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Use of Carbon Dioxide Treated Amine- Modified Biomass As A Soil Modifier In Agricultural Soils

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Abstract
This paper reports on modification of biomass with amino compounds and its subsequent application as a soil modifier. The resultant was found to react with carbon dioxide at a rate of 4.89 cm^3 of the gas per gram as confirmed by FTIR analysis. Carbon dioxide treatment crosslinked the biomass to produce a material with excellent water adsorption properties. It was observed that its volume increased by 200% when exposed to waster as compared to same mass of the parent biomass using the same quantity of water. The carbon dioxide treatment produced a carbamate that has antibacterial properties. This extended the life of the material when applied in the field to offer an extended coverage duration without degradation. It also enhanced soil aeration and provided sufficient water for plants generally grown locally in Kenya (maize and arrow roots) to maturity. It was found out that 1.0 kg of that material per a plant contributed to an average growth height of maize of 268.25 cm as well as arrow roots to rapidly bloom producing a plant with a leaf dimension of 68.45 cm within three months of growth. Results confirmed that 0.4 g of the modified material was capable of enabling a (one) maize plant produce 1.055 kg of dry grains upon maturity. The modified material contributed positively to the growth of the respective plants as well as their yield thus has a potential for application in the improvement of soil properties as well as absorption of carbon dioxide from the air.

Key words
Plants growth, Soil modifier, carbon dioxide, arid areas, water retention

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I. INTRODUCTION

The extensive use of fossil fuels has given rise to elevated levels of carbon dioxide in the atmosphere leading to an unpredictable climate change with erratic rainfall patterns and rapid evaporation of water from the soil (Fawzy et al., 2020). This contribute to land degradation hence desertification, that makes a challenge to grow food crops or any other vegetation in most areas which were hitherto bread baskets within the tropics that result to an uncomfortable environment to flora and fauna. The use of fossil fuels despite being a climate disaster has an advantage in that the fuel is cost effective and in abundant supply. Alternative sources of renewable energy sources have a challenge because they not sustainable (Owusu, *et al.,* 2016). Despite fossil fuels severely damaging our environment, its use is hard to quit (Holechek *et al.,* 2022). This convenient source, yet high-carbon energy source whose growth transited from wood and charcoal to coal has caused extreme and serious weather events. Due to the density of coal, it has been the preferred fuel as the primarily an industrial fuel which is contributing to the observed negative effects worldwide. This is by spewing enormous quantities of carbon dioxide in the environment which results to global warming.

The current method of removal of carbon dioxide gas is by direct air capture then stored as a liquid latter to be treated into chemically inert substances (Wadhams, 2016). This is an expensive method and utilizes huge amounts of energy (Leonzio, *et al.,* 2022). Moreover aqueous amine-based liquids carbon dioxide capture agents have offensive odour hence not friendly to the environment. To overcome the challenge, this project anchored an amine on a solid substrate nonvolatile biomaterial to capture carbon dioxide in gaseous form and hold it as a solid derivatized material. This will removed the greenhouse gas from the air because amines have a high affinity for carbon dioxide (Didas, 2012). This capture by the modified biomass was done by treating the modified biomaterial with carbon dioxide in the laboratory. This was intended to be a potential method for the capture of the greenhouse gas into a solid substrate and exploit the resultant as a source of water for the soil **(**Lefebvre et al., 2019)**.** The aim of this study was intended to reverse the negative effects due to carbon dioxide by using amine modified biomass in the agricultural fields.

This offers a solution for the removal of carbon dioxide from the atmosphere and producing a material with some antibacterial activity as well as water retention ability for application in the soil to offer improved soil properties for plant growth (Paustain, et al., 2019; Sayari, *et. al.,* 2012; **Bundjaja *et. al*., 2021**). This paper reports on the use of amine modified biomass capable of interacting with carbon dioxide, crosslinking the product making an excellent water adsorbent that reverses the problem of global warming due to carbon dioxide and its subsequent results of desertification. The phenomenon of water absorption and is volume variation improved the aeration of the soil.

This is a new approach of exploiting a modified biomaterial that is capable of reacting with carbon dioxide to produce a material with anti-bacterial activity. This was achieved by the use of the abundantly available biomass (grass) in which an amine was chemically anchored within its chemical structure. The carbon dioxide treatment of the biomass over and above crosslinking produced a carbamate that has antibacterial properties (Didas, 2012; **Bundjaja *et. al*., 2021**). The product was therefore capable an extended duration as a soil modifier unlike untreated biomass such as manure. The resultant was then applied in the field for the growth of some selected plants. This achieved its dual objective by offering remedial measures of using cost effective and naturally occurring bio material capable of absorbing carbon dioxide to produce a water loving antibacterial material. Due its extended life span in the soil, it enhanced the water content in the soil. Due to its integrity it was applied in agricultural farms to offer and extended soil conditioning cover and be a source of water to plants. Such an investment can not only improve food production due to improved soil-water management but also an extended supply of water to plants ensuring a sustainable food production as well as mitigate the effects of global warming by sorption of carbon dioxide.

II. MATERIALS AND METHODS

2.1Apparatus and reagents

All the apparatus used in this study were first soaked in bath of a mixture of equimolar dilute hydrochloric and nitric acid 1.0 M to remove any contaminant in the apparatus. They were then cleaned with Millipore water and later dried in the oven at 60 ºC. The chemical and reagents used in the study were of analytical grade sourced from Sigma Aldrich through their Nairobi outlet- Kobian Kenya ltd. The biomass used in the study was sourced from the Kenyatta University lawns while the amino material of bio origin was from a local small species of fish called Omena and was sourced from Gikomba market (Nairobi – County of Kenya). All the reagents used in the study unless otherwise stated were dispersed in Millipore water. Functional groups within modified analyte were characterized using Shimadzu IR Prestige-21 spectrometer model 800 series from 4000 to 400 cm^{-1} with scan speed 20 cm^{-1}.

2.2 Sample preparation

In the laboratory, all the biomaterials were dried in an oven at 60 °C for 12 h, cooled and then pulverized to powder using a blender and stored in clean synthetic bags.

2.3 Preparation and Bubbling of the Synthetic Carbon (IV) Oxide

A solid sample (2.20 g) sodium carbonate was placed in a filter flask where 0.1M hydrochloric acid was added drop wise until all sodium carbonate reacted. Produced carbon dioxide gas was passed over the wet modified starch in an aseptic closed flask. The volume of excess gas was obtained.

Figure 1

2.4 Synthesis of carbon dioxide water adsorbent materials

Synthesis of carbon dioxide treated biomass hydrogels was done according to Wawro and Kazimierczak (2008). It involved the formation of a solid biomass derivative by anchoring amine groups from Omena wastes on grass substrate and the treatment of the resultant with carbon dioxide. The method of synthesizing hydrogel by cross linking biomass with amine groups was adopted from the study carried out by Chowdary and Chandra (2009) who treated starch with urea to form starch–urea carbamate.

