chemical fertilizers. Compared with the chemical fertilizer application pattern and the conventional fertilization, the NO-3-N leakage rates in the leakage water are significantly decreased by 57.5% and 61.9% under the combined application patterns of organic manure and chemical fertilizers, with the lowest NO-3-N leakage rate for the combined application pattern of 3/4 N in chemical fertilizer and 1/4 N in organic manure. The proper pattern of combined application of organic manure and chemical fertilizers based on yield, income and environment is the pattern of combined application of 3/4 N in chemical fertilizer and 1/4 N in organic manure under this experimental condition.

Zhi-hong *et al.*, (2008) conducted an experiment with American celery as tested material, the treatments of different fertilizers (CK, normal organic fertilizer, pond dregs, refining organic fertilizer) and different application rate were set up to measure the heavy metal content in soil and celery. The influence of biogas residues on heavy metal in soil was lowest and that of refining organic fertilizer was highest. The content of Cd in soil was increased with the application of organic fertilizer and raised obviously with the application rate inclement of organic fertilizer. The content of heavy metal in different part of celery in order was root leaf stem. The application of organic fertilizer changed the content of heavy metal in soil and the content of Cd and Zn changed greatly.

Ilker UZ *et al.*,(2016) set an experiment to investigate impact of vermicompost on chemical and biological properties of an alkaline soil with high lime content in the presence of plant under the open field conditions in semiarid Mediterranean region of Turkey. Plots were amended with fertilizers in different rates and celery (*Apium graveolens* L. var. *dulce* Mill.) was grown as the test plant. In general, vermicompost appeared to be more effective to increase organic matter, N, P, and Ca compared to farmyard manure. Soil alkaline phosphatase and β-glucosidase activities, especially in the second growth season, were significantly elevated by the vermicompost application. Urease activity, however, appeared not to be influenced by the type of organic fertilizer. A slight but statistically significant difference was detected between organic amendments in terms of number of aerobic mesophilic bacteria with vermicompost giving the lower values. Results showed that, in general, vermicompost significantly alters chemical and biological properties of the alkaline soil with high lime content during celery production under field conditions compared to farmyard manure and that it has a high potential to be used as an alternative to conventional organic fertilizers in agricultural production in the Mediterranean region of Turkey.

Maia *et al.,* (2019) conducted a research to know the influence of application of organic fertilizer of solid and liquid organic fertilizer super fertifort against growth and plants production of celery on three different soil types; to know the influence of interaction of solid organic fertilizers and liquid organic fertilizer super fertifort towards the growth and development of crops of celery on three different soil types and to find out the optimum dosage of organic fertilizer and liquid manures dosage solid super fertifort on the growth and development of crops of celery on three types of different resistant. Finding of the research was solid fertilizer treatment 1000 Gr./plant combined with a dose of liquid organic fertilizer fertilizers super fertifort 15 ml/plant with the treatment code can increase plant growth and development, UN celery plants with a height ranging between 16.81 cm-22.66 cm, number of leaf celery plants ranged from 14.42 strands – strands of 22.92 and weight is the weight of wet clumps total fresh weight, weight gr 41.75 fresh heaviest consumption 40.08 gr. Occurs tangible interaction towards the growth and development of crops of celery on the treatment dose of solid fertilizers with fertilizer dose organic fertifort super liquid 15 ml/plant. Solid manure treatment on 1000 g/plant, which is the best dose with the result that the maximum dose of liquid organic fertilizer and super fertifort 15 ml/plant is the ideal dosage with maximum results.

The experiment was conducted by Xianjun *et al.*, (2008) to study the effect of the fertilizing biogas slurry once and separately on physiological character, quality and yield of celery in order to provide a basis for application of biogas slurry on celery. The experiments with design method of complete random were conducted to study. The result is as following: Either once or separately fertilizing biogas slurry, Photosynthesis physiological index and quality of celery were obviously increased, the dry matter content of celery was decreased,

and moreover there was no significant difference in dry matter content of celery. The contents of chlorophyll and the catalase activity of celery were increased 19.06%,6.52% in the once top-dressing treatment with 300ml biogas slurry(A1I) than that applied chemical fertilizer(A1I).The contents of VC and the reducing sugar of celery were increased 9.07% and 51.31% in the once top-dressing treatment with 900ml biogas slurry(A2I) than that applied chemical fertilizer(B2I) while the content of nitrate was decreased 31.65%.There was no significant difference in quality and yield of celery between the fertilizing biogas slurry once and separately. The separately fertilizing chemical fertilizer treatment significantly reduced the content of nitrate in comparison with once fertilizing.

Jabłońska-Ceglarek *et al.*, (2004) set an experiment to concern the effect of green manure and soil liming on the yielding of rooted celery, 'Edward' cv. Celeries were cultivated directly after organic fertilization. The plants intended for green manure were sown in July and they were ploughed over in October. The yielding of celery was related to the weather conditions in particular years of the experiment. The highest yields of celery were obtained in 2002. A significant influence on the yield of storage roots and the leaves of rooted celery was exerted by soil liming and the kind of applied organic fertilizer. A higher yield of callosities - both total and commercial – was obtained on the soil where the carbonate lime fertilizer was used. The best yields were obtained of celeries cultivated after ploughing in faba bean and manure. Green manure in the form of phacelia, rye and winter vetch had a similar or greater yield-forming effect than rye straw in the quantity of 6 t·ha-1. Joint application of soil liming and organic fertilization in the form of green manure of faba bean made it possible to obtain the highest total yield of the storage roots of rooted celery. The highest yield of leaves and the total yield of rooted celery, 'Edward' cv., were obtained in the cultivation in the limed soil with ploughed in manure.

LU *et al.*, (2009) drive an orthogonal designed for researching planting density and factors of N and K affects its yield. And single factor designed for researching the relativity between N, K, and Zn formula fertilization affects its yield. Form this experiment, the best fertilization of level in high fertilization soil is 5211 stems per 667 m2,15 kg nitrogenous fertilizer per 667 m2 and 12 kg K2O per 667 m2. The best fertilization of level in low fertilization soil was 25 kg per 667 m2 nitrogenous fertilizer added 15 kg K_2O and 2 kg $ZnSO_4$.

Sallam *et al.,* (2019) was conducted the study during two successive seasons of 2014-2015 and 2015-2016 at Biotechnology Department, Photochemistry Department and Farm of

Applied Research Center of Medicinal Plants (ARCMP) affiliated to the National Organization for Drug Control and Research (NODCAR). The work aimed to investigate the effect of inoculation *Apium graveolens* L. seeds with arbuscular mycorrhizal fungi (my) and/or microbein (mi) biofertilizer and foliar spray plants with Thidiazuron (TDZ) combined with chemical fertilizer at half or full dose of NPK on number of spores Am fungi (kg $soil^{-1}$), AM fungi colonization , enzymatic activities (dehydrogenase activity & Nitrogenase activity, growth parameters (fresh weight of shoots per plant (g), fresh weight of roots per plant (g), dry weight of shoots per plant (g), dry weight of roots per plant (g), Plant height (cm), number of umbel per plant & dry weight of fruits per plant) and chemical composition (plant pigments [chlorophyll a, chlorophyll b and carotenoides], macro elements content (%), total carbohydrates, and crude protein). The results in both seasons showed that, the highest values of number of AM fungi spores (kg $soil^{-1}$) in celery (*Apium graveolens* L.) roots, AM fungi colonization %, enzymatic activities, growth parametersand chemical composition obtained at inoculating seeds with mixture of mycorrhizal and mycrobein at full dose of NPK.

Mingyue *et al.* (2013) set a field plot experiment in Tianjin to study the effect of different ratio organic nitrogen and inorganic nitrogen fertilizer on yield, quality of celery and soil nitrate content. The results showed: the different ratio of organic nitrogen and inorganic nitrogen could increase the yield, improve the quality and decrease the soil nitrate content. In this study, yield of 50% ratio of organic nitrogen treatment was 121327 kg/km^2, higher than other treatments, contracted with 100%N treatment, increased by 9.01%; the Vc content was 108.6 mg/kg, increased by 53.82%; nitrate of celery was 1644.4 mg/kg, decreased by 36.48%.With the ratio of organic nitrogen increased, soil organic matter was increased and soil nitrate content was decreased after celery was harvested.

WANG *et al.* (2011) conducted research to study the effect of different microbial organic manure application on yield and quality of the celery and soil properties in greenhouse. The results showed that the content of organic manure, available N, available P, available K and total salts was significantly increased along with the increased microbial organic manure application rate, yet pH was decreased at the same time. The yield of celery was increased along with increased application rate of microbial organic manure between 15 t/hm~2 and 45 t/hm~2.Vc was decreased but soluble sugar was significantly increased, while NO_3~--N content in the celery was also obviously increased along with enhanced organic manure application, but the celery still was green vegetable in grade A.

Navarro *et al.,* (2020) lead an experiment to study the influence on a celery crop of organic amendments (animal and vegetable) obtained on the farm, as opposed to inorganic fertilization. This influence was evaluated for the yield and the nutritional, organoleptic, and sanitary quality of the resulting crops. The yield and size of the marketable parts of the celery plants were greater with the inorganic treatment; however, the nutritional and sanitary quality was better in the organic treatments, while the chromatic attributes, as well as the total P and Ca, were not affected by the deferent fertilization treatments applied. It is therefore concluded that the organic management model is environmentally and economically sustainable.

2.2 Influence of Biochar

Boersma *et al.*, (2017) examined the effects of applying 10 t ha^{-1} of blue mallee (Eucalyptus polybractea) biochar in combination with fertilizer rate treatments (either full or half the regional recommended rate) on crop yield, yield parameters and soil properties of a cool temperate vegetable cropping system on a red Ferrosol. Biochar amendment did not improve crop yield or other yield parameters of cauliflower, peas and broccoli crops. Similarly, soil parameters including nitrate and ammonium were unaffected by biochar treatment. We suggest the lack of biochar effect on crop and soil parameters was related to the inherent chemical fertility and structural robustness of Ferrosols, which may have mitigated any potential benefits from biochar amendment. Our results demonstrate that biochar application may not bring significant soil quality and crop productivity improvements to high-input agricultural systems.

Junxiang *et al.*, (2021) performed a pot experiment to estimate the effect of maize (*Zea mays* L.) straw biochar application on nitrous oxide (N_2O) and methane (CH_4) emissions, N_2O emission factors and vegetable yield through cultivation of choy sum (*Brassica rapa* L. ssp. *chinensis*) and amaranth (*Amaranthus mangostanus* L.) for 99 days in 2011 at Nanjing, China. Eight treatments were established as follows: control (CK), 100% urea nitrogen (N) (Urea), urea and manure N at 5:5 (UM1) or 7:3 (UM2) combination, biochar incorporation with urea at 20 Mg ha^{-1} (UB1) or 40 Mg ha^{-1} (UB2) and biochar incorporation at 30 Mg ha^{-1} with UM1 (UM1B) or UM2 (UM2B). UB1, UB2, UM1B and UM2B significantly decreased N_2O emission by 77% to 86%, while UM1 and UM2 did not show significant N_2O emission difference in comparison with Urea. CH_4 emissions were not affected by biochar amendment or manure application. On average, UM1B and UM2B significantly enhanced vegetable production by 32, 48 and 28% as compared to Urea, average

UM1/UM2 and average UB1/UB2, respectively. N_2O–N emission factors with biochar application were 0.4–0.7%, while those without biochar being 2.5–3.2%. Comprehensively considering vegetable yield, N_2O emission, CH_4 emission and N_2O–N emission factor, the most effective combination in this study was biochar at 30 Mg ha^{-1} when applied with chemical N fertilizer and manure. In conclusion, biochar application greatly reduced N_2O emissions and N_2O–N emission factors while maintaining vegetable production.

