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Effects of Different Soil-biochar on Physico-Chemical Soil Properties, Rooting and Growth of *Bougainvillea glabra* and *Ficus benjemena* Using Stem Cuttings

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Authors' contributions

This work was carried out in collaboration between all authors. Author II designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors HVA and PKT managed the analyses of the study. Author PKT managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A study was conducted at the Department of Horticulture, KNUST, to determine the effect of biochar-soil mixes on the soil physico-chemical properties for rooting and growth performance using air-layering. A 2X5 Factorial Randomized Complete Block Design which consisted of five soil-biochar amendments (2 part Coconut husk biochar: 1 part Topsoil, 2 part Maize stover biochar: 1 part Topsoil, 2 part Rice husk biochar: 1 part Topsoil, 2 part *Paspalum conjugatum*bochar: 1 part Topsoil and only Topsoil) and the two plant type (*Bougainvillea glabra* and *Ficus benjamena*). Parameters measured for the air layers included; days to root emergence, number of survived air layers, number of rooted air layers and root length (cm) per air layer. The 2Rhb: 1Tp mix recorded the highest water holding capacity of 601.70%, 21.8 times greater than the Tp. The 2Pcb:1Tp recorded the highest percentage increase of air porosity of 10.6%, better than Tp. The total nitrogen in 2Pcb:1Tp at 4WAP recorded an increase of 38.7% as the highest among the media 4WAP. 2 part Maize stover biochar: 1 part Topsoil recorded 23.0% increase in organic matter

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4WAP which was the highest among the media. 2Msb: 1Tp had a slight percentage increase of 6.0% as the highest among the media 4WAP.There was an increase of 45.7% 0f calcium content in 2Pcb: 1Tp which was the highest among the media at 4WAP. The results indicated that, significant ($p<0.05$) interaction between media and plant material type for the number of days to sprouting of *Bougainvillea glabra* air layers in 2Pcb:1Tp and 2Msb: 1Tp, 2Rhb: 1Tp1 and 2Pcb:1Tp, 2Rhb: 1Tp and 2Pcb:1Tp and 2Msb:1Tp and 2Pcb:1Tp influenced the number of fully developed leaves 5 WAP, 6 WAP and 7 WAP respectively. There were significant differences in the number of roots per air- layer of *Bougainvillea glabra* in 2Msb: 1Tp, 2Rhb: 1Tp and 2Pcb: 1Tp. Root length per air layers for *Bougainvillea glabra* was also significantly influenced by 2Msb:1Tp and 2Pcb: 1Tp.

Keywords: Adventitious; porosity; media; acidification; liming.

1. INTRODUCTION

Ornamental plant nurseries have become a thriving economic activity creating a viable employment for a number of families globally and providing invaluable service to the fast-growing landscape and floricultural industries. Vegetatively propagated ornamental plants continue to increase in popularity because of their tremendous production, marketing and garden successes experienced by individuals and floriculturists [1]. Moreover, a majority of such plants reproduces asexually under natural conditions [2]. In Ghana, the establishment of ornamental plant nurseries has become a significant feature of the urban landscape, springing up mainly along major roads and highways, along streets, footpaths and some situated in private homes. Nurseries are mainly used for the artificial regeneration of plants through the use of planting materials like seeds, leaf cuttings, stem cuttings, budding, grafting and layering [3]. *Bougainvillea glabra* and *Ficus benjamena* are among the highly economical ornamental plants used in most landscape beautifications. Bouganvillea, produces beautiful flowers with different colours, whiles the beautiful foliage of *Ficus benjamena* make them truly outstanding plant materials with unique aesthetic value [4]. A key step for a successful vegetative multiplication of these species begins with adventitious root formation, which is massively associated with difficult to root phenomena leading to a huge significant economic loss [5,2]. This condition, however, limits nursery managers and floriculturists to reach their full potential in propagating such important plants for their economic value and biodiversity conservation. Furthermore, field soils are generally unsatisfactory for the production of plants in pots or containers, simply because soils provide less aeration, drainage and water retention capacity required. Lehmann et al. considered the term biochar as a relatively new development, coming in conjunction with soil management and carbon sequestration issues [6]. Biochar has been shown to be beneficial for growing plants when it is added to soil because it contains stable carbon (C) and after using biochar to amend soils, its carbon remains sequestered for much longer periods than it would in the original biomass that biochar was made from. Plant yield increased with biochar addition and this has been demonstrated repeatedly for acidic and highly weathered tropical field soils [7,8,9,10]. Okunlola reported of a successful rooting of *Bougainvillea spectabilis* cuttings using plant hormones [11]. Adzraku et al. reported on a successful propagation of some difficult to root ornamental plants (*Ixora coccinea* and *Ficus benjamena*) using cuttings and different biochar-amended media [12]. There is, however, little research reports on how different soil-biochar mixes influences physicochemical soil properties, rooting and growth of *Bougainvillea glabra* and *Ficus benjamina*. This study, therefore, sought to assess biochar as a medium for propagating these important difficult to root plants.