2.5 Methods of Analysis

2.5.1. Gel fraction Determination

In this study, the carbon dioxide treated biomass hydrogel was put into commonly used tea bags and immersed into water for 12 hours to dissolve soluble fraction. The hydrogels were then dried by vacuum drier at 50.0 °C (Kampouris & Andreopoulos, 1989).The dissolved fraction was determined using the following equation.

$$Soluble\,Fraction = \frac{w_o - w_g}{w_g} \times 100\%$$

Where w_g is the weight of dry hydrogels after extraction and w_o is the initial weight of the hydrogel.

2.5.2. Swelling Rates

Gravimetric method was used to measure the swelling rate of the biomass hydrogel. Dry hydrogel samples of different weights (W_o) were immersed in distilled water and dispersed at room temperature with a magnetic stirrer at 120 rpm. Swollen samples were filtered by a sieve to remove excess water. Then, the weights of wet hydrogels were measured (W_t) when no more water was dropping off (Zhang *et al*., 2007). The following equation was used to calculate the swelling ratios of hydrogels.

$$Swelling\,Ratio = \frac{w_o - w_t}{w_o}$$

Where w_t is the weight of swollen hydrogels at time t, and w_o is the initial weight of dried biomass hydrogels.

2.5.3. pH Determination

The pH determination of the unmodified and modified samples was carried out using pH Meter Model….. This was done to determine the change in pH after modification. Titration method was used to determine the NH_2 concentration. Each modified sample (0.5 g) was dispersed in 100 mL of distilled water, and then an aqueous HCl solution with pH 1.9 was slowly dropped at the rate of 0.1mL min^{-1} (Le *et al.*, 2018).

2.5.4. FTIR characterization

The parent, the modified and carbon dioxide treated derivatives was characterized using Shimadzu IR Prestige-21 spectrometer model 800 series from 4000 to 400 cm^{-1} with scan speed 20 cm^{-1}. This was done to confirm the presence of anchored functional groups on the modified biomaterial. (Qiu and Hu, 2013).

2.5.5. Moisture analysis

The Karl Fischer moisture analyzer as reported by Meyers (2000) was used to determine the moisture content. It contains iodine, sulfur dioxide, and imidazole used as oven standards and function based on the reaction below.

$$ROH + SO_2 + 3RN + I_2 + H_2O \rightarrow (RNH)SO_4R + 2(RNH)I.$$

Samples were quickly taken to prevent absorption of moisture from the atmosphere and into tightened plastic bottles. They were further pulverized with a motor and pestle to expose the moisture trapped inside the samples particles. The rest procedure was done according to the Karl Fischer moisture analysis protocol.

2.5.6. Bacterial activity

The antimicrobial activity on the modified material was investigated by the basic methods of Agar disk-diffusion method as reported by Heatley (1944). The modified material which served as the antimicrobial agent was mixed with agar growth media which diffuses into the agar and then coated on filter paper discs (Balouiri, *et., al,* 2015). The plates (about 6 mm in diameter) were placed in petri dishes containing the test material and then inoculated with a standardized inoculum of the test microorganism. The Petri dishes are incubated under suitable conditions suitable for the growth of the microorganism. At those conditions, germination and then the diameters of inhibition growth zones were measured and recorded in tabular form.

2.5.7. Land preparation and Planting

The barren land was mechanically prepared by debushing, tilling and levelling. Conventional tillage was done by use of a fork jembe to loosen the soil to allow aeration and water filtration. The land was divided into two potions of about 10 m^2 each for planting maize (corn) and arrowroots (Mareanta arundinacea) also called "nduma" respectively. The actual digging of rows in the first potion of land was done for planting maize at the recommended spacing of 75-85 cm. Five rows were made and six maize seeds planted in depth of 5cm in each row at spacing of 25 cm. Varying masses of the carbon dioxide treated material were applied in each of the seed/seedling holes.

The next plot was prepared for planting arrowroots. The land was plowed twice to loosen the soil and to provide favorable condition for root development. Three rows were prepared in which and six arrow roots suckers of the same size were planted 40 cm apart in each row. Varying masses of the carbon dioxide treated material were applied in each of the sucker's hole.

Both the maize and arrowroots were planted during the dry season.

2.5.8. Watering of the plants

To the planted seedlings, 1000 ml of water was added to arrow roots while 500 ml was added to maize plants in the first day of planting. The plants were later watered with the same amount of water on a weekly basis.

2.5.9. Weeding

Simultaneous weeding and cultivation was done during the first two months for the maize plants and three months for arrow roots. Alternate hilling-up and off-barring for both plants was also done during this period until the plants were bid enough to cover the spaces between rows.

III. RESULTS AND DISCUSSION

3.1. Introduction

The results of each of the experiment are presented in spectrum and Tables and are discussed according to their respective order as is in the experimental methods.

3.2. Cellulose Characterization of Modified and Unmodified Cellulose

Cellulose is an organic water insoluble bio-polymeric material which is monofunctional in terms of aliphatic hydroxyl groups (Glasser, 2008; Schatz & Lecommandoux, 2010). The primary hydroxyl groups is located in C-6 and while the secondary one in C-2 and C-3 respectively. The C-1 has reducing properties while the C4 has non-reducing properties. Substitutions of its -OH groups take place in the C-6, C-2 and C-3 thus available for the derivatization reactions. Below shows a presentation of a linear glucose polymer and a cellulose polymer.

Scheme 1

Substitution reactions in the cellulose polymer has been reported to depend on the reaction conditions (Fu *et al.*, 2016). However, a study by Wang and co-workers (2008) reported to have observed that that in all cases, independent of the degree of substitution or reaction conditions, the hydroxyl group at C-6 was the most reactive followed by C-2, with the least reactive being C-3. Moreover, it is possible to change the conformation of hydroxyl group attached to C-6. This significantly affect the crystallinity of its structure and the way hydrogen bonds are formed structure (Olsson & Westm, 2013). It is therefore expected that in the modification of a cellulose polymer with amines such as ethylenediamine and one from a species of locally available fish called Omena. The substituent will be anchored in C-6 which is most reactive as shown in the reaction scheme below.

Scheme 2

That anchoring was expected to be in C-6 as it is a primary hydroxyl group and is highly accessible compared to the secondary OH groups (Poletto and Ornaghi, 2015). The lower steric hindrance in C-6 compared to the ones in C-2 and C-3 positions makes it more accessible for the substitution reaction (Klemm *et al.,* 2005). Therefore, C-6 becomes most reactive for derivatization reactions (Vo *et al.,* 2010). The resulting modified bio-material was as presented in Figure 1 below.