Taiwo MA *et al.,* (2021) stated a conclusion from their experiment that Tillage, biochar, poultry manure, NPK fertilizer and their combined application could improve soil quality, sustainability and carrot productivity. The effects of two tillage treatments: conventional tillage (CT) and reduced tillage (RT) each combined with 30 Mg ha^{-1} biochar (B); 10 Mg ha^{-1} poultry manure (PM), 300 kg ha^{-1} NPK 15-15-15 fertilizer, 150 kg ha^{-1} NPK 15-15-15 fertilizer +15 Mg ha^{-1} biochar +5 Mg ha^{-1} poultry manure and a control (no biochar/poultry manure/NPK fertilizer) on soil properties, growth and carrot yield were investigated. The research was carried out for two consecutive growing seasons (2018 and 2019) at Owo in the forest-savanna transition zone of Nigeria on a sandy loam. Reduced tillage had relatively lower soil bulk density, penetration resistance, dispersion ratio and temperature and had significantly higher ($p = 0.05$) soil aggregate stability, mean weight diameter, porosity and water content than conventional tillage and these resulted in higher soil pH, organic C, N, P, K, Ca and Mg, growth and fresh root yield of carrot compared with conventional tillage. Reduced tillage increased fresh carrot root yield by 2.3 Mg ha^{-1} and 2.6 Mg ha^{-1} for the first and second growing seasons, respectively, compared with conventional tillage, which corresponded to a 11.1% increment for both years. Application of biochar alone, poultry manure alone and complementary application of NPK fertilizer, biochar and poultry manure decreased soil bulk density, penetration resistance, dispersion ratio and temperature and increased soil water content, porosity, aggregate stability and mean weight diameter whereas NPK fertilizer did not improve these soil physical properties. Biochar alone, poultry manure alone, NPK fertilizer alone and combined application of NPK fertilizer, biochar and poultry manure increased soil total N, available P, and exchangeable K, Ca and Mg concentrations compared with the control. Application of biochar alone improved soil pH, OC, K, Ca and Mg better than the NPK fertilizer. Poultry manure improved soil pH, OC, N, K, Ca and Mg better than the NPK fertilizer. Combined application of NPK fertilizer, biochar and poultry manure at sub-optimal rates gave higher soil N, P, K, Ca and Mg concentrations, higher plant, number of leaves, root length, root diameter and fresh carrot root yield compared with NPK fertilizer or biochar or poultry manure alone. Compared with control, NPK fertilizer alone, biochar alone, poultry manure alone and mixture of NPK fertilizer, biochar and poultry manure increased fresh carrot root yield by 43, 24, 46 and 76%, respectively. Reduced tillage in combination with NPK fertilizer, biochar and poultry manure gave the highest fresh carrot root yield. The results indicated that reduced tillage in combination with NPK fertilizer, biochar and poultry manure prove to be an effective and sustainable management strategy for improving soil quality and carrot yield than conventional tillage in combination with NPK fertilizer, biochar and poultry manure.

Li *et al.,* (2015) conducted a field experiment to determine the effects of nitrogen (N) fertilization and biochar addition on the net global warming potential (net GWP), greenhouse gas intensity (GHGI) and net ecosystem economic budget (NEEB). These experiments were conducted in an intensive vegetable field with 4 consecutive vegetable crops in 2012 and 2013 in southeastern China. The experiment was conducted with a 32-factorial design in triplicate at N fertilizer rates of 0, 1475, 1967 kg N ha−1 and biochar rates of 0, 20, and 40 t ha−1. Although CH4 emissions were not obviously affected by N fertilization, N2O emissions increased by 27.2–116.2% and the net GWP increased by 30.6–307.2%. Consequently, the GHGI increased significantly, but vegetable yield and the NEEB did not improve. Furthermore, biochar amendments did not significantly influence CH4 emissions, but significantly decreased the N2O emissions by 1.7–25.4%, the net GWP by 89.6–700.5%, and the GHGI by 89.5–644.8%. In addition, vegetable yields significantly increased by 2.1–74.1%, which improved the NEEB. Thus, N fertilization did not increase vegetable yields or the NEEB. However, N fertilization did increase the net GWP and GHGI. In contrast, biochar additions resulted in lower N2O emissions and net GWP and GHGI, but increased vegetable yield and the NEEB in the intensive vegetable production system. Therefore, appropriate biochar amendment should be studied to combat changing climate and to improve the economic profits of vegetable production.

Gao and DeLuca, (2016) stated that Biochar, a solid carbon rich material and by-product of pyrolysis, has been identified as an amendment to improve soil fertility as well as sequester carbon (C). A growing number of studies have been conducted to test the effect of biochar in soil environment within the past ten years requiring frequent updated reviews and mini reviews to summarize this rapidly growing body of literature. In this paper, we will summarize and review possible mechanisms of biochar effects on soil nitrogen (N) and phosphorus (P) transformations, nutrient leaching, and crop yield, providing an outlook of biochar implementation in soil environment for future research.

Jianxiong *et al.*, (2020) performed a study to assess the effects of biochar on Cd uptake by various vegetables and its downward movement in saline-alkali soil and carried out in polluted pots experiment. The results showed that the biomass of vegetables increased significantly by 16.9% to 519.9% while the Cd concentration in green pepper and eggplant fruits was decreased by 6.8% to 11.5% and 15.1% to 15.4% with the biochar application. The Cd in contaminated soil profile was transferred from topsoil (0-6 cm) to subsoil (6-12 cm) that was observed as 14.30 ± 4.17 mg kg-1. The concentrations of Cd in soil with different fractions like exchangeable, reducible and oxidizable and the Cd uptake by vegetables were reduced. The release of residual Cd was decreased by 0.3 to 20.1% over time with biochar application (0-12 cm). The biochar was effective in mitigating the soil Cd pollution by preventing the vertical Cd leaching.

Ke Zhou *et al.*, (2018) set an experiment to investigate the effects of biochar addition, irrigation and fertilization management on phosphorus (P) leaching as well as water utilization efficiency (WUE) in vegetable fields in northeast China. The P leaching amounts in 100WF+B and 80WF+B were only 15.91% and 11.36%, respectively, of that in CK. The P uptake amounts in the three treatments in descending order were 100WF+B, 80WF+B, and CK. The WUE in 100WF+B and 80WF+B were 15.3 and 25.2 kg/(ha mm) higher, respectively, than that in CK. There were no significant differences between the yield of CK and 80WF+B. The yield of 100WF+B was 3.4 t/ha higher than the yield of CK. Biochar significantly increased WUE, yield, TP (total phosphorus) and AP (available phosphorus) contents in the surface layer as well as P uptake and decreased P leaching when comparing 100WF+B to CK. Fertilization and irrigation reduction decreased P leaching and significantly increased WUE, but the yield was affected when comparing 80WF+B to 100WF+B. Biochar combined with fertilization and irrigation reduction significantly increased WUE and decreased P leaching without affecting yield when comparing 80WF+B to CK.

Wang *et al.*, (2015) sated that, Biochar addition to soils has been frequently proposed as a means to increase soil fertility and carbon (C) sequestration. However, the effect of biochar addition on greenhouse gas emissions from intensively managed soils under vegetable production at the field scale is poorly understood. The effects of wheat straw biochar amendment with mineral fertilizer or an enhanced-efficiency fertilizer (mixture of urea and nitrapyrin) on N_2O efflux and the net ecosystem C budget were investigated for an acidic soil in southeast China over a 1-yr period. Biochar addition did not affect the annual N_2O emissions (26–28 kg N/ha), but reduced seasonal N_2O emissions during the cold period. Biochar increased soil organic C and CO_2 efflux on average by 61 and 19%, respectively. Biochar addition greatly increased C gain in the acidic soil (average 11.1 Mg C/ha) compared with treatments without biochar addition (average −2.2 Mg C/ha). Biochar amendment did not increase yield-scaled N2O emissions after application of mineral fertilizer, but it decreased yield-scaled N2O by 15% after nitrapyrin addition. The results suggest that biochar amendment of acidic soil under intensive vegetable cultivation contributes to soil C sequestration, but has only small effects on both plant growth and greenhouse gas emissions.

William & Qureshi (2015) conducted an experiment to evaluate Biochar as Fertilizer for the Growth of Some Seasonal Vegetables. Biochar was used to replace inorganic fertilizers. Biochar was synthesized by the process of pyrolysis using horse dung (5kg) and dry grass (25kg) to check its effect on the growth of some local vegetables i.e., okra, beans, coriander and mint. These plants were kept in three different environments i.e., outdoor, indoor and greenhouse conditions. In each condition three replications were made for each plant and biochar was applied on them. Control plants (without biochar) were also grown in each condition. Parameters studied were pH, water holding capacity, ammonia, nitrates, chlorophyll content, fertility analysis, temperature and humidity, number of leaves, plant height and length of leaves. It was found that biochar showed positive result in growth of plants.

CHAPTER 3

MATERIALS AND METHODS

CHAPTER 3

3 MATERIALS AND METHODS

In this chapter, methodology that was used in the execution of the experiment is illustrated. It includes a brief description of experimental site, climatic condition, cropping materials used for the experiment, treatments, data collection, procedures, and statistical analysis.

3.1 Experimental Site

The study was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh during winter season from November, 2019 to January, 2020 to study the influence of different organic manures & biochar on growth & yield of celery (*apium graveolens*). The geographical location of the study site is in 24.09°N latitude and 90.26°E longitudes. The altitude of the location was 8 m from the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka-1207 which has been shown in the Appendix I.

3.2 Soil Characteristics

The study site is under the Agroecological Zone of Madhupur Tract (AEZ-28) and the Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the study. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Science Laboratory of Bangladesh Rice Research Institute (BRRI), Gazipur, Dhaka. The soil was having a texture of sandy loam with pH and organic matter capacity 5.6 and 0.78%, respectively and the the soil composed of 27% sand, 43% silt, 30% clay. There is a detail data of the characteristics of soil are presented in Appendix II.

3.3 Climatic Condition

Experimental site is located in the subtropical monsoon climatic zone. Heavy rainfall during the months from April to September (Kharif season) and scant of rainfall during the rest of the year (Rabi season) is common here. Sufficient sunshine and moderately low temperature prevail during October to March (Rabi season) which is generally preferred for vegetable cultivation. Detail meteorological data during the study was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka-1212 and presented in Appendix III.

3.4 Cropping materials

The studied crop used in this study was Celery seed. Seeds were collected from Citadel Global Corporation, Bangladesh. Before sowing in the selected seedbed, a germination test was done. Seeds were sown after soaking them in water for 24 to 48 hours. The seedlings emergence took place within 15 - 20 days after showing.

3.5 Treatments of the Experiment

The two factorial experiments was conducted to evaluate the effect of organic manures and biochar on growth and yield of Celery (*Apium graveolens*). Factors are follows:

Factor A: Organic Manures (Four Levels)

OM_0: Control i.e. no manure

OM_1: Vermi-compost @3.5 t/ha

OM_2: Cowdung @ 10 t/ha

OM_3: Trichocompost (@1.5 t/ha) Trichoderma treated with Vermicompost

Factor B- Biochar (Three Levels)

B_0: No Bio Char

B_1:Biochar @ 4 t/ha

B_2: Biochar @ 2 t/ha

There were 12 (3 × 4) treatments combination such as OM_0B_1, OM_0B_2, OM_0B0, OM_1B_1, OM_1B_2, OM_1B_0, OM_2B_1, OM_2B_2, OM_2B_0, OM_3B_0, OM_3B_2 and OM_3B_0.