2. MATERIALS AND METHODS

2.1 Study Site

The field experiment was done at the Department of Horticulture, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi from May, 2014 to September, 2014. The mean monthly rainfall at the shady area ranges between 20.1mm –211.3 mm.The mean daily maximum temperature ranges from 24.9ºC to 29°C while mean daily minimum temperature ranges from 20ºC to 22ºC. The Daily range of relative humidity from May –August was 58.4 % in the night and 78.2% in the afternoon. Mean monthly sunshine durations (hrs) ranges from 3.4 –5.2 hours in May to 2.1–4.3 hours in June to August. Mean monthly wind speed and direction (Knot) was 2.9– 4.1

2.2 Experimental Design and Procedure

The experimental Design used was a 2X5 Factorial Randomised Complete Block design (RCBD) with five treatments and two stock plants which were replicated three times given a total of (30) treatments on each plant of all the two stock plants used. Each treatment was represented by six cuttings.The feedstock used for the biochar production were; Maize stovers, Rice Husks, Coconut husks and *Paspallium* clippings. The maize stovers and *Paspallum* clippings were both collected from the trial fields and mowed lawns respectively at the Department of Horticulture KNUST. The rice husks were also obtained from Aboabo rice mills in Kumasi. Coconut husks were obtained from coconut sellers at Tech Junction in Kumasi. All feedstock were air dried properly before they were charred with a Bioreactor at Biochar Reactor Center at Chirapatre in Kumasi. Sterilizedtop soil was obtained from the Department of Horticulture in Kumasi. This served as a control for the experiment. The two plants *Ficus benjamina* and *Bougaivilleaglabbra* were obtained from the Department of Horticulture, KNUST. Straight cuttings from the two plants, namely *Bougainvillea glabra* and *Ficus benjamina* were taken early morning to avoid excessive moisture lost from the cut surface. Perforated polythene bags of dimension 15 cm x 10 cm were filled with equal volumes of each media. Cuttings of each stock plant were inserted into the filled polythene bags. The perforations on the black polythene bags helped to drain excess water from the media. Before cuttings were inserted into the medium, the medium was moistened and allowed to settle overnight. A dibber was used to create holes for the insertion of the cuttings. After inserting the cuttings in an upright form, the medium was firmed around the cuttings and watered.

2.3 Media Preparation

The Coconut husks, only the fibrous part were chopped into pieces and air dried for a week. The Maize stovers, Rice husks and *Paspalum* clippings were air dried for 48hrs, then charred in the Biochar Reactor for 72/48/24/12hrs, At 105ºC, 70ºC, 50c and 30ºC respectively.

2.3.1 Top soil

The top soil was obtained from the Department of Horticulture, KNUST. It was sieved to get rid of unwanted materials such as stones and other plant parts. The sieved top soil was then pasteurised for three hours (3hrs) using a steam chamber at a temperature of 100ºC.

2.3.2 The charring process

The feedstock was fed into the biochar reactor through the biochar inlet and pyrolysis was conducted in the reactor to obtain biochar. The temperature profile during pyrolysis was determined using a K-type thermocouple. Different temperature profile ranges from 20ºC to 300ºC was used for the different feedstock since they were not all of the same lignin material. The biochar was grinded and sieved through a 1mm sieve to make it suitable for chemical analysis. Analyses of the biochar include elemental analysis, pH and water holding capacity, to determine the physico-chemical impact of biochar additions to soil.

2.3.2 Media formulation

The formula for media formulation was based on a volume by volume (v/v) combination of the various biochar (2parts) with pasteurised soil (1Part).

The following media combination was done and coded as fellow;

- Topsoil = Tp
- 2 parts Coconut husks biochar :1part Topsoil =2Chb: 1Tp
- 2 parts Maize stover biochar :1part Topsoil =2 Msb:1Tp
- 2 parts Rice husks biochar:1part Topsoil = 2Rhb:1Tp
- 2 parts Paspallum clippings biochar:1part Topsoil =2Pcb:1Tp

2.4 Media Analysis

2.4.1 pH determination

The pH of the biochar was determined according to the procedures recommended by McLaughlin for the settlement of floating biochar particles [13]. The pH was measured with Metrohm 827 Lab pH meter.