Figure 1

The modified material was a dump dark brown in colour similar to decaying vegetative material. It was air dried and then the parent and modified forms were characterized using FTIR.

3.3. FTIR Characterization of Modified and Unmodified Cellulose

Finely ground dry Powderly Solid sample materials of both the raw bio-mass were characterized using ATR-FTIR spectrophotometer. The results are presented as shown in Figure 2.

Figure 2

The results show a strong band at 3370.66 cm^{-1} appeared. This was attributed to either -OH (Daffalla, et. *al*., 2012). The finely ground dry powderly solid parent material was then modified using a synthetic amine and an amine of biological origin from a local fish called silver cyprinid (*Rastrineobola argentea*) and omena in our native language . The two modified samples were analyzed and the results obtained are presented in Figure.

Figure 3

The results show that the band at 1019.40 cm^{-1} on the EDA modified biomaterial refers to C-O-C stretching, while the signals at 3420.81 cm-1 could be attributed to the presence of the –NH functional group (Shakir, *et al*., 2019). The band at 1421.56 was assigned to –CN while 1239.29 cm^{-1} could be as a result of an amide (Bonin *et al*., 2010). This confirms a successful amine modification. The resulting modified materials were then separately treated with carbon dioxide and the results obtained were as presented in Figure 4.

Figure 4

The results show bands at 3353.30 cm^{-1} and 3428.53 in A and B respectively. This could be attributed to the low presence of –NH functional group after modification. This as result of the difference in resonance frequency contributed by steric effects after reprivatizing the respective amino functional groups (Childers et al., 2016). The peak at 1626.96 cm^{-1} and 1630.84 in the omena and EDA modified respectively were assigned to CO-NH due to the reaction between the amine group and carbon dioxide (Wang *et al.,* 2015). A similar observation was reported by Schlueter (1988) as he studied nitrogen attached carbon atoms in ring-opening polymerization breaking a carbon-carbon sigma bond. The peaks at 1139.95, 1200.50, and 1402.27 cm^{-1} are due to C-O stretching after modification. The band at 1039.69 cm^{-1} refers to C-O-C stretching.

The findings confirm modification of the parent bio- material with amino functional groups and there was evidence of the material chemically interacting with carbon dioxide. Thus the bio-material was modified with hydrophilic functional groups. (Nebhani *et al.,* 2016). The bio-material modified was investigated for its response to changes in their environment upon stimulation with some factors. The study investigated the effect humidity on volume variation of the modified material.

3.4: Effect of modification on volume variation upon interaction with water

The volume variation of the unmodified (UM/BM), EDA modified (EDA/BM) omena modified (OMENA/BM) and their respective carbon dioxide treated modified biomaterial (EDA/BM/CO_2, OMENA/BM/CO_2) were investigated upon their interaction with water. The results obtained was a presented in Figure 5.

Figure 5

The physical properties of the modified is affected by their interaction with water by swelling. The swelling behavior of these materials was calculated according to Flory-Huggins theory (Metters 2006; Suzuki *et al*., 2008). The result show that all the modified material responded to water by increasing in volume with varying extents of stimulation. The stimulation increased the volume by 200% as compared to their dry mass. Carbon dioxide modified samples shows the highest swelling percentage rate of 400 to 450 percent after one hour while the unmodified samples indicated the least swelling percentage rate.

3.5. Effect of modification on pH variation

To confirm the presence of the amine anchored group, a mass of 0.500 g of the amine modified biomaterial was dispersed in 100 ml of water and then treated with 0.1M hydrochloric acid and the time variation of pH the solution monitored. The results obtained was as presented in Figure 6 below.

Figure 6

The results show that the two different materials were observed to have different pH values as they were anchored with different amino groups. It was observed that the EDA modified was more basic as compared to the omena modified whose values were 9.1 and 7.55 respectively before treatment. Upon acid treatment, thus when H^+ ions were added, they react with the amine ion to increase the acidity whereas the concentration of the amine (basic) ion decreases. The different dissociation constants of each respective material contribute to the observed pH variation, thus variation of the concentration of the species involved will regulated by the equilibrium constant meaning that pH will be as observed (Persat, Chambers & Santiago, 2009). The pH increases to 9.3 and 7.65 after 11 minutes between the two modified forms respectively, which could be attributed to the protonation of NH_2 groups (Persat, Chambers & Santiago, 2009). The pH then decreases after 11 minutes due to excess hydrogen ions. The decreased with time this could be due to the formation of carbamic esthers (Jäger et al., 2000). This shows a summary of concentration amine groups obtained titrimetrically presented in a tabular form. The results show the samples modified with ethylenediamine and "omena" indicated the higher concentration of amino groups as compared to carbon dioxide treated derivatives. This is because of the formation of carbamates on the amino groups.

3.6. Absorption of carbon dioxide

An experiment on the treatment of the modified material with carbon dioxide was carried out. It was done to determine the average volume of carbon dioxide absorbed by the hydrogel from 10 to 100 grams of the solid material. The volume of excess and absorbed carbon dioxide was recorded as presented in Table 1.

Table 1

The results show that the volume of carbon dioxide absorbed increased with the increase of the mass of modified grass. This is because of the increase of the amine groups which function as the active site for the attachement of carbon dioxide molecules. A mss of 100g of the sample absorbed the largest volume of carbon dioxide. The modified material was then tested for bacterial activity.

3.7. Effect of modification on bacterial activity

The amine-carbon dioxide modified biomass unlike untreated has an advantage in that it has an improved anti-bacterial activity and may sustain the supply of needed moisture to annual (seasonal) and potted plants in the fields and offices respectively (Valk *et al*., 2015). This study investigated the effect of modification on bacterial activity.

Carbohydrates under moist conditions attract bacteria that bind to it and multiply on its solid surface. This is due to the presence of essential nutrients in biomass that enhance a relationship to occur between microorganisms and plant cells that promotes a successful colonization and its ability to flourish in the cells (Bacon and Hinton, 2006). In this study, different samples of the parent and modified bio material in a petri dish were inoculated with a *Bacillus Subritis* bacteria. The microbial analysis were carried out to various biomaterial samples treated with amines from waste omenas, ethylene di amine and carbon dioxide as shown in Figure 7.

Figure 7

The microbial analysis results obtained were as presented in Table 2.

Table 2

The results show that the treated grass cellulose provides higher antimicrobial activity. The modified materials and carbon dioxide treated exhibited the lowest number of bacteria colonies of 8×10^1 and 5×10^1 respectively. This strong antimicrobial functions confirmed that the modification improved the shelf life of the modified product. This makes it effective to improve water retention capacity in soil for an extended duration capable to supply of water to seasonal plants from planting to maturity. As a result it offers sustenance by the provision of the critical moisture content before the plants wilted due to plasmolysis.