3.6 Preparation of Seedbed and Seedlings Raising

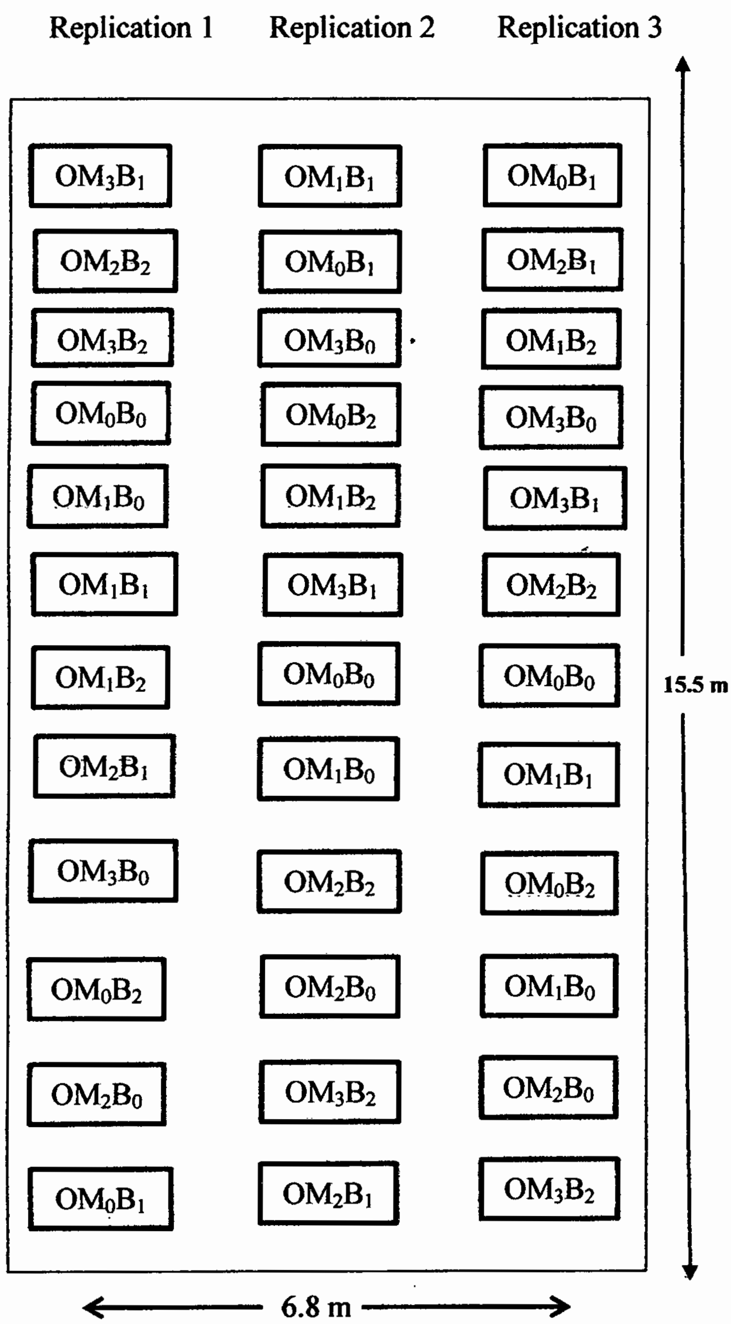
The celery seedlings were raised at Horticulture Farm, of Sher-e-Bangla Agricultural University (SAU), Dhaka, under intensive care in one seed bed of 3 m × 1 m size. Soil of the seed bed was deeply ploughed and clods were broken into small pieces to get good tilth. All rubbish, weeds, and stubbles were removed carefully. Seedbeds were dried in the sun to prevent the soil borne diseases. Seed were sown in each seed bed on 10th November 2019 to get seedlings of 45 days old at the time of transplanting. After sowing, the seedbeds were covered with fine layer of soil followed by light watering. Thereafter the beds were covered with dry straw or water hyacinth to maintain sufficient moisture. The cover of dry straw was removed immediately after emergence of seed sprout. Seeds were completely germinated within 14-15 days after sowing. Shading by polythene was given over the seedbed to protect the young seedlings from scorching sunlight and heavy rainfall. Chemical fertilizers were not applied for rising of celery seedlings. Inter-cultural operations and irrigation were done from time to time to provide a favorable condition for good growth and raising quality seedlings.

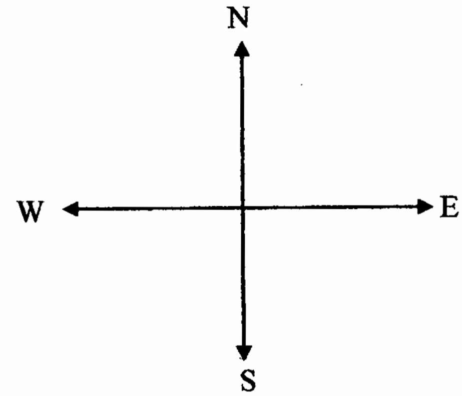
3.7 Design and Layout of the Experiment

The two factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 105.4 m^2 with length 15.5 m and width 6.8 m which were divided into three equal blocks. Each block was divided into 12 plots where 12 treatments combination allotted randomly. There were 36 plots and the size of each plot was 1.6 m × 0.75 m. The distance was maintained between two blocks and two plots that were 0.5 m and 0.5 m, respectively and the seedlings spacing is 0.4 m × 0.15 m. The layout of the experiment is shown in Figure 1.

3.8 Preparation of the Main Field

The selected field was ploughed and opened up in the 1st week of October 2019 with a power tiller, and left exposed to the sun for two weeks. Then cross ploughing was done for five times followed by laddering to make the land suitable for transplanting of seedlings. All unwanted plants, weeds, stubbles and residues were removed from the field. Finally, a good tilth was achieved. The experimental plot was partitioned into the unit plots in accordance with the experimental design mentioned in Figure 1. The soil was treated with insecticides (Cinocarb 3G @ 4 kg/ha) at the time of final land preparation.





Factor A: Organic Manures

1. OM_0: Control i.e., no manure
2. OM_1: Vermi-compost @3.5 t/ha
3. OM_2: Cowdung @ 10 t/ha
4. OM_3: Trichocompost @ 1.5 t/ha

Factor B- Biochar

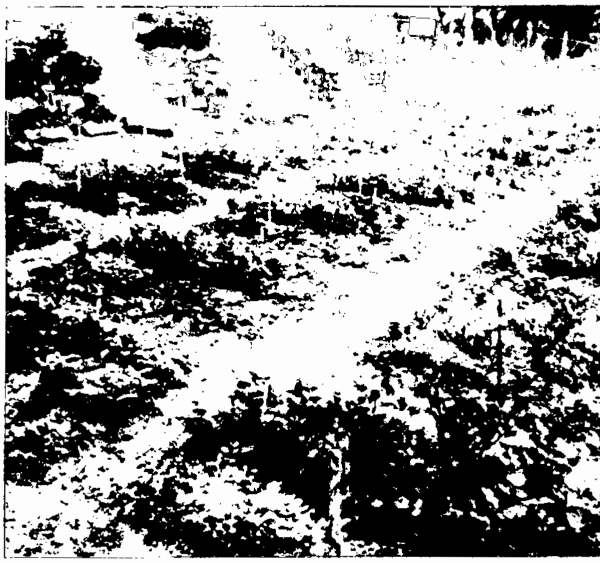
1. B_0: Control,No Biochar
2. B_1:Biochar @ 4 t/ha
3. B_2: :Biochar @ 2 t/ha

Plot size: 1.6 m × 0.75 m

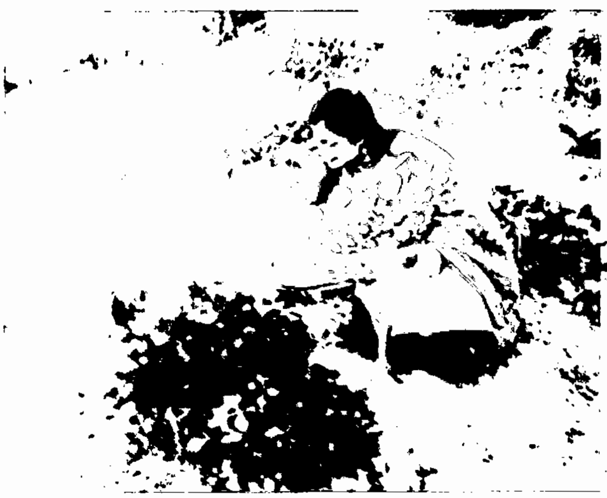
Spacing: 45 cm × 30 cm

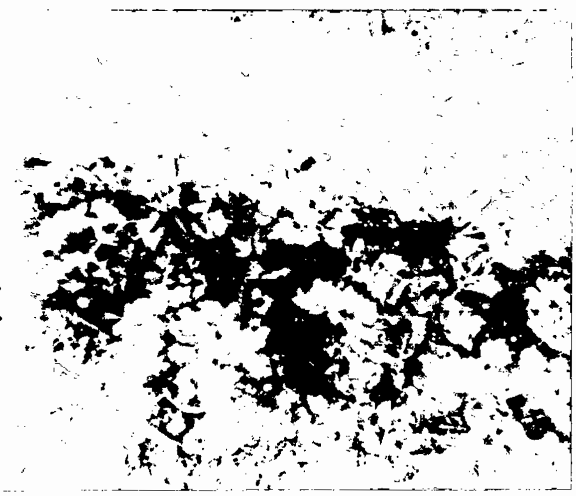
Spacing between replication: 50 cm

Figure 1: Layout of Experiment



a b





c d

Plate-1: a. Experimental Field; **b.** Field Visit; **c.** Data Collection; **d.** Single Bed

3.9 Application of Manure

The entire amount of cow dung, vermicompost and trichocompost were applied as per treatment as a basal dose during final land preparation. No inorganic fertilizers were applied in the experimental field.

Cow dung @ 1.7 kg/plot
Vermicompost @ 1.2 kg/plot
Trichocompost @ 1.2 kg/plot

3.10 Transplanting of Seedlings

Healthy seedlings of 30 days old were transplanting in the experimental plots on 12 January 2020. The seedlings were uprooted carefully from the seed bed to avoid root damage. To minimize the root damage, seed beds were watered an hour before uprooting the seedlings. Transplanting was done in the afternoon. The seedlings were watered immediately after transplanting. Seedlings were transplanted in the plot with maintaining distance between row to row and plant to plant was 45 cm and 30 cm, respectively. The young transplants were shaded by polythene sheet up to 7 days until they were set in the soil. They were kept open at night to allow them receiving dew. A number of seedlings were also planted in the border of plots for gap filling operations.

3.11 Intercultural Operations

After raising seedlings, various intercultural operations such as gap filling, weeding, irrigation pest and disease control etc. were accomplished for better growth, development and yield of celery.

3.11.1 Gap Filling

The transplanted seedlings were kept under careful observation in the experimental field. A few seedlings were damaged during transplanting and such seedling were replaced by new seedlings from the same stock. Those seedlings were transplanted with a big mass of soil with roots to minimize transplanting shock.

3.11.2 Weeding

Hand weeding was done after the establishment of the seedlings as and when necessary. Shallow hoeing should be done as the roots are present at the top layer of soil.

3.11.3 Irrigation

Light irrigation after seedling transplanting was given at every morning and afternoon in the plots. Following transplanting and it was continued for one week for rapid and well establishment of the transplanted seedlings in new soil.

3.11.4 Pest and Disease Control

Pest and disease control is a very important task for establishment of seeding in the field. This will ensure healthy produce and high yields. Despite applying of Cinocarb 3G applications during final land preparation, a few seedlings were damaged due to the infestation of soil-borne pathogens. It was controlled both mechanically and spraying Darsban 29 EC @ 3%. The common insect pests found in celery are leaf miner, carrot weevil, and aphids and the diseases are fusarium wilt, early and late blight, yellow rot, celery mosaic and aster yellow. To control insect pests, insecticide Carbaryl @ 2% or neem extract might be applied.

3.11.5 Harvesting

The celery crop matures or ready for harvest in 100-120 days after sowing depending on the variety grown. Each plant should be cut just below the surface with a sharp sickle. The plants should be trimmed and prepared for transport to the market place.

3.12 Data Collection

From each unit plot four celery plants were randomly selected. Data were collected in respect of the following parameters to assess plant growth, yield attributes and yields as affected by different treatments of the experiment. Data on plant height, number of leaves and other physical data were collected at 25, 40, and 55 days after transplanting (DAT). All other yield contributing characters and yield parameters were recorded during harvest and after harvest.

3.12.1 Plant Height

Plant height was measured from selected plants in centimeter from the ground level to the tip of the longest leaf and mean value was calculated. Plant height was also recorded at 15 days interval starting from 25 days after Transplanting (DAT) up to 85 days to observe the growth rate of plants.

3.12.2 Number of Leaves per Plant

Number of leaves was manually counted from selected plants and each leaf was counted from bottom to top up to fully opened leaves maintaining 15 days interval starting from 25 days after transplanting (DAT) up to 55 days and their average was computed as average number of leaves per plant.

3.12.3 Leaf Length

The length of leaf was measured from the pointy part at one end of the leaf to the point where the leaf joins the stalk at the other end. A meter scale used to measure the length maintaining 15 days interval starting from 25 days after transplanting (DAT) up to 55 days and was expressed in centimeter (cm).

3.12.4 Leaf Breadth

Leaf breadth was recorded as the average of five leaves selected at random from the plant of inner rows of each plot starting from 25 to 55 DAT at 15 days interval. Thus mean was recorded and expressed in centimeter (cm).

3.12.5 Fresh Weight of Leaves per Plant

The fresh weight of leaves per plant was recorded from the average of selected plants in gram (g) with a beam balance at harvest.

3.13 Statistical Analysis

The data obtained for different characters were statistically analyzed by using Statistix 10 computer package program to find out the significance of the difference for biochar and organic manure on yield and yield contributing characters of celery. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. Difference between treatments was assessed by Least Significant Difference (LSD) test at 0.05% level of significance (Brady and Weil 2001).