2.4.2 Water holding capacity (WHC)

A filter paper was placed on the screen inside a Hilgard cup. The cup was gently filled with 20 g of air-dried biochar and placed in a shallow pan of water allowing only the bottom few centimetres of the cup to become wet. The biochar was allowed to become saturated from the bottom of the cup to the surface. The cup was removed from the pan of water and placed in humid enclosure till drainage was completed. The total weight of moist biochar and moisture container was taken after the biochar was carefully removed from the Hilgard cup, put in a pre-weighed container. The biochar was then dried in an oven at 105ºC until no further water loss occurred, and reweighed to record the oven-dried sample The WHC was then determined for all the media.

2.4.3 Estimation of Ca, Mg, P, K

Phosphorus, potassium, calcium and magnesium were determined by taking a 1.0 g of the biochar, ashed in a muffle furnace at 550ºC, after which the ash was dissolved in 10 ml of 1.0 M HCl solution and filtered. The filtrate was diluted to100 ml with distilled water. The 100 ml sample solution was divided into two; half for Ca and Mg and the other P and K analysis.

2.4.4 Nitrogen determination

Kjeldahl method was determined total nitrogen. Approximately 2.0 g of oven dried biochar was weighed into a 500 ml Kjeldahl flask, and 10 ml of distilled water added to it. Ten (10) ml of concentrated sulphuric acid (H_2SO_4) was also added followed by one tablet of Kjeldahl catalyst. The mixture was then digested on a Kjeldahl digestion apparatus for 3 hours for the mixture to turn yellowish or colourless. The flask was removed after a clear mixture is obtained. The digest was cooled and transferred to a 500 ml volumetric flask and topped up with 40ml distilled water. A 20 ml aliquot of the solution was transferred into a tecator distillation flask and 10 ml of 40% NaOH solution was added and steam from the tecator apparatus allowed to flow into flask. The distillate was received (condensed) into a flask containing 10ml of boric acid. The content in the flask (distillate) was titrated with 0.1 M HCl from a burette with bromocresol green-methyl red as indicator.

2.5 Data Collection

Data collected were;

i) Days to root emergence: This was the number of days it took for the air-layers to show the sign of rooting. This was taken as and when the roots appeared from the 1st day after air layering till the end of the experiment.
ii) Number of survived air-layers: This was the number of air-layers that did not die during the experiment period but did not root after callus formation. This was taken at the end of the experimental period.
iii) Number of rooted air-layers: This was the number of air-layers that had successfully rooted. Records were taken at the end of the experimental period.
iv) Root length per air-layer: The root length was measured using a pair of dividers and ruler from the point of attachment of the roots to the distal end of the stem cuttings. This was done on two randomly selected roots and the average root length recorded. The root length measurement was done at the end of the experimental period.

2.6 Data Analysis

Data was subjected to Analysis of Variance (ANOVA) using Statistix software version 9.0. Least significant difference (Lsd) test at 5% probability level was used to separate treatment means.

3. RESULTS

3.1 Climatic Conditions of the Experiment Location

The mean monthly rainfall ranged between 20.1mm to 211.3 mm. Rainfall peak with maximum of 156 mm and mean minimum of 67 mm. The mean daily maximum temperature ranges from 24.9ºC to 29ºC while mean daily minimum temperature ranges from 20ºC to 22ºC. The Daily range of relative humidity from May- August was (78.4%) in the night and (58.2%) in the afternoon. Mean monthly sunshine durations (hrs) ranges from 3.4 to 5.2 hours in May to 2.1 to 4.3 hours in June to August. Mean monthly wind speed and direction (Knot) was 2.9 to 4.1

3.2 Water Holding Capacity of the Different Media

The water holding capacity varied among the different media (Fig. 1). The 2Rhb:1Tp mix recorded the highest water holding capacity of 601.70%, 21.8 times greater than the Tp only with water holding capacity of 28.23%. The Tp recorded the least water holding capacity while the other media, 2Chb:1Tp (120.59%), 2Msb:1Tp (190.69%) and 2Pc:1Tp had water holding capacity of 4.3, 6.8 and 9.1 times respectively (Fig. 1).