Modified samples were more effective in inhibiting rapid bacterial growth, probably due to the high percentage of protonated amine and carboxyl groups (Shigemasa and Minami, 1995; Liu *et al.*, 2001).The mode of action of the treated sample is believed to come from interaction and disruption of the bacteria cells envelope. Various researches has proven that the inhibition action takes place on the bacteria surface (Muzzarelli *et al.*, 1990; Cuero, 1999; Savard *et al.*, 2002; Raafat et al., 2008). Polycationic and polyanionic nature due to positively charged (NH_4^+) and negatively charged ($-COO^-$) of the modified sample might be the critical factor that contribute to their interaction with charged surface components of fungi and bacteria. This leads to cell surface reactions that ceases the vital bacterial activities (Helander *et al.*, 2001; Zakrzewska *et al.*, 2005; Je and Kim, 2006).This is due to the fact that a reaction between amine modified starch produce a carbamate which has antibacterial activity (Chowdary and Chandra, 2009). The modified material was then applied for in the field for the growth of plants.

3.8. Application of the modified biomass supply of water to the plants in the field

The experiment was carried out in a virgin land one of Kenyatta University plots of dimensions 16 by 30 m. Kenyatta University is situated at Coordinates at Latitude -1.181056 and Longitude 36.927234. The area is relatively flat and characterized by arid and semi-arid conditions. The experiment was done during "dry season the summer" period between July and September 2021. In that garden, two types of plants maize and arrow roots (Zea mays and Maranta arundinacea respectively) were planted using varying masses of the biomass hydrogel prepared from the modified plant material. Five and three rows were prepared for planting maize and arrow roots respectively. In each row, holes were dug for the purpose of planting one seedling per hole. In each of the holes, varied masses of the modified material were added followed by planting a seedling. As a control experiment, the modified material was not added in a selected row and the results compared. To the planted seedlings, 1000 ml of water was added to arrow roots plants while 500ml was added to maize plants during the first day of planting. The plants were later watered with the same amount of water on weekly basis and were not showing signs of wilting. A sample of (1 g) of the soil mixture on the surface of every plant was taken three times after every 24 hours for a period of two weeks to determine the moisture content. The height of the plant, length of the leaf blade and number of leaves on each maize stalk and arrow root were recorded on weekly basis. The plot was as shown in figure 8 and the block diagram in Table 4.

Table 3

3.8.1. Application of Hydrogel on maize plants.
Small plots were prepared and in them maize and arrow roots were planted separately. Varying quantities of the modified material were applied in each of the different rows as shown in Table 4 Figure 8 shows a plots in which maize was planted.

Figure 8

The results show that there is a direct relationship between the mass of the biomaterial used has a direct relationship with the quality of the health of the maize plants as well as that of the arrow roots. The higher the mass, the better the quality of the plants.

The variation of the mass of the plants against the growth of the plants was monitored and the results obtained were as recorded in Table 4, and the height of the plants recorded as shown in Table 4.

Table 4

It was observed that an increase in the mass of the modified bio material enhanced growth which implies that the bio material maintained a high water retention capacity which was available for plant growth. Plant sample row S_5 where 0.4 kg per plant of the treated biomass. Plants in row of the treatment regime of S_1 and S_2 required a watering supply on weekly basis to alleviate wilting. There was a significant relationship of the mass of the modified biomass with the height of the plants, number of leaves and the length of leaves. The observed parameter were 72.70 cm, 5.00 and 52.96 cm in the same order within the first 30 days.

The results show that there was a positive effect on the quantity of the mass of the modified biomaterial of growth parameters such as height and the length of the leaf blade. Similar finding were reported by Muller, Reymond & Tardieu (2019) who monitored the elongation rate of a maize leaf as a factor of stress from many parameters of which water was one of the factors. Another study reported similar observation reported in this study Granier & Tardieu, 1999*a*, *b*. The results of the heights of the maize plants at maturity on varied amount of hydrogel were presented in Figure 12 and Table 5.

Table 5

The results show that the amount of Biomass hydrogel used per treatment significantly affected the average plant height of maize plants at maturity. The Average Plant height was recorded as 212.75, 232.5, 248.5 and 268.25 cm respectively. S_5 treatment (1.0 kg/plant) resulted to the highest average plant height while lowest average height was recorded in S_1 (without hydrogel). The results show that there was a positive effect on the quantity of the mass of the modified biomaterial to the growth parameters. The variation of height with the mass of the biomaterial used was recorded in Table 6.

Table 6

The results show that the amount of Biomass hydrogel used per treatment significantly affected the average maize yield at maturity. The Average maize yield was recorded as 0.3825, 0.4525, 0.74 and 1.055 kilograms respectively. S_5 treatment (1.0kg/plant) resulted to the highest average yield while lowest average yield was recorded in S_1 (without hydrogel). The results show that there was a positive effect on the quantity of the mass of the modified biomaterial to the maize yields.

4.7.2. ANOVA

The **Analysis of variance** test was carried out to determine the influence of the application of the modified biomaterial on the growth of the selected plants. The test was intended to provide the validity by practical observations on the reliability of the application of the modified material in the soil for growth of some selected plants. The test was carried out on both the maize an the arrow roots and the results are as presented in sections 3.7.2.1 and 3.7.2.2 respectively

3.7.2.1 ANOVA analysis for maize plants

The quality of the maize plants in the plots and the yield were analyzed statistically using analysis of variation, where the mass of the biomaterial was a key variable. The results obtained were as presented in Tables 7.

Table 7

The calculated values showed a significant difference in the height and the yields of the maize planted with the four different amounts of hydrogels.

3.7.2.2 ANOVA analysis for the arrow root plants (Maranta arundinacea)

The effect of the application of the carbon dioxide treated biomaterial was investigated where the plants were planted in three rows each having a different amount of the biomass. Table 8 shows how the different parameters affected the quality of the arrow roots as well as the ANOVA analysis.

Table 8

The arrow roots were planted in well prepared plot in a similar process as the maize plants. Each of the respective row of the plant had a difference amount of the modified biomaterial. The results show that there was significant increase of the height, number of leaves, leaf diameter of the plants with the increase in the mass of the modified bio-biomass. This was due to the material providing sufficient water for the plants due to its capability of enhancing soil water retention (Johnson & Woodhouse, 1990). The application of the modified material ensures an uninterrupted continuous supply of water to the plants resulting to increased plant leaf longevity compared to control. Therefore, the modified biomass has a significant capability of water-retention when incorporated in soil. The absorbed water is released slowly to the soil as plant requirement, thus improving the plant growth rate under limited water supply (Huttermann *et al*., 1999).