3.14 Economic Analysis

The economic indicator, benefit cost ratio (BCR) analyses were done according to the procedure of Alam *et al.* (1989). It was calculated by the following equation:

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross Return Per Hectare (Tk.)}}{\text{Total Cost Of Production Per Hectare (Tk.)}}$$

CHAPTER 4

RESULTS AND DISCUSSION

CHAPTER 4

4 RESULTS AND DISCUSSION

The experiment was conducted at Sher-e-Bangla Agricultural University (SAU), Dhaka. Data on different growth and yield parameter were recorded. The analyses of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendix IV-VIII. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Plant Height

Different levels of planting time showed significant variation on the plant height of celery at 25, 40 and 55 days after transplanting (Figure 2). At 25, 40, and 55 DAT the tallest plant (12, 29 and 41 cm, respectively) was recorded from OM_3, OM_2, OM_2 treatment, respectively. The shortest plant was recorded from OM_0 at 25, 40 and 55 DAT as 10, 24 and 36 cm, respectively. At 25 DAT, OM_0 and OM_2 was statistically similar. Data revealed that different treatments of organic manures produced different heights of plant and the tallest plant was found from 55 DAT for all the treatments. The findings of the present study corroborate with the findings of Sowbhagya (2014). They reported that manure is of value as a source of humus, a source of both major and minor nutrients as a carrier and promoter of beneficial organisms and possibly as a source of growth promoting substances.

Different biochar treatments showed slight differences on plant height of celery at 25, 40 and 55 DAT (Figure 3). At 25 DAT the plant heights are almost similar for all biochar treatments (11 cm). At 40 DAT the tallest plant (29 cm) was recorded from B_2. At 55 DAT the tallest plant was found from B_1 (40 cm) and the shortest plant in 40 and 55 DAT was found in B_1 treatments (25 and 36 cm, respectively). Study referred that application of mehagoni + mango combined biochar in lower amount (8 t/ha) can increase the plant height than the other treatments because of its influence on growth and physiological functions.

Combined effect of different organic manures and biochar showed significant differences on plant height at 25, 40 and 55 DAT (Table 1). At 25 DAT the tallest plant (12.47 cm) was recorded from OM_3B_0 which was statistically similar to OM_1B_2 (12.28 cm) and the shortest plant (9.673 cm) was found in OM_1B_1 which was statistically identical to OM_2B_2 (9.77 cm).

At 40 DAT the tallest plant (37.09 cm) was found in OM_2B_2 and the shortest plant (23.51 cm) was recorded from OM_0B_0. At 55 DAT the tallest plant (42.44 cm) was found in OM_2B_2 which was statistically identical with OM_2B_1 (42.26 cm), OM_3B_1 (41.81 cm).

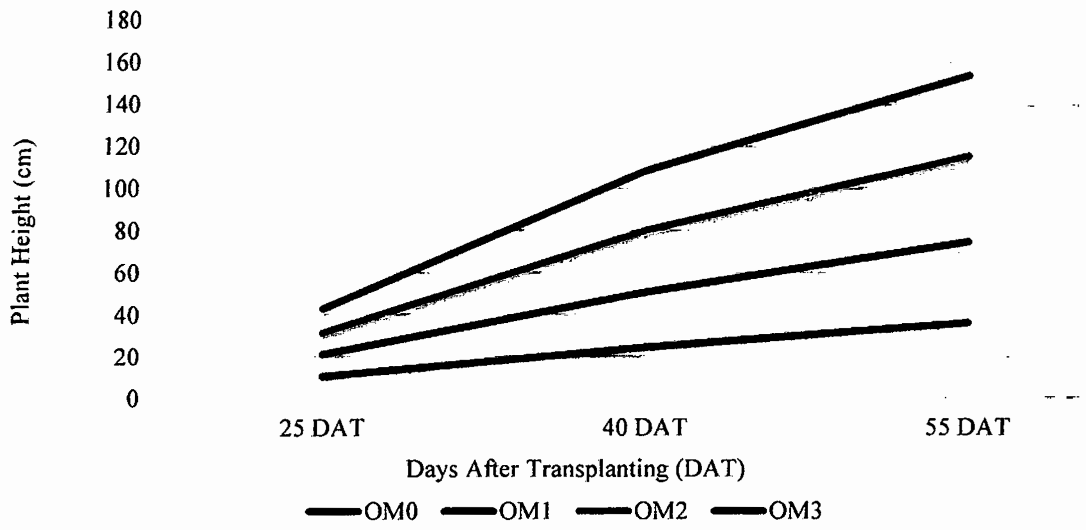


Figure 2: Effect of Organic Manure on Plant Height at Different DAT; i.e., OM_0: Control/No Manure, OM_1: Vermicompost, OM_2: Cow Dung, OM_3: Trichocompost

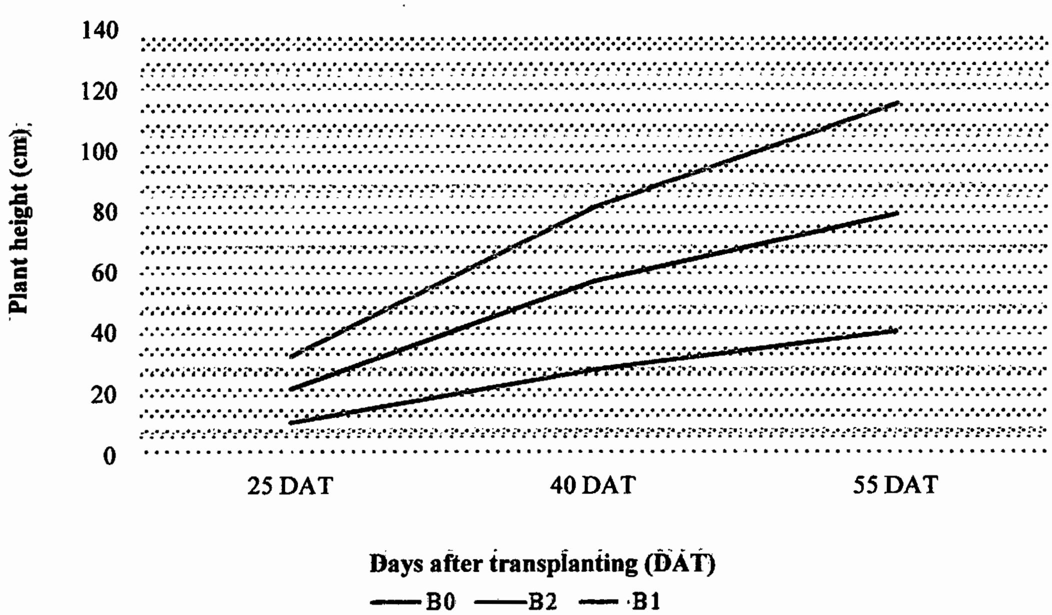


Figure 3: Effect of biochar on plant height at different DAT; i.e., B_0: Control, B_1: Biochar @ 4 t/ha, B_2: Biochar @ 2 t/ha

Table 1: Combined effects of organic manure and level of biochar on plant height at different days after transplanting of celery

Treatment combination	Plant height (cm) at		
	25 DAT	40 DAT	55 DAT
OM_0B_1	10.61 cde	25.52 dg	36.89 de
OM_0B_2	10.28 def	23.86 fg	35.45 f
OM_0B_0	10.11 ef	23.51 g	34.82 f
OM_1B_1	9.673 f	26.14 c-f	40.53 b
OM_1B_2	12.28 a	27.41 cd	38.69 c
OM_1B_0	10.11 def	25.64 d-g	37.16 d
OM_2B_1	10.81 cd	26.70 cde	42.26 a
OM_2B_2	9.77 f	37.09 a	42.44 a
OM_2B_0	9.99 ef	24.27 efg	38.19 cd
OM_3B_1	11.58 b	32.63 b	41.81 a
OM_3B_2	10.98 bc	28.38 c	38.67 c
OM_3B_0	12.47 a	24.52 efg	35.78 ef
$LSD_{0.05}$	0.636	2.23	1.26
Level of significance	**	**	**
CV (%)	3.50	4.87	1.93

** = Significant at 5% level of probabilityIn a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

Here, OM_0: Control i.e., no manure, OM_1: Vermi-compost @3.5 t/ha, OM_2: Cowdung @ 10t/ha, OM_3: Trichocompost (@1.5 t/ha) B0: Control B1: Biochar @ 4 t/ha, B_2: Biochar @ 2 t/ha

4.2 Number of Leaves per Plant

Leaves are important vegetative organ, as it assists plant in photosynthesis, transpiration and respiration process. The leaves are important since, in addition to an assimilation area, they are also used as main cultivable parts of celery. Number of leaves per plant at 25, 40 and 55 DAT (Days after transplanting) showed statistically significant differences due to different level of organic manures (Figure 4). At 25, 40 and 55 DAT the highest number of leaves/plant (7, 12 and 25, respectively) was recorded from OM_1 whereas the lowest number of leaves per plant (6, 11, and 20 respectively) was found from OM_0.

Different nutrients have appreciated effect on the number of leaves per plant at different DAT. Higher leaf number indicates wholesome growth and development. In terms of different organic nutrient sources, number of leaves per plant of celery at 25, 40 and 55 DAT showed statistically significant differences (Figure 5). At 25, 40 and 55 DAT the highest number of leaves per plant (7, 12 and 23, respectively) was found for B_2: Biochar @ 4 t/ha.In case of 25 DAT leaf numbers per plant was almost similar for all biochar treatments. The lowest number of leaves per plant (11 and 20) was found at 40 and 55 DAT, respectively from B_0 treatment. Due to available nutrients in biochar, plants grown with this treatment produce higher number of leaves. Result was supported by Jahan *et al.* (2014) who mentioned that application of vermicompost performed the best response on leaf number of cauliflowers.

Combined effect of organic manures and biochar showed significant variation on number of leaves per plant at 25, 40 and 55 DAT (Table 2). At 25 DAT highest number of leaves per plant (6.06) was recorded from OM_1B_2. At 40 DAT showed the highest number of leaves per plant (13.89) was recorded from OM_2B_2 and at 55 DAT showed the highest number of leaves per plant (23.22) was recorded from OM_3B_1 which was statistically identical with OM_1B_2 (22.34). At 25, 40 and 55 DAT the lowest number of leaves per plant (5.17, 9.06 and 19.22) was found from OM_0B_1, OM_2B_1, OM_0B_0. At 55 DAT the lowest number of leaves per plant found from OM_0B_0 which was statistically identical with OM_0B_1 and OM_2B_1.

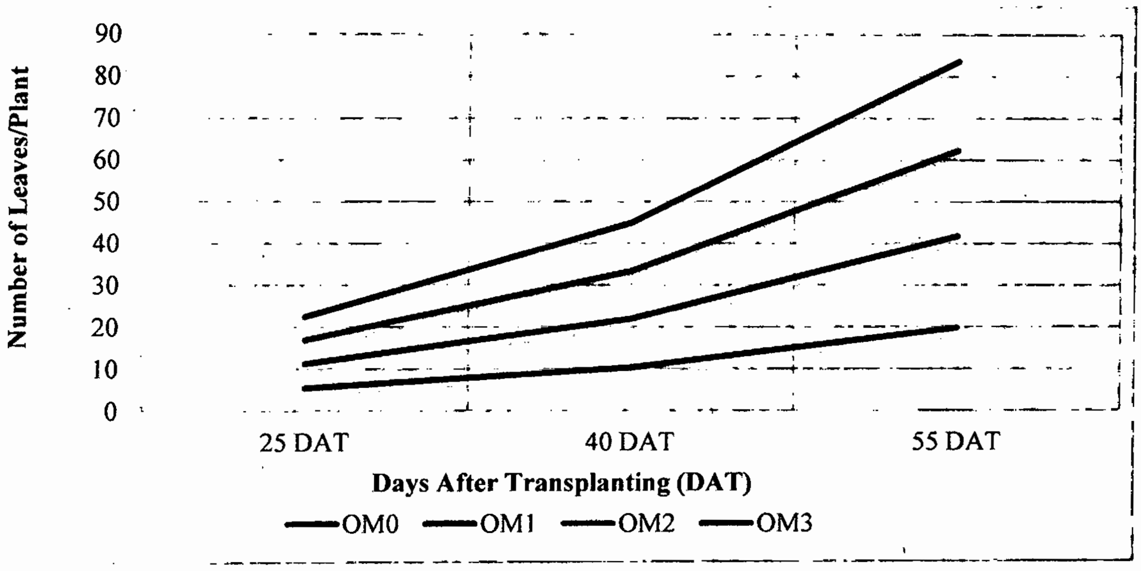


Figure 4: Effect of Organic Manure on Number of Leaves at Different DAT; I.E., OM_0: Control/No Manure, OM_1: Vermicompost, OM_2: Cow Dung, OM_3: Trichocompost