The calculated value was greater than F-test tabulated value as shown in Table 8(D) show that there is a significant difference on the height of the arrow roots planted with the four different mases of the modified material.

IV. CONCLUSIONS

This study successfully modified biomass from grass with amines from both synthetic and bio origin as confirmed by FTIR analysis. The amine modified biomass was also found to react with carbon dioxide at a rate of 4.89 cm of the gas per gram of the biomass which resulted in being crosslinked further. The interaction with carbon dioxide produced a carbamate that has high antibacterial properties thus capable of being applied in the field remain un-degraded for an extended duration of time. The resultant was a modified biomass that possess excellent water adsorption properties. This was confirmed by its volume variation upon interaction with water enabling soil aeration and being a suitable soil modifier. Its swelling was above 200% of the swelling capacity compared to same mass of the dry parent grass biomass. When applied in the field, it served as a good source of water for maize and arrow roots that were sustained to grow to maturity for a duration of more than three months. The results confirmed that the modified material influenced the growth of vegetation as 1.0 kg per a plant contributed to an average growth height of maize of 268.25 cm as arrow the root bloomed to produce a plant with leaf with a dimension of 68.45 cm within three months of growth. It was found out that 0.4 g of the modified material was capable of enabling a (one) maize plant produce 1.055 kg of maize after maturity. Thus the modified material contributed positively to the growth of the respective plant to maturity as well as the yield. The modified biomaterial can reverse the negative effects due to carbon dioxide in the environment of global warming and retain sufficient water in the soil for vegetative cover to alleviate desertification.

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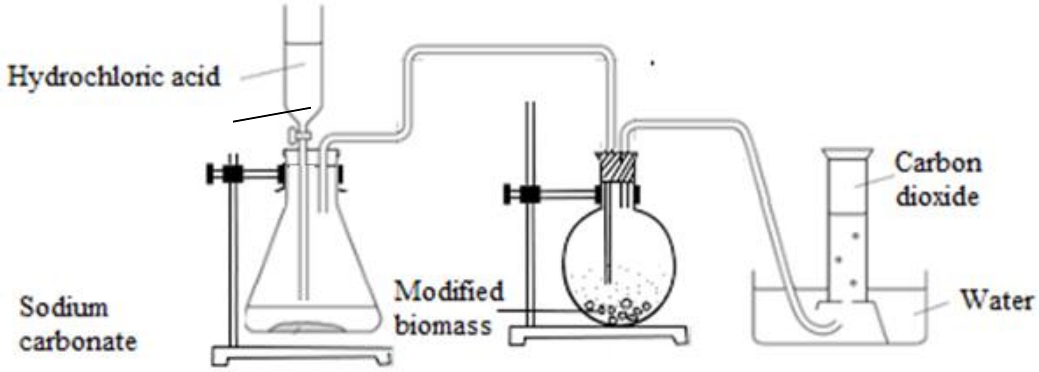
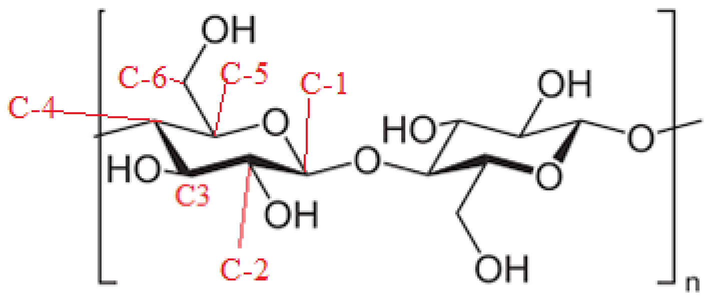
SCHEMES AND FIGURES

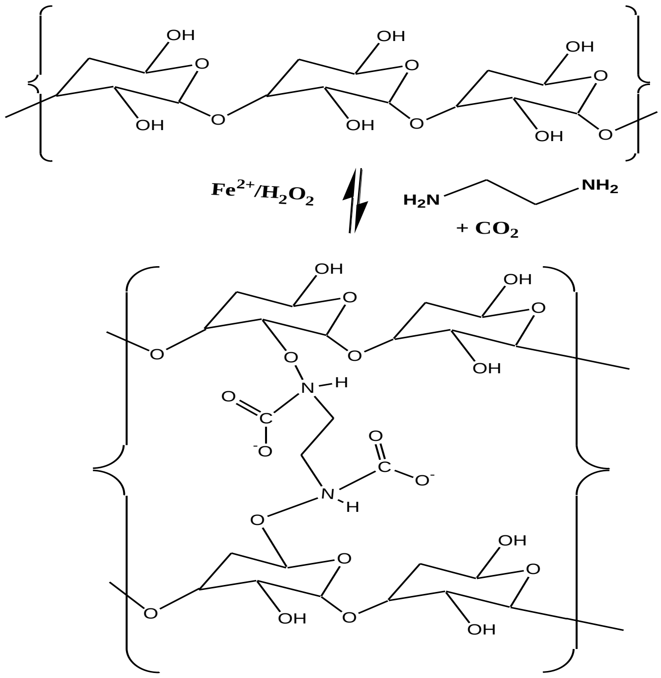


~~Fig 1: Setup~~ for carbon dioxide treated amine modified biomass.