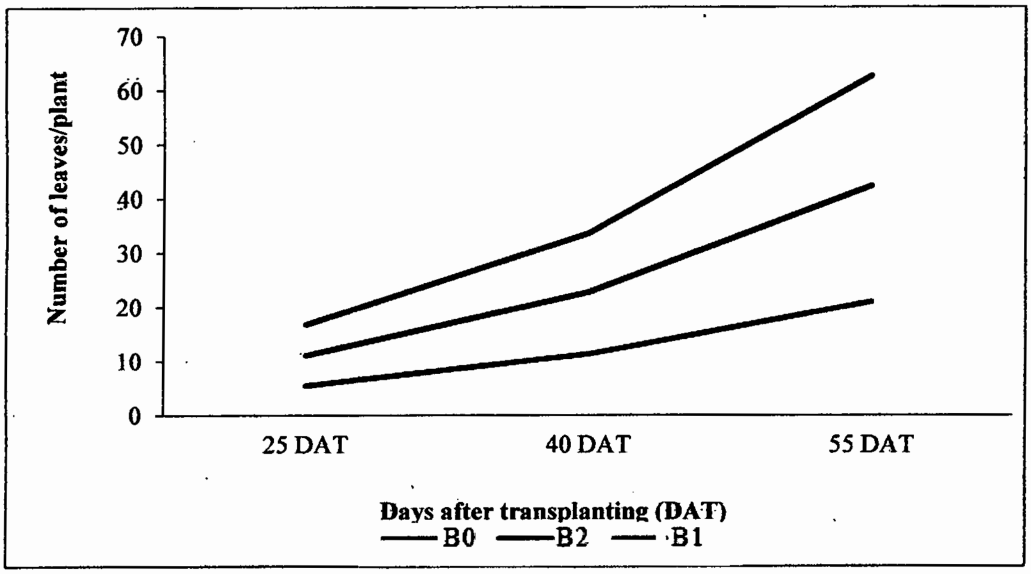


Figure 5: Effect of Biochar on Number of Leaves at Different DAT; i.e., B_0: Control, B_1: Biochar @ 4 t/ha, B_2: Biochar @ 2 t/ha

Table 2 Combined Effects of Organic Manure and Level of Biochar on Number of Leaves/Plant at Different Days after Transplanting of Celery

Treatment combination	Number of leaves/plants at		
	25 DAT	40 DAT	55 DAT
OM_0B_1	5.17 g	10.56 e	19.28 f
OM_0B_2	5.39 efg	9.44 fg	20.67 de
OM_0B_0	5.67 bcd	10.83 e	19.22 f
OM_1B_1	5.78 bc	12.78 b	22.34 ab
OM_1B_2	6.06 a	10.44 e	21.94 bc
OM_1B_0	5.56 cf	11.44 d	21.61 bcd
OM_2B_1	5.33 fg	9.06 g	19.33 f
OM_2B_2	5.86 ab	13.89 a	21.67 bcd
OM_2B_0	5.55 cf	11.39 d	20.50 de
OM_3B_1	5.61 be	13.00 b	23.22 a
OM_3B_2	5.44 def	12.06 c	20.95 cde
OM_3B_0	5.72 bc	9.61 f	19.83 ef
$LSD_{0.05}$	0.240	0.438	1.09
Level of significance	**	**	**
CV (%)	2.56	2.31	3.09

** = Significant at 5% level of probabilityIn a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

Here, OM_0: Control i.e., no manure, OM_1: Vermi-compost @3.5 t/ha, OM_2: Cowdung @ 10 t/ha, OM_3: Trichocompost @1.5 t/ha

B_0: Control, B_1: Biochar @ 4 t/ha, B_2: Biochar @ 2 t/ha

4.3 Leaf Length

There was significant variation on the length of leaf due to different treatments of manures and biochar (Figure 6 and 7). The application of OM_2 treatment produced the longest leaf at 25, 40 and 55 DAT as 6, 18 and 22 cm, respectively and the lowest leaf length was produced by OM_0 treatment as 5, 14 and 19 cm, respectively for 25, 40 and 55 DAT (Figure 6). Balyan *et al.* (1988) observed that nitrogen fertilizer improved the number of leaves per plant and leaf size index over the control. Poultry litter releases nitrogen fast. Organic manures which increase the water holding capacity of the soil are desirable for the celery crop whenever they can be used. The length of leaf varied slightly due to application of different biochar treatments (Figure 7). The maximum length of leaf (23 cm) was obtained in 55 DAT by applying B_1 treatment and the shortest length was found in 25 DAT by applying all the three treatments. The treatment combinations of organic manures and biochar's significantly influenced the length of leaf. The longest leaf was found in OM_2B_0 (6.11 cm) at 25 DAT, in OM_2B_2 (22.19 cm) at 40 DAT and in OM_1B_1 (23.47 cm) at 55 DAT. On the other hand, the shortest leaf (5.85 cm) was obtained from OM_1B_1 treatment which was statistically identical with the results of OM_0B_0 treatment (4.35 cm) which is shown in Table 3.

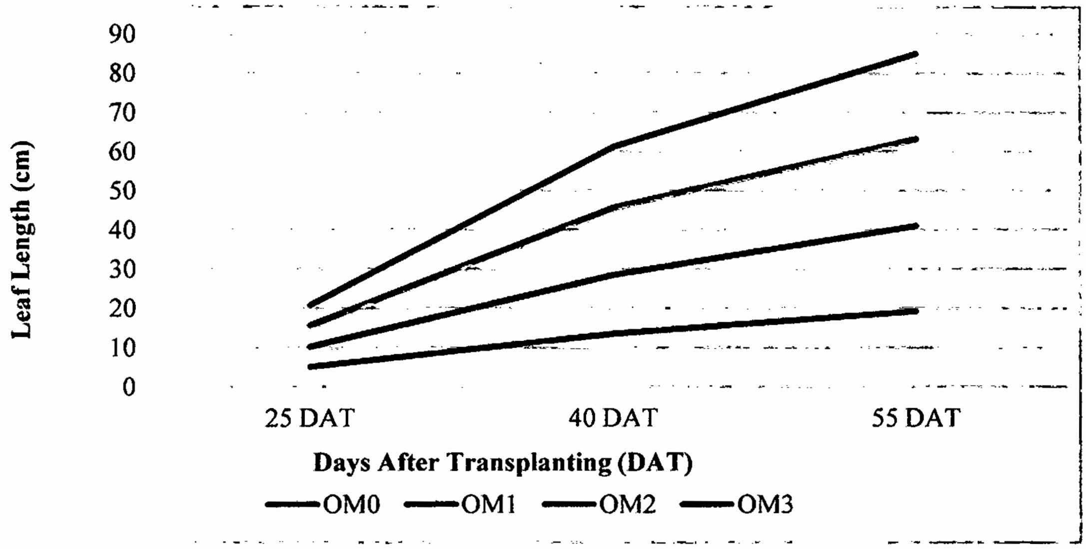


Figure 6: Effect of Organic Manure on Leaf Length at Different DAT; i.e., OM_0: Control/No Manure, OM_1: Vermicompost, OM_2: Cow Dung, OM_3: Trichocompost

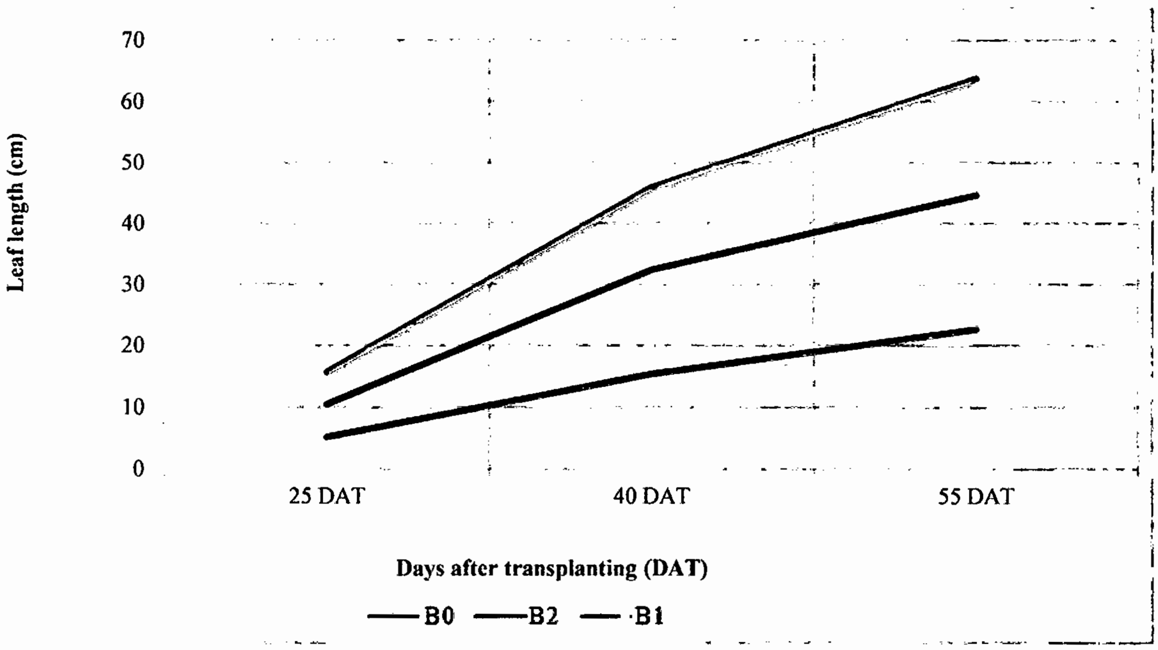


Figure 7: Effect of biochar on leaf length at different DAT; i.e., B_0: Control, B_1: Biochar @ 4 t/ha, B_2:Biochar @ 2 t/ha

Table 3 Combined Effects of Organic Manure and Biochar on Leaf Length at Different Days after Transplanting Of Celery

Treatment Combination	Leaf length (cm) at		
	25 DAT	40 DAT	55 DAT
OM_0B_1	5.58 bc	13.18 f	20.88 c
OM_0B_2	5.38 cd	13.88 ef	20.07 cd
OM_0B_0	4.35 g	13.31 f	16.58 e
OM_1B_1	4.50 g	13.88 ef	23.47 a
OM_1B_2	5.85 ab	15.58 cd	22.24 b
OM_1B_0	4.92 ef	15.25 de	19.69 d
OM_2B_1	5.40 cd	16.85 bc	22.79 ab
OM_2B_2	4.68 fg	22.19 a	23.01 ab
OM_2B_0	6.11 a	12.88 f	20.70 c
OM_3B_1	5.06 de	17.33 b	23.02 ab
OM_3B_2	5.07de	16.22 bcd	22.82 ab
OM_3B_0	5.44 c	12.89 f	19.55 d
$LSD_{0.05}$	0.330	1.38	0.906
Level of significance	**	**	*
CV (%)	3.73	5.34	2.52

** = Significant at 1% level of probability, * = Significant at 5% level of probability

Here, OM_0: Control i.e., no manure, OM_1: Vermi-compost @3.5 t/ha, OM_2: Cowdung @ 10 t/ha, OM_3: Trichocompost @1.5 t/ha.

B_0: Control, B_1: Biochar @ 4 t/ha, B_2: Biochar @ 2 t/ha

4.4 Leaf Breadth

The breadth of leaf significantly varied with the application of different sources of organic manures and biochar treatment (Figure 8 and 9). The maximum breadth of leaf was found in OM_3 (4 cm), OM_2 (14 cm) and OM_2 (18 cm) treatments at 25, 40 and 55 DAT, respectively while by applying different amount of biochar, higher leaf breadth was resulted in B_0 (3 cm), B2 (14 cm) and B1 (18 cm) treatments at 25, 40 and 55 DAT, respectively. Maximum leaf breadth was seen at 55 DAT for both organic manure and biochar treatments. Similar result was also observed by Ali and Kashem (2018) which supported the present study. There was a significant variation due to the combined effect of organic manures and biochar treatments (Table 4). The maximum breadth of leaf was found from combined OM_3B_2 treatment (3.64 cm) at 25 DAT while at 40 and 55 DAT the highest leaf breadth was reported by applying OM_2B_2 (15.83 cm) and OM_2B_1 (18.63 cm) treatments, respectively. The lowest leaf breadth was found from OM_0B_2 treatment (2.61 cm) at 25 DAT while at 40 and 55 DAT the lowest leaf breadth was seen by applying OM_3B_0 (10.82 cm) and OM_3B_0 (16.38 cm) treatments, respectively. At 55 DAT the lowest leaf breadth found at OM_3B_0 treatment was statistically identical with OM_3B_0 treatment.