RESULTS AND DISCUSSION



Scheme 1 Glucose polymer



Scheme 2 Amine modification of cellulose

Figure 1: Modified grass biomass

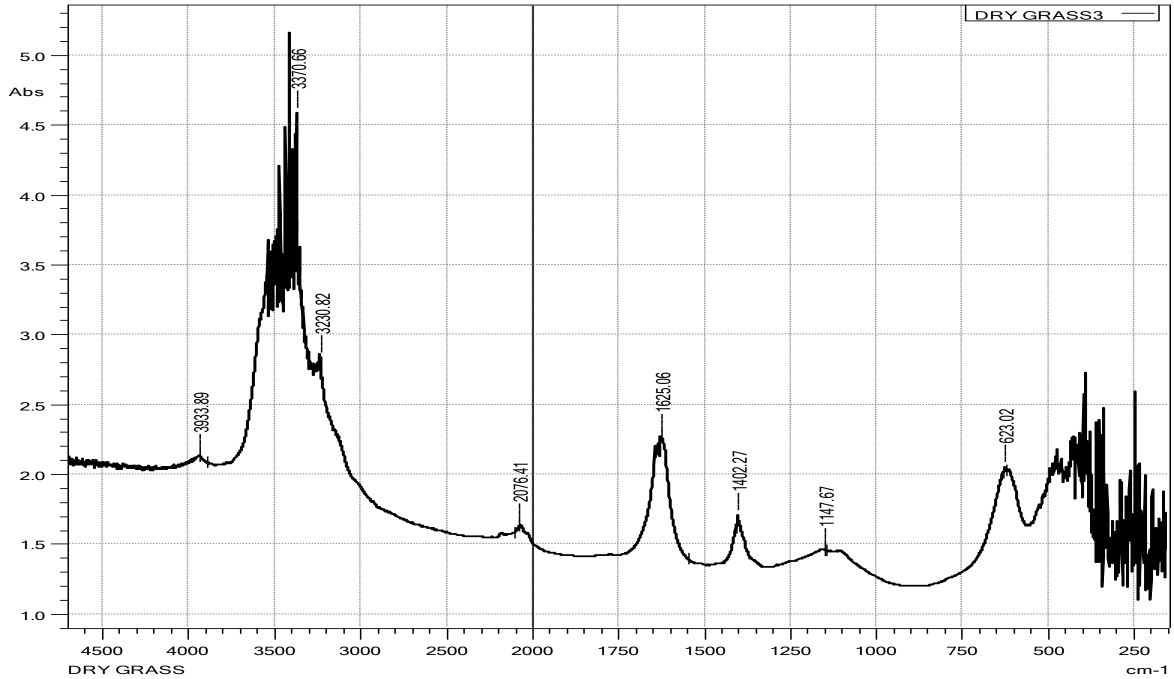


Figure 2 FTIR Spectra for unmodified biomass

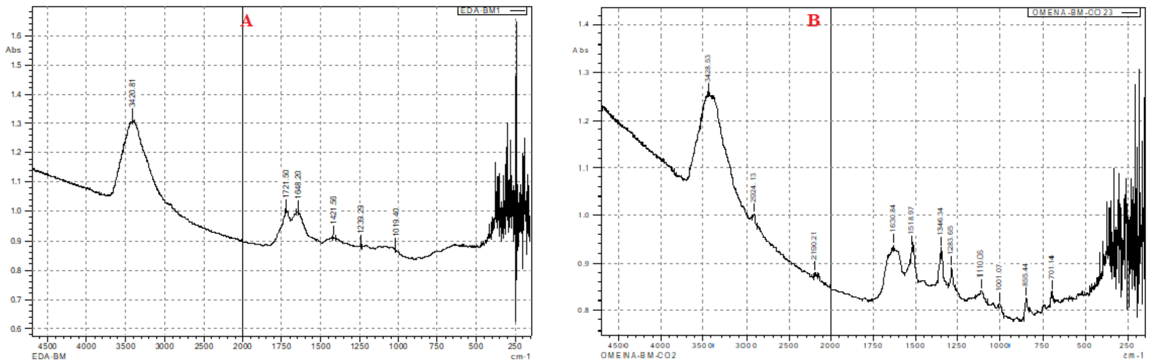


Figure 3 FTIR spectra for EDA -Modified Biomaterial (A) silver cyprinid (Omena) modified grass (B)

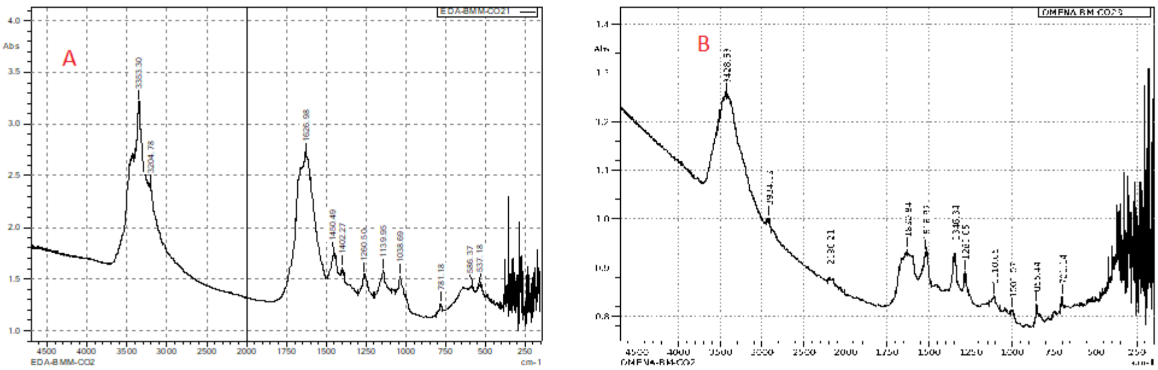


Figure 4 FTIR spectra of carbon dioxide treated EDA (A) and Omena (B) modified biomass

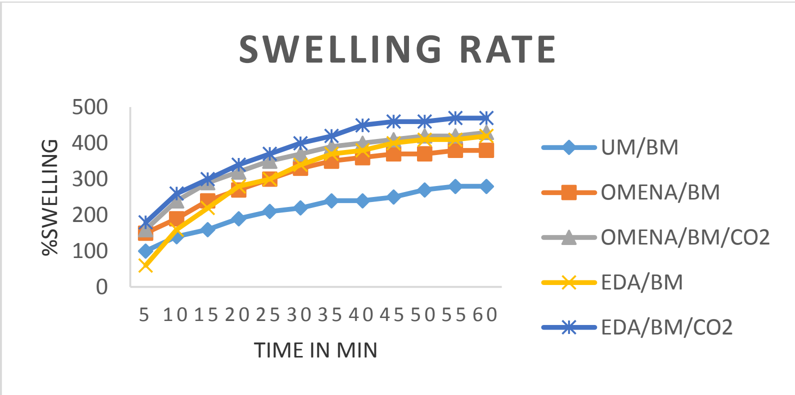


Figure 5 Swelling rates of Unmodified and modified samples.