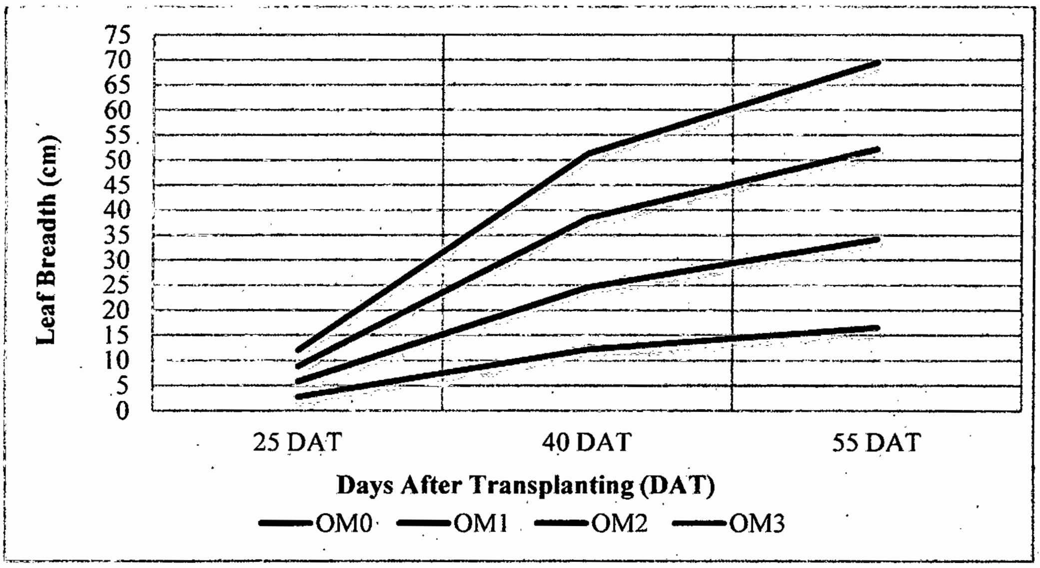


Figure 8: Effect of Organic Manure on Leaf Breadth at Different DAT; i.e., OM_0: Control/No Manure, OM_1: Vermicompost, OM_2: Cow Dung, OM_3: Trichocompost

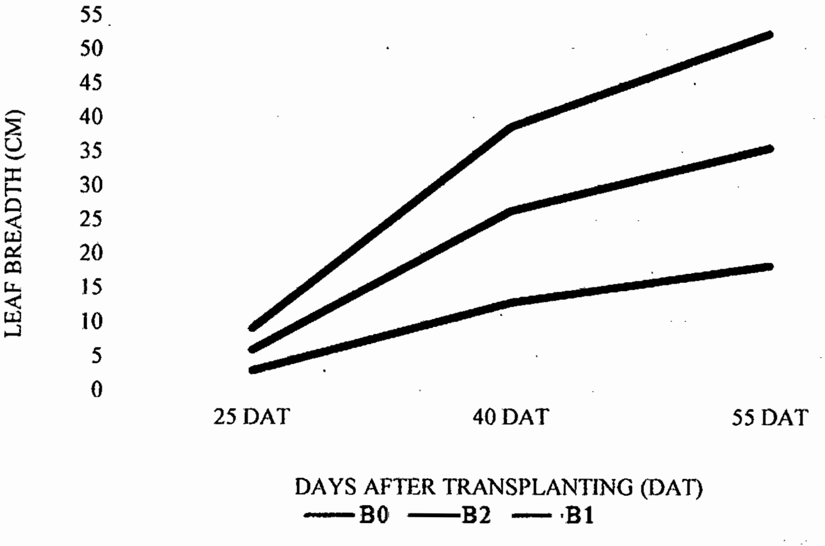


Figure 9: Effect of Biochar on Leaf Breadth at Different DAT; i.e., B_0: Control, B_1: Biochar @ 4t/ha, B_2: Biochar @ 2 t/ha

Table 4: Combined Effects of Organic Manures and Biochar on Leaf Breadth at Different Days after Transplanting of Celery

Treatment Combination	Leaf breadth (cm) at		
	25 DAT	40 DAT	55 DAT
OM_0B_1	2.66 fg	11.53 fg	17.49 cd
OM_0B_2	2.61 g	12.17 def	16.41 e
OM_0B_0	2.86 def	12.64 de	15.81 f
OM_1B_1	2.81 efg	12.24 def	18.48 ab
OM_1B_2	3.09 cd	11.93 ef	17.22 d
OM_1B_0	3.37 b	13.16 cd	17.28 d
OM_2B_1	3.07 cd	12.92 cde	18.63 a
OM_2B_2	2.80 efg	15.83 a	17.72 cd
OM_2B_0	3.20 bc	12.57 de	17.39 d
OM_3B_1	3.00 cde	14.26 b	18.03 bc
OM_3B_2	3.64 a	13.64 bc	17.58 cd
OM_3B_0	2.91 de	10.82 g	16.38 e
$LSD_{0.05}$	0.207	0.921	0.516
Level of significance	**	**	*
CV (%)	4.10	4.25	1.76

** = Significant at 1% level of probability, * = Significant at 5% level of probability

Here, OM_0: Control i.e., no manure, OM_1: Vermi-compost @3.5 t/ha, OM_2: Cowdung @ 10 t/ha, OM_3: Trichocompost @1.5 t/ha.

B_0: Control, B_1: Biochar @ 4 t/ha, B_2: Biochar @ 2 t/ha

4.5 Fresh Weight of Leaves per Plant

Leaves of the celery crops are consumed due to their high nutritive value in many countries. As the use of celery leaves in human consumption is common, so their proper growth and development should be maintained. Different treatments of organic manure and biochar showed slight variations on the fresh weight of leaves per plant of celery (Figure 10 and 11). The highest fresh weight of leaves (148 g) was recorded from OM_2 and the lowest fresh weight of leaves (129 g) was recorded from OM_0. Emam (2005) and Shapla (2013) reported similar findings for other vegetative crops. Slight variations were recorded for the fresh weight of leaves due to different biochar applications (Figure 11). The highest fresh weight of leaves per plant (148 g) was recorded from B_1 Biochar @ 4 t/ha) and the lowest fresh weight of leaves (135 g) was recorded from B_0 (Control). Abd *et al.* (2019) reported vermicompost has positive effect on the fresh weight of leaves in lettuce. Combined effect of organic manures and biochar showed significant influence on the fresh weight of leaves per plant of celery (Table 5). The highest fresh weight of leaves per plant (154.90 g) was recorded from OM_3B_1 and the lowest fresh weight of leaf (128.20 g) was recorded from OM_3B_2 which was statistically identical with OM_3B_0.

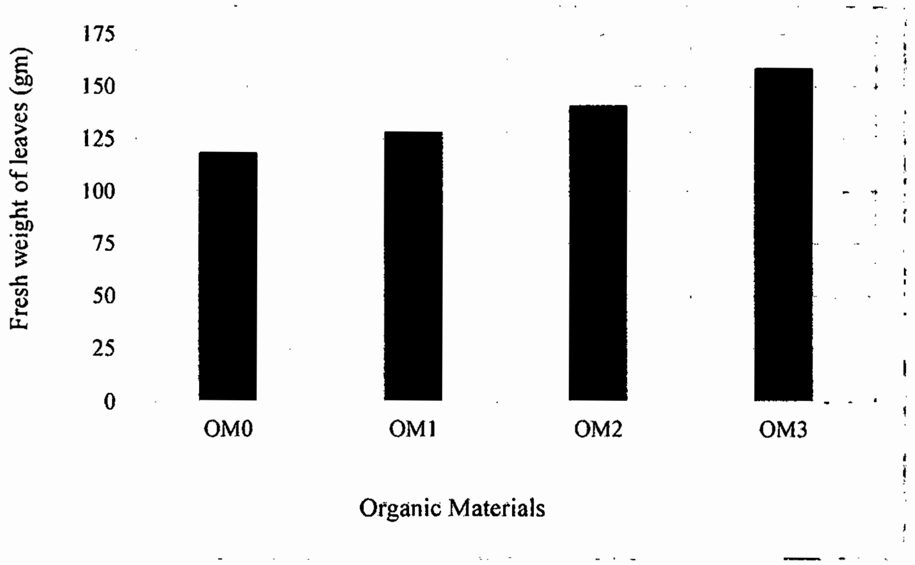


Figure 10: Effect of Organic Manures on Fresh Weight of Leaves per Plant

Here, OM_0: Control i.e., no manure, OM_1: Vermi-compost @3.5 t/ha, OM_2: Cowdung @ 10 t/ha, OM_3: Trichocompost @1.5 t/ha.

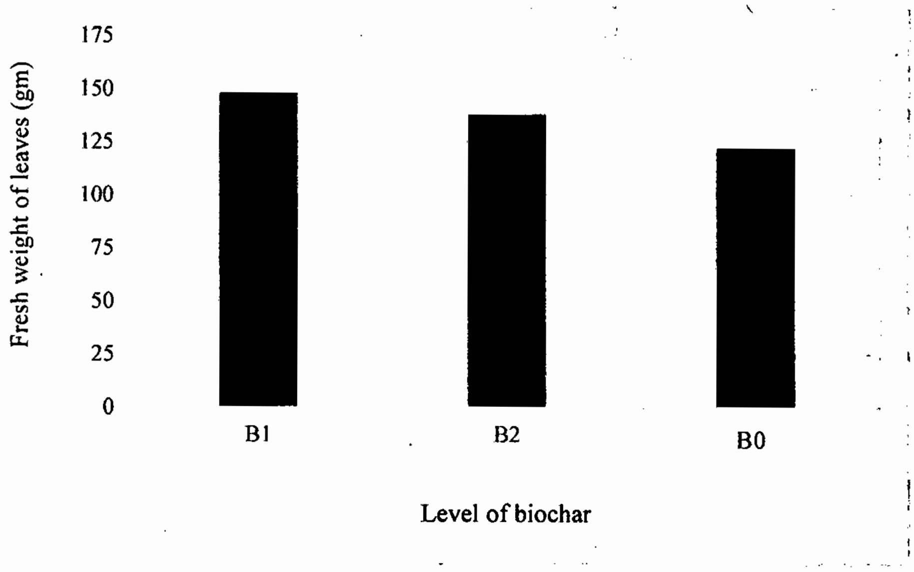


Figure 11: Effect of Biochar on Fresh Weight of Leaves per Plant

Here,
B_0: Control, B_1: Biochar @ 4 t/ha, B_2: Biochar @ 2 t/ha

Table 5: Combined Effects of Organic Manures and Biochar on Fresh Weight of Leaves at Different Treatments

Treatment combination	Fresh weight of leaves (gm)
OM_0B_1	132.30 de
OM_0B_2	131.90 de
OM_0B_0	132.50 de
OM_1B_1	137.00 cd
OM_1B_2	137.10 cd
OM_1B_0	139.80 c
OM_2B_1	147.00 b
OM_2B_2	149.60 ab
OM_2B_0	141.50 c
OM_3B_1	154.90 a
OM_3B_2	128.20 e
OM_3B_0	130.80 e
$LSD_{0.05}$	0.539
Level of significance	**
CV (%)	2.30

** = Significant at 5% level of probability.In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

Here, OM_0: Control i.e., no manure, OM_1: Vermi-compost @3.5 t/ha, OM_2: Cowdung @ 10 t/ha, OM_3: Trichocompost @1.5 t/ha.
B_0: Control, B_1: Biochar @ 4 t/ha, B_2: Biochar @ 2 t/ha

4.6 Economic Analysis

The economic analysis was done and has been presented in Table 6 and Appendix IX. Input and overhead cost were recorded for all the treatments of unit plot and calculated on per hectare basis. The price of celery at the local market rate was considered. The total cost of production ranged between Tk. 139072 to Tk. 577032 per hectare among the different treatment combinations. The variation was due to different cost of celery cultivar and different sources of organic manures. The highest cost of production (Tk 577032) per hectare was recorded in the treatment combinations OM_3B_1 while the lowest cost of production TK. 139072 per hectare was recorded in the combination OM_0B_2 (Appendix IX). The gross return from the different treatment combinations ranged between Tk. 1885860.9 to Tk. 2838315.9 per hectare. The return was the total income through sale of harvested celery @Tk. 210 per kg. Among the different combinations, OM_3B_1 gave the highest net return (2204136.6) while the lowest net return Tk. was obtained from the treatment combination of OM_3B_2 (1449417.1). The benefit cost ratio (BCR) was found to be the highest (13.8) in the treatment combination OM_0B_0 while the lowest BCR (3.84) was recorded from OM_1B_1. The present experiment revealed that the application of the treatment combination of OM_3B_1 found to be conducive to higher economic return from celery.

Table 6: Economic analysis of celery cultivation as influenced by biochar and organic manures

Treatment combination	Total cost of production (A + B)	Yield ha^{-1} (ton)	Gross Return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
OM_0B_1	355332	3.9	585000	229668	1.65
OM_0B_2	252852	3.5	525000	347148	1.51
OM_0B_0	98372	1.5	225000	95662	1.18
OM_1B_1	440000	6.8	1020000	580000	1.75
OM_1B_2	490000	6.5	975000	475600	2.25
OM_1B_0	395000	5.1	765000	430000	1.77
OM_2B_1	620000	7.1	1065000	445000	2.40
OM_2B_2	578652	6.5	975000	420348	2.31
OM_2B_0	504652	5.2	780000	395000	1.97
OM_3B_1	1010030	**13.2**	1980000	790000	**2.51**
OM_3B_2	870600	10.3	1545000	665400	2.30
OM_3B_0	682872	9.1	1365000	597250	2.20

CHAPTER 5

SUMMARY AND CONCLUSION

CHAPTER 5

5 SUMMARY AND CONCLUSION

The experiment was conducted in the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka to find out the effect of biochar and organic nutrient sources on the growth and yield of celery. The experiment consisted of two factors: Factor A: Organic Manures (four levels) as OM_0: Control i.e., no manure, OM_1: Vermi-compost @3.5 t/ha, OM_2: Cow dung @10 t/ha, OM_3: Trichocompost @1.5t/ha and Factor B- Biochar (three levels) B_0: Control, B_1: Biochar @4 t/ha, B_2: Biochar @ 2t/ha. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

Organic manures had significant effect on different growth and yield. Data revealed that the tallest plant was found from 55 DAT for all the organic manure treatments and at 40 DAT the tallest plant (29 cm) was recorded from biochar treatment, B_2. Combined effect of different organic manures and biochar showed, at 25 DAT the tallest plant (12.47 cm) was recorded from OM_3B_0. Number of leaves per plant at 25, 40 and 55 DAT showed statistically significant differences due to different level of organic manures. At 25, 40 and 55 DAT the highest number of leaves/plant (7, 12 and 25, respectively) was recorded from OM_1 whereas the lowest number of leaves per plant (6, 11, and 20 respectively) was found from OM_0. The lowest number of leaves per plant (11 and 20) was found at 40 and 55 DAT, respectively from Control treatment. Combined effect of organic manure and biochar at 55 DAT produced highest number of leaves per plant (23.22) was recorded from OM_3B_1. The application of OM_2 treatment produced the longest leaf at 25, 40 and 55 DAT as 6, 18 and 22 cm, respectively and the lowest leaf length was produced by OM_0 treatment as 5, 14 and 19 cm, respectively for 25, 40 and 55 DAT. The longest leaf was found in combined OM_1B_1 treatment (23.47 cm) at 55 DAT. On the other hand, the shortest leaf (5.85 cm) was obtained from OM_1B_1 treatment. The maximum breadth of leaf was found in OM_3 (4 cm), OM_2 (14 cm) and OM_2 (18 cm) treatments at 25, 40 and 55 DAT, respectively while by applying different amount of biochar, higher leaf breadth was resulted in B_0 (3 cm), B_2 (14 cm) and B1 (18 cm) treatments at 25, 40 and 55 DAT, respectively. Maximum leaf breadth was seen at 55 DAT for both organic manure and biochar treatments. The maximum leaf breadth was found from combined OM_2B_1 treatments (18.63 cm) at 55 DAT. The lowest leaf breadth was found from combined OM_0B_2 treatment (2.61 cm) at 25 DAT. The highest fresh weight of leaves (148 g) was recorded from OM_2 and the lowest fresh weight of leaves (129 g) was recorded from OM_0. The highest fresh weight of leaves per plant (148 g) was recorded from B_1 treatment Biochar @ 4 t/ha and the lowest fresh weight of leaves (135 g) was recorded from B_0 treatment (Control). The highest fresh weight of leaves per plant (154.90 g) was recorded from OM_3B_1 and the lowest fresh weight of leaf (128.20 g) was recorded from OM_3B_2. In terms of economic performance, the highest gross return (1980000Tk/ha) and net return (791000 Tk/ha) were obtained from OM_3B_1 treatment where the lowest gross return (225000Tk/ha) and net return (95662 Tk/ha) were obtained from OM_0B_0 treatment, respectively.

From the above results, it can be concluded that the treatment combination of OM_3B_1 showed highest yield advantage regarding celery yield. Therefore, it can be considered as the best treatment combination. So, considering gross return, net return and BCR of celery production under biochar and organic manure combinations, OM_3B_1 might be chosen as the best treatment for commercial production purposes.

References

Agbede TM (2021) Effect of tillage, biochar, poultry manure and NPK 15-15-15 fertilizer, and their mixture on soil properties, growth and carrot (Daucus carota L.) yield under tropical conditions, Heliyon, Volume 7, Issue 6, e07391, ISSN 2405-8440 doi.org/10.1016/j.heliyon. 2021.e07391.

Asif HM, Akram M, Usmanghani K, Akhtar N, Pervaiz AS, Uzair M, Ramzan M, Ali SM and Rehman R (2011) Monograph of Apium graveolens Linn. Journal of Medicinal Plants Research Vol. 5(8), pp. 1494-1496, 18 April, 2011 Available online at http://www.academicjournals.org/JMPR

Boersma M, Wrobel-Tobiszewska A, Murphy L and Eyles A (2017) Impact of biochar application on the productivity of a temperate vegetable cropping system, New Zealand Journal of Crop and Horticultural Science, 45:4, 277-288, DOI: 10.1080/01140671.2017.1329745

Brady NC and Weil RR (2001) The nature & froperties of soils. Prertice Hall (13thed). NJ, USA.

Constanze W, Hans-Peter S, Dieter G, Wolfgang L and Claudia K (2018) Biogeochemical potential of biomass pyrolysis systems for limiting global warming to 1.5°C. Environmental Research Letters, 13(4), 044036. doi.org/10.1088/1748-9326/aabb0e

Crombie K, Mašek O, Sohi S, Brownsort P and Cross A (2012) "The effect of pyrolysis conditions on biochar stability as determined by three methods" (PDF). Global Change Biology Bioenergy. 5 (2): 122–131. doi:10.1111/gcbb.12030

Gao Si and DeLuca TH (2016) "Influence of biochar on soil nutrient transformations, nutrient leaching, and crop yield." Adv. Plants Agric. Res 4(5): 1-16.

GAO W, Sohi S, Brownsort P and Cross A (2011) "Effects of combined application of organic manure and chemical fertilizers on yield and quality of celery and soil nitrate leaching under greenhouse condition." *Plant Nutrition and Fertilizer Science* 17(3): 657-664.

Gauri M, Javed Ali S and Shahid Khan M (2015) A review of *Apium graveolens* (Karafs) with special reference to Unani medicine. Int Arch Integr Med. 2:131-136.

Garg SK (1980). Glucosides of Apium graveolens. Planta Med., 38(4): 363.

Jabłońska-ceglarek R, Zaniewicz-bajkowska A and Rosa R (2004) The effect of green manure and soil liming on the yielding of rooted celery, 'edward' cv. Electronic Journal of Polish Agricultural Universities, Horticulture, Volume 7, Issue 1.

Jianxiong Sun, Qinya Fan, Jingwen Ma, Liqiang Cui, Guixiang Quan, Jinlong Yan, Limin Wu, Kiran Hina, Basit Abdul and Hui Wang (2020) Effects of biochar on cadmium (Cd) uptake in vegetables and its natural downward movement in saline-alkali soil, Environmental Pollutants and Bioavailability, 32:1, 36-46, doi: 10.1080/26395940.2020.1714487

Junxiang Jia, Bo Li, Zhaozhi Chen, Zubin Xie & Zhengqin Xiong (2012) Effects of biochar application on vegetable production and emissions of N_2O and CH_4, Soil Science and Plant Nutrition, 58:4, 503-509, DOI: 10.1080/00380768.2012.686436

Ke Zhou, Yue-yu Sui, Xin Xu, Jin-yuan Zhang, Yi-min Chen, Meng Hou, Xiao-guang Jiao (2018). The effects of biochar addition on phosphorus transfer and water utilization efficiency in a vegetable field in Northeast China, Agricultural Water Management, Volume 210, Pages 324-329. doi.org/10.1016/j.agwat.2018.08.007.

Khalil MK, Taha KF, Nesem MA, Sallam SS (2019) Phytochemical studies on celery (Apium graveolens l.) Plant under using chemical fertilization, biofertilizer and thidiazuron treatments. Az. J. Pharm Sci. Vol. 59, March.

Kooti W, Ghasemiboroon M, Ahangarpoor A, Nesem MA, Sallam SS (2014) The effect of hydro-alcoholic extract of celery on male rats in fertility control and sex ratio of rat offspring. J Babol Univ Med Sci. 16(4): 43–49.

Kooti W and Daraei N (2017) A Review of the Antioxidant Activity of Celery (Apium graveolens L). Journal of Evidence-Based Complementary and Alternative Medicine, 22(4), 1029–1034. https://doi.org/10.1177/2156587217717415

Li B, Fan CH, Zhang H, Chen ZZ, Sun LY and Xiong ZQ (2015) Combined effects of nitrogen fertilization and biochar on the net global warming potential, greenhouse gas intensity and net ecosystem economic budget in intensive vegetable agriculture in southeastern China, Atmospheric Environment, Volume 100, Pages 10-19, ISSN 1352-2310, doi.org/10.1016/j.atmosenv.2014.10.034.

Lu X, Sun LY and Xiong ZQ (2009) "Study on effects of density and fertilization on celery cultivation." *Guangdong Agricultural Sciences* 6(1): 12.

Maia CMBF, Madari BE, Novotny EH (2011) Advances in biochar research in Brazil. Dynamic soil, Bynamic plant, 5(1): 53-58.

Maia T, Domingos CBBM, Gomes K and Edmundo Viegas (2019) "The influence of application of organic manures dosage solid and liquid dosage superfertifort against growth and yield of crops of celery." *International Journal of Development Research* 9(1): 25216-25221.

Malhotra SK (2006) Celery. In Handbook of herbs and spices (pp. 317–336). http://www.sciencedirect.com/science/article/pii/B978184569017550018X

Mateo-Sagasta J, Marjani Zadeh S and Turral H (2017) Water pollution from agriculture: a global review. [online] Fao.org. [Accessed 22 July 2021].

Mingyue, Li, Chen ZZ, Sun LY and Xiong ZQ (2013) "Effect of Combined Application of Organic Nitrogen and Inorganic Nitrogen Fertilizer on Yield, Quality of Celery and Soil Nitrate Content." Chinese Agricultural Science Bulletin 2:13.

Navarro AS, Romero JAS, Sanjuan MCS, Bernardeau MAB, Delgado Iniesta MJ (2020) Medium-Term Influence of Organic Fertilization on the Quality and Yield of a Celery Crop. Agronomy, 10, 1418. https://doi.org/10.3390/agronomy10091418

Newman and Jacqueline (2006) "Chinese Celery". Vegetables and Vegetarian Foods. 13 (3): 15–34. Retrieved 17 April 2017.

Nickavar B, Kamalinejad M and Izadpanah H (2007) In vitro free radical scavenging activity of five Salvia species. Pak J Pharma Sci; 20:291–294.

Rupasinghe HPV (2020) Special Issue "Flavonoids and Their Disease Prevention and Treatment Potential": Recent Advances and Future Perspectives. Molecules, 25(4746), 1–7.

Ryder EJ (1979) Leafy Salad Vegetables, AVI Publishing Company, USA. PP.1-110.

Sallam and Samir (2019) "Effect of chemical fertilization, biofertilizer and thidiazuron on growth and yield of celery (apium graveolens l.) Plant." *Al-Azhar Journal of Pharmaceutical Sciences* 59.1: 27-53.

Sowbhagya HB (2014) Chemistry, Technology, and Nutraceutical Functions of Celery (Apium graveolens L.): An Overview. Critical Reviews in Food Science and Nutrition, 54(3), 389–398. https://doi.org/10.1080/10408398.2011.586740

Shawky E, Nada AA and Ibrahim RS (2020) Potential role of medicinal plants and their constituents in the mitigation of SARS-CoV-2: Identifying related therapeutic targets using network pharmacology and molecular docking analyses. RSC Advances, 10(47), 27961–27983. https://doi.org/10.1039/d0ra05126h

Thakur S, Mayank SB, Ansari AJ, Khandelwal A, Arya A, Poduri R and Joshi G (2020) Exploring the magic bullets to identify Achilles' heel in SARS-CoV-2: Delving deeper into the sea of possible therapeutic options in Covid-19 disease: An Update. Food and Chemical Toxicology.