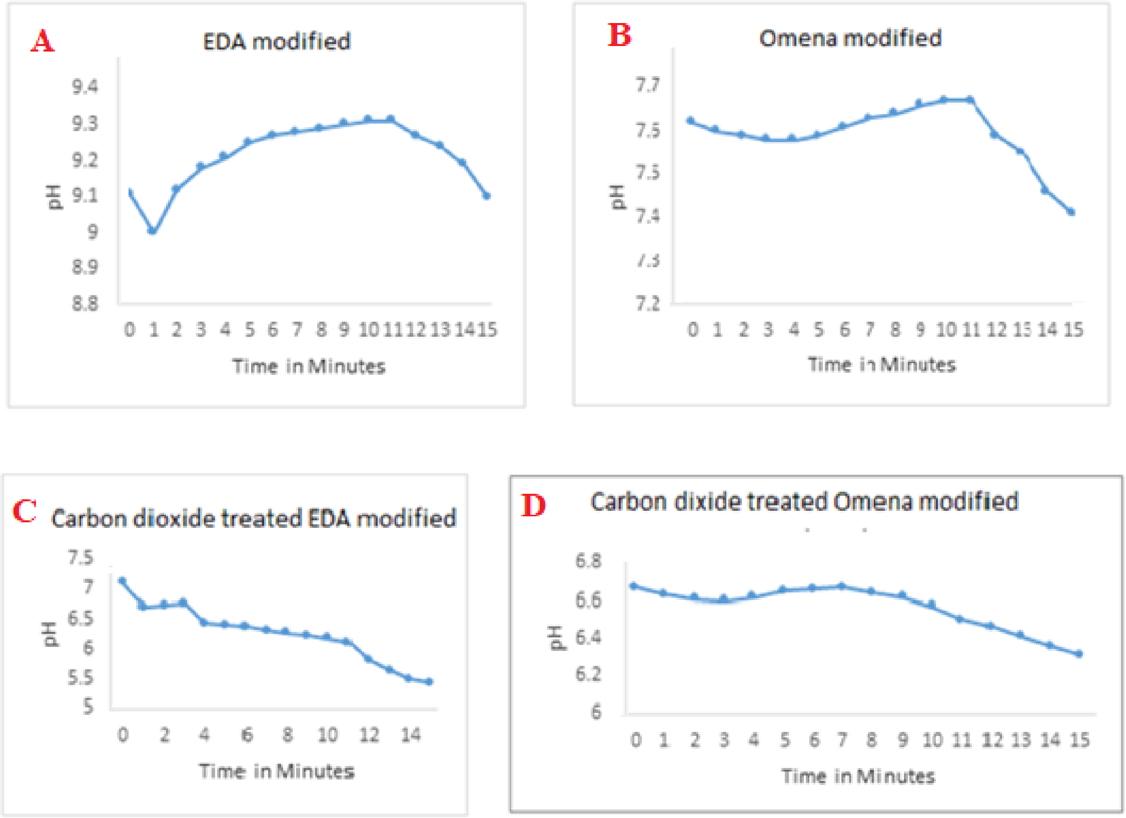


Figure 6 Variation of pH with time for the amine anchored and carbon dioxide treated amine anchored biomaterial

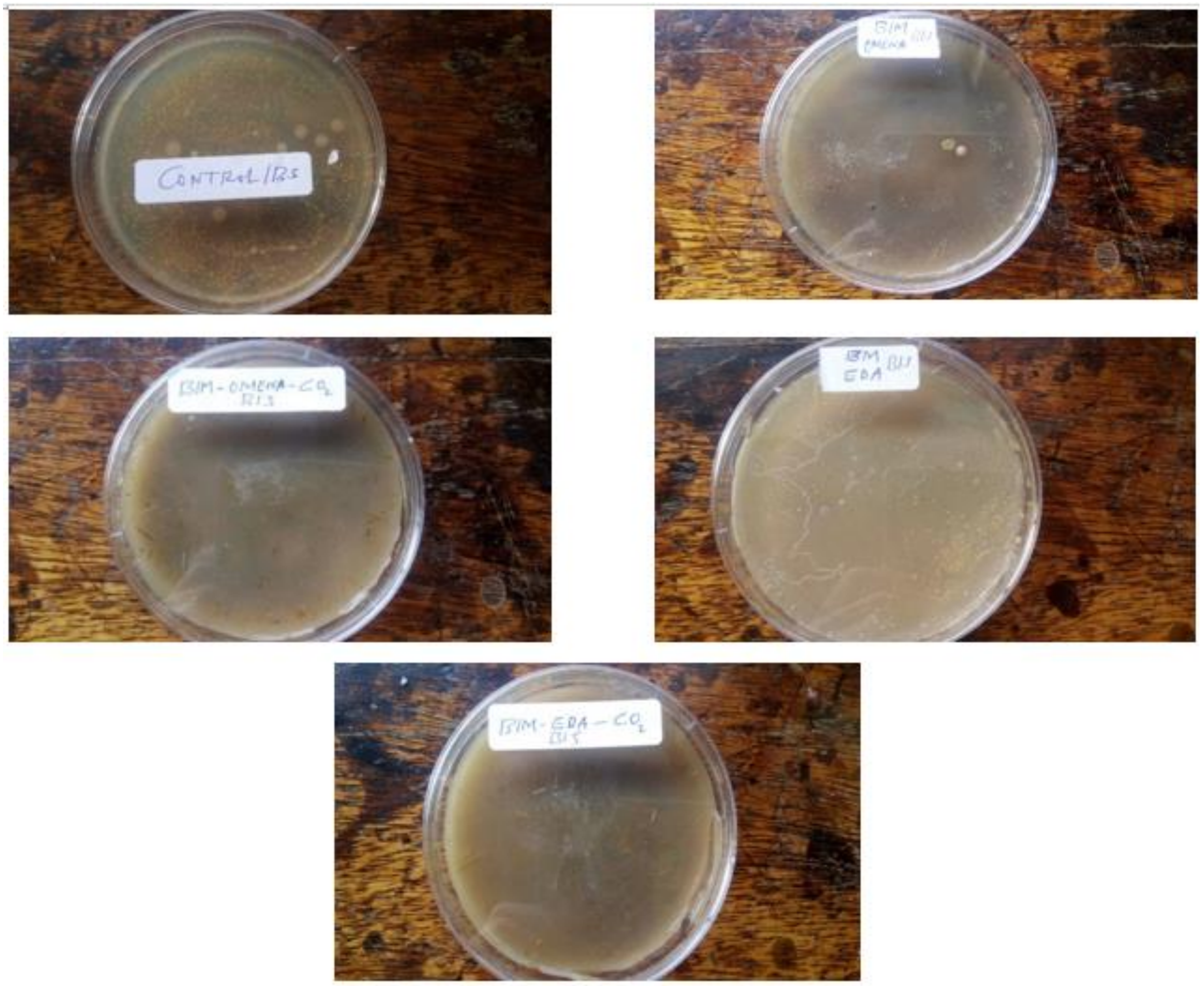


Figure 7 Microbial Analysis

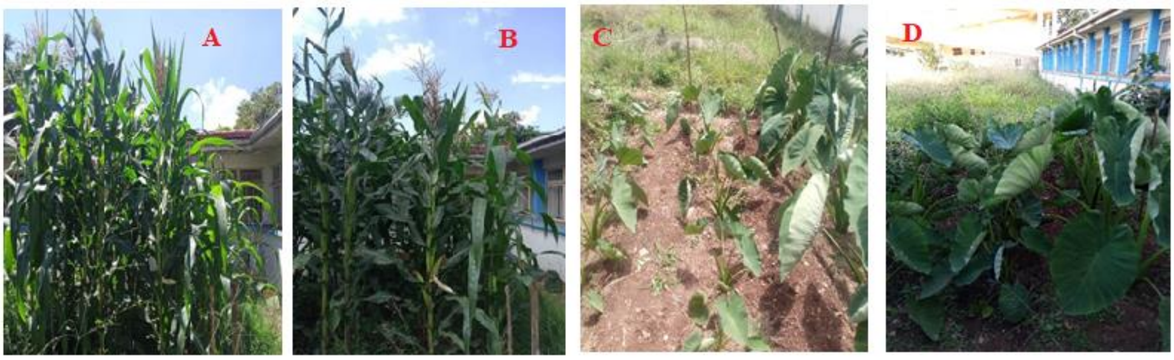


Figure 8 Maize plants after two months (A) at maturity (B) plus arrow roots after 3 months (C) and at maturity (D)