Schuchert and Wolfgang (2012) "Celeriac (Apium graveolens L. var. rapaceum)". Crop Exhibition. Max Planck Institute for Plant Breeding Research. Retrieved 28 January 2012.

Singh and Rajeev (2012) Organic Fertilizers: Types, Production and Environmental Impact.

Uz I, Sonmez S, Tavali IE, Citak S, Uras DS and Citak S (2016) Effect of Vermicompost on Chemical and Biological Properties of an Alkaline Soil with High Lime Content during Celery (Apium graveolens L. var. dulce Mill.) Production. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 44(1), 280-290.

Liu Changquan, Xie Deti, Li Bing, Arya A, Poduri R and Joshi G (2005) Effect of different kinds and dosage of organic manure on the yield and quality of celery Zhongguo Nong xue Tong bao = Chinese Agricultural Science Bulletin. 21(1):192-195.

Wang J, Chen Z, Xiong Z, Chen C and Xu X (2015) Effects of biochar amendment on greenhouse gas emissions, net ecosystem carbon budget and properties of an acidic soil under intensive vegetable production. Soil use and management, 31(3), 375-383.

Wang Q, Quan S and Rui W (2011) "Effect of Different Microbial Organic Manure Application on Quality and Yield of Celery and Soil Properties in Greenhouse." *Northern Horticulture* 3(1).

Weber K and Quicker P (2018) "Properties of biochar". Fuel. 217: 240–261. doi:10.1016/j.fuel.2017.12.054

Wellman F (1937) "Control of Southern Celery Mosaic in Florida by Removing Weeds That Serve as Sources of Mosaic Infection". United States Department of Agriculture. 54 (8): 1–16.

William K and Qureshi RA (2015) Evaluation of Biochar as Fertilizer for the Growth of Some Seasonal Vegetables, *Journal of Bioresource Management, 2* (1): 1-17. doi: 10.35691/JBM.5102.0011

Xianjun H, Hong J and Xie Y (2008) "Effect of Biogas Slurry on Quality and Yield of Celery." *Chinese Agricultural Science Bulletin* 7 (2), 88-91.

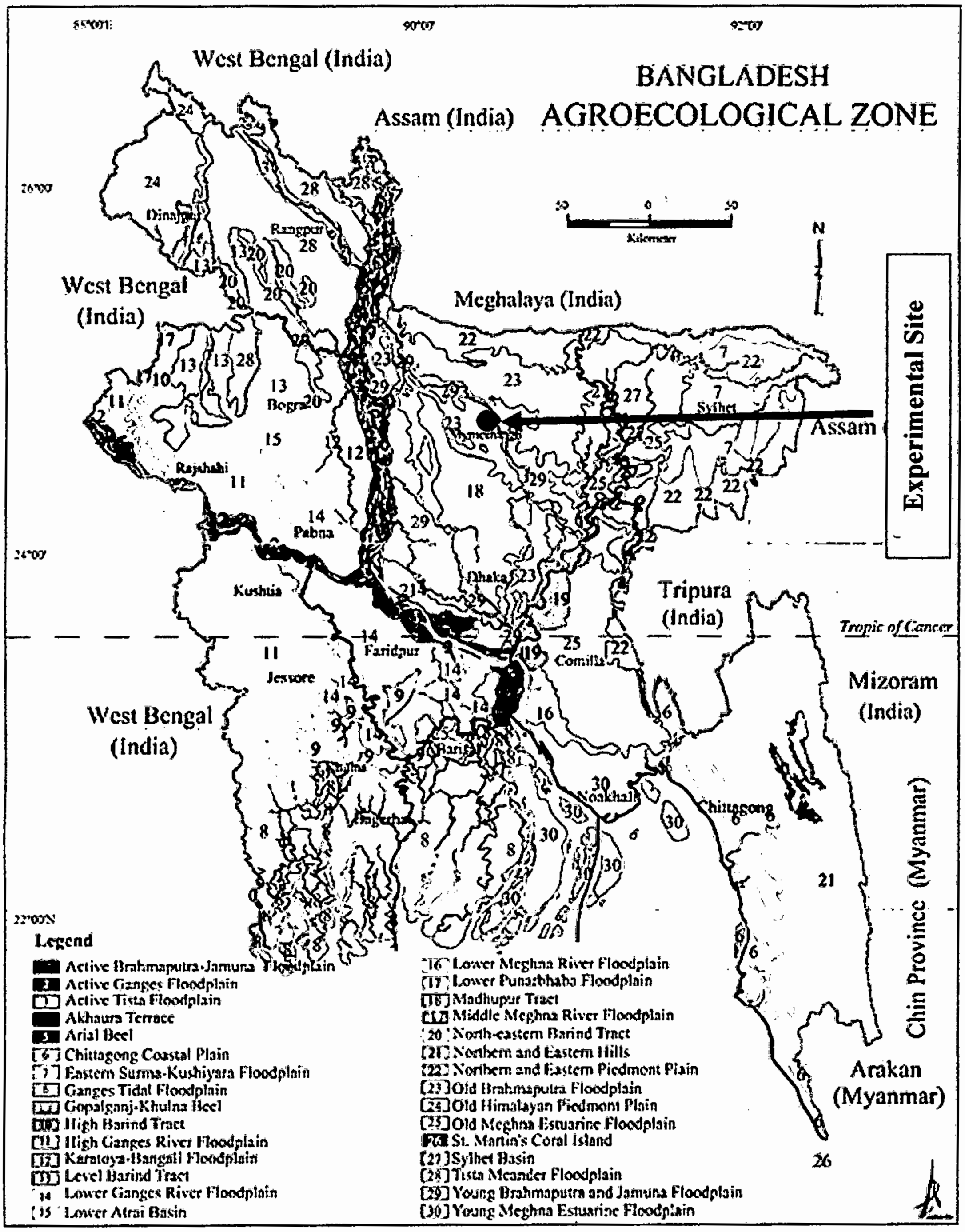
Yildiz L, Başkan KS, Tütem E and Apak R (2008) Combined HPLC-CUPRAC (cupric ion reducing antioxidant capacity) assay of parsley, celery leaves, and nettle. Talanta; 77:304–313.

Zhi-hong MA, Li J and Pan L (2008) "The Influence of Different Organic Fertilizer on the Heavy Metal Residual in the Soil and Celery". *Journal of Anhui Agricultural Sciences* 21 (2): 6-12.

APPENDICES

Appendices

Appendix I. Map Showing the Experimental Site under Study



Appendix II. Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture farm field, SAU
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly levele

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	26
%Silt	43
% clay	31
Textural class	Sandy loam
pH	5.9
Catayan exchange capacity	2.64 meq 100 g/soil
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10

Appendix III. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2019 to April 2020

Month	Air Temperature (°C)		Relative Humidity (%)	Rainfall (mm)	Sunshine (hr.)
	Maximum	Minimum			
November, 2019	30.2	19.7	68	13	7.2
December, 2019	26	16.4	68	13	7.5
January, 2020	27.1	14.6	59	1	7.9
February, 2020	28.3	16.8	63	115	6.9
March, 2020	31.5	21.1	61	39	6.9
April, 2020	33.6	23.6	69	212	6.8

Appendix IV. Analysis of variance (mean square) of the data for plant height at different days after transplanting of Clery.

Source of Variation	**df**	**Plant Height (cm) at**		
		25 DAT	**40 DAT**	**55 DAT**
Replication	2	0.079	5.334	0.158
Organic materials (A)	3	4.043**	46.328**	41.855**
Level of boron (B)	2	0.103NS	69.629**	45.839**
AxB	6	2.833**	41.635**	3.555**
Error	22	0.141	1.744	0.553

Appendix V. Analysis of variance (mean square) of the data for number of leaves/plant at different days after transplanting of Celery.

Source of variation	**df**	**Number of leaves/plants at**		
		25 DAT	**40 DAT**	**55 DAT**
Replication	2	0.004	0.018	1.865
Organic materials (A)	3	0.228**	3.494**	8.615**
Level of boron (B)	2	0.148**	1.408**	3.335**
AxB	6	0.168**	10.335**	4.035**
Error	22	0.020	0.067	0.415

Appendix VI. Analysis of variance (mean square) of the data for leaf length at different days after transplanting of Celery.

Source of variation	**df**	**Leaf length (cm) at**		
		25 DAT	**40 DAT**	**55 DAT**
Replication	2	0.050	0.411	0.591
Organic materials (A)	3	0.182**	22.861**	17.252**
Level of boron (B)	2	0.037NS	34.380**	40.691**
AxB	6	1.451**	16.667**	0.813*
Error	22	0.038	0.667	0.286

Appendix VII. Analysis of variance (mean square) of the data for leaf breadth at different days after transplanting of Celery.

Source of variation	df	Leaf breadth (cm) at		
		25 DAT	40 DAT	55 DAT
Replication	2	0.000	0.991	0.144
Organic materials (A)	3	0.374**	4.675**	3.066**
Level of boron (B)	2	0.128**	3.645**	6.429**
AxB	6	0.252**	6.069**	0.235*
Error	22	0.015	0.296	0.093

Appendix VIII. Analysis of variance (mean square) of the data for fresh weight of leaves of Celery.

Source of Variation	df	Fresh weight of leaves (gm)
Replication	2	123.672
Organic materials (A)	3	290.419**
Level of boron (B)	2	165.314**
AxB	6	181.497**
Error	22	10.132

Appendix IX. Cost of production of celery per hectare

A. Input cost (Tk./ha)

Treatment Combination	Labor Cost	Seed Cost	Irrigation	Pesticides	Biochar	Cow Dung	Vermi-compost	Tricho-compost	Seed Bed Preparation and Seed Sowing	Transplanting Cost	Subtotal (A)
OM_0B_1	12000	12500	2500	3000	200000	0	0	0	3000	8000	221,000
OM_0B_2	12000	12500	2500	3000	100000	0	0	0	3000	8000	141,000
OM_0B_0	12000	12500	2500	3000	0	0	0	0	3000	8000	41,000
OM_1B_1	12000	12500	2500	3000	200000	0	210000	0	3000	8000	451,000
OM_1B_2	12000	12500	2500	3000	100000	0	210000	0	3000	8000	351,000
OM_1B_0	12000	12500	2500	3000	0	0	210000	0	3000	8000	241,000
OM_2B_1	12000	12500	2500	3000	200000	180000	0	0	3000	8000	421,000
OM_2B_2	12000	12500	2500	3000	100000	180000	0	0	3000	8000	321,000
OM_2B_0	12000	12500	2500	3000	0	180000	0	0	3000	8000	221,000
OM_3B_1	12000	12500	2500	3000	200000	0	0	375000	3000	8000	616,000
OM_3B_2	12000	12500	2500	3000	100000	0	0	375000	3000	8000	516,000
OM_3B_0	12000	12500	2500	3000	0	0	0	375000	3000	8000	416,000

Biochar = 50 Tk/kg
Cow Dung= 18 Tk/kg
Vermicompost = 60 Tk/kg
Trichocompost = 250 Tk/kg

B.Overhead cost (Tk. ha^{-1})

Treatment Combination	Cost of Leased Land for 6 Months (8% of Value of Land Tk. 10,00,000/-	Miscellaneous Cost (Tk. 5% of the Input Cost)	Interest on Running Capital for 6 Month (8% of Cost Year-1)	Subtotal (B)	Subtotal (A)	Total Cost of Production (A + B)
OM_0B_1	40000	18850	12470	74352	221,000	355332
OM_0B_2	40000	21000	7452	67452	191,000	252852
OM_0B_0	40000	4700	4300	58372	49,000	98372
OM_1B_1	40000	75874	85947	248932	501,000	739932
OM_1B_2	40000	43598	71040	154452	651,000	837452
OM_1B_0	40000	39097	60900	129972	441,000	680972
OM_2B_1	40000	45512	53452	135132	521,000	681132
OM_2B_2	40000	38985	61667	134652	381,000	578652
OM_2B_0	40000	34985	49187	104172	293,000	427172
OM_3B_1	40000	63985	95347	197332	796,000	1040832
OM_3B_2	40000	58985	88867	182852	616,000	938352
OM_3B_0	40000	60980	69382	169372	595,000	782872

**Price of Celery per Kg = Tk. 150.0