LIST OF TABLES

Table 1 Average volume of excess and absorbed carbon (IV) oxide by the modified samples

Sample Mass in Grams	Average Vol. of Excess CO_2 (cm^3)	Average Vol. of CO_2 Absorbed (cm^3)
10	485.50 ± 1.15	14.50 ± 0.51
20	425.50 ± 1.12	74.50± 0.56
30	370.90 ± 1.00	129.10 ± 0.76
40	321.80 ± 0.96	178.20 ± 0.86
50	256.40 ± 0.97	243.60 ± 0.90
60	201.80 ± 0.95	298.20 ± 0.89
70	141.80 ± 0.89	358.20 ± 1.10
80	92.70 ± 0.88	407.30 ± 1.12
90	54.50 ± 0.70	445.50 ± 1.16
100	10.90 ± 0.66	489.10 ± 1.20

Table 2 Average amount of Bacterial colonies of the modified and Unmodified Samples

Sample	Inoculums Volume (1ml)	Dilution Factor	Average No. of BS Colonies	CFU/Ml
Control	1	1×10^{-1}	284	284×10^1
Biomass	1	1×10^{-1}	207	207×10^1
BM-Omena	1	1×10^{-1}	21	21×10^1
BM- EDA	1	1×10^{-1}	15	15×10^1
BM/OMENA/CO_2	1	1×10^{-1}	8	8×10^1
BM/EDA/CO_2	1	1×10^{-1}	5	5×10^1

Table 3 Block Diagram Representing Maize Planted in Five Rows Using Different Amount of Carbon dioxide Modified derivative.

MASS	PLANTS					
0.0 Kg	A_1	A_2	A_3	A_4	A_5	A_6
0.1 Kg	B_1	B_2	B_3	B_4	B_5	B_6
0.2 Kg	C_1	C_2	C_3	C_4	C_5	C_6
0.3 Kg	D_1	D_2	D_3	D_4	D_5	D_6
0.4 Kg	E_1	E_2	E_3	E_4	E_5	E_6

Table 4 Effect of different irrigation and hydrogel levels on Growth parameters of Maize in the second Month

	Av. Plant Height (cm)	Av. No. of Leaves	Av. Length of Leaf (cm)
S_1-Control	50.20	3	38.20 ± 1.05
S_2- 0.1kg/Plant	62.30	4	43.90 ± 1.10
S_3- 0.2kg/Plant	75.20	5	55.10 ± 0.65
S_4- 0.3kg/Plant	83.70	6	61.40 ± 0.90
S_5- 0.4kg/Plant	92.10	7	**66.20** ± 0.80
Mean	72.70	5.00	52.96 ±0.9

Table 5 Effect of different hydrogel levels on the Height of Maize (cm) at Maturity

	ROWS/mass of biomaterial				
	A- Control	B- .1kg/Plant	C- .2kg/Plant	D- 0.3kg/Plant	E- 0.4kg/Plant
HEIGHT/cm	194	215	232	247	266
	198	210	230	249	268
	195	212	235	248	270
	200	214	233	250	269
Mean	196.75±1.4	212.75±1.1	232.5±1.0	248.5±0.6	268.25±0.9

NB: S_1 – unmodified biomass sample
S_2 – S_5 – Modified biomass samples with different masses

Table 6 Effect of different hydrogel levels on the Maize Yield (Kgs) at Maturity

	ROWS/mass of biomaterial				
	A- Control	B- 0.1kg/Plant	C- 0.2kg/Plant	D- 0.3kg/Plant	E- 0.4kg/Plant
Yield/Kg	0.36	0.40	0.43	0.74	1.10
	0.32	0.35	0.40	0.65	1.22
	0.29	0.37	0.50	0.80	1.00
	0.33	0.41	0.48	0.77	0.90
	Mean; 0.325	0.3825	0.4525	0.74	1.055

NB: S_1 – unmodified biomass sample
S_2 – S_5 – Modified biomass samples with different masses

Table 7 (A) ANOVA analysis for the heights of maize plants (A) and yields (B) at maturity.

A

Source of Variation	SS	DF	Ms (Variance)	F Calc.Value	Tab. Value α = 0.05
Total	12861.75	19			
Groups	12797.50	4	3199.38		
Error	64.25	15	4.28	747.52	3.06

B

Source of Variation	SS	DF	Ms (Variance)	$F_{Calc.Value}$	Tab. Value α = 0.05
Total	1.563	19			
Groups	1.483	4	0.3709		
Error	0.08	15	0.00533	69.54	3.06

Table 8. (A) Mass per row of the plants, (B) Effect of mass of the modified biomaterial on the leaf size, (C) effect of height at maturity and (D) ANOVA analysis

A

Mass per row of the plants,

MASS	PLANTS					
0.0 Kg	A_1	A_2	A_3	A_4	A_5	A_6
0.5 Kg	B_1	B_2	B_3	B_4	B_5	B_6
1.0 Kg	C_1	C_2	C_3	C_4	C_5	C_6

B

Effect of different irrigation and hydrogel levels on Growth parameters of Arrow Roots in the first three Months

Treatment	Av. Plant Height (cm)	Av. No. of Leaves	Av. Length of Leaf (cm)
S_1-Control	14.50	3	11.40± 1.05
S_2- 0.5kg/Plant	22.30	5	16.10± 1.00
S_3- 1.0kg/Plant	29.60	5	31.70± 0.70
Mean	22.13	6.00	19.73± 0.91

C

Effect of different hydrogel levels on the Height of Arrow roots (cm) at Maturity

	S_1- Control	S_2- 0.5kg/Plant	S_3- 1.0kg/Plant
	35.5	49.90	68.70
	34.0	51.30	67.90
	35.0	50.00	69.00
	36.4	52.20	68.20
Mean	35.23±1.2	50.85±1.1	68.45±1.0

Mean: 35.23±1.2 68.45

D

Summary of ANOVA

urce of Variation	SS	DF	Ms (Variance)	F Calc.Value	Tab. Value α = 0.05
Total	2217.79	11			
Groups	2210.40	2	1105.2		
Error	0.08	9	0.8211	1345.98	4.26

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