3.3 Air Porosity

The 2Pcb:1Tp recorded the highest percentage increase of air porosity of (10.6%), whiles the Tp recorded the least percentage increase of (1.1%) in air-porosity. However, the 2 Rhb:1 Tp, 2 Chb: 1T p and 2 Msb:1Tp had percentage increase of 8.7%, 2.9% and 8.69% respectively more than the Tp (Fig. 2).

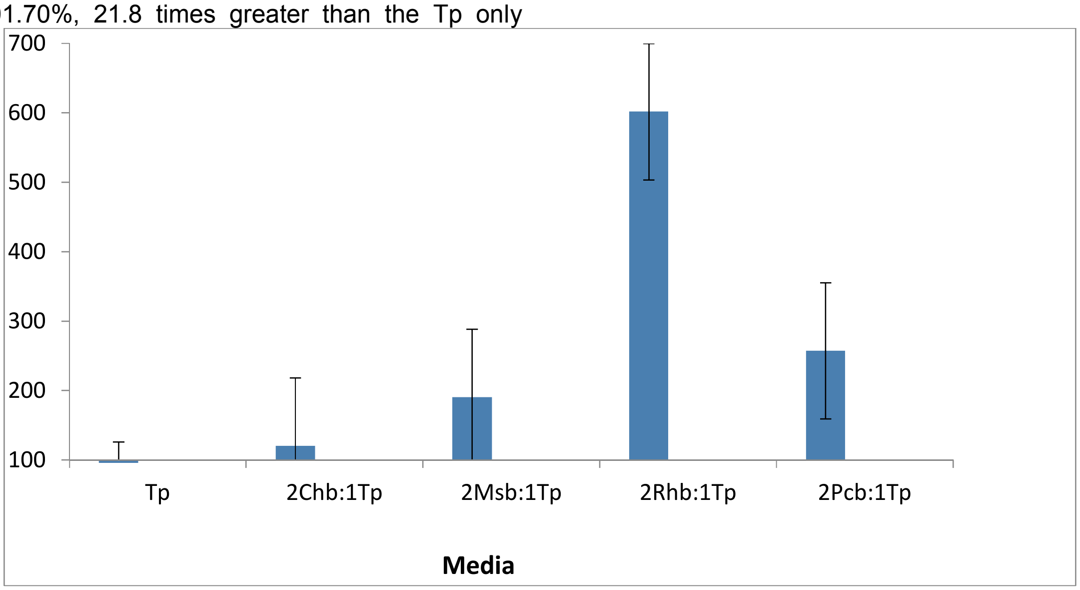

Fig. 1. Water Holding Capacity of different Media

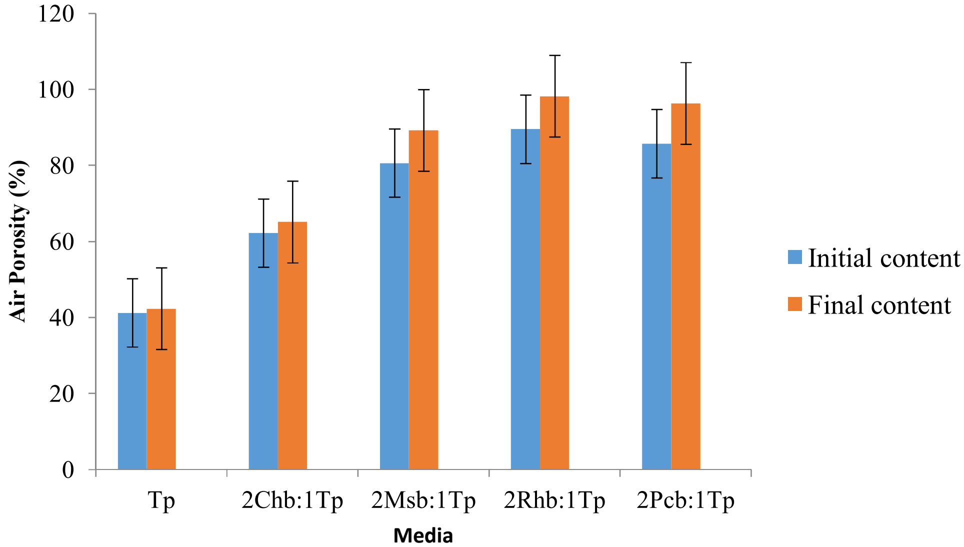

Fig. 2. Percentage air-porosity of the different media before and at the end of experiment

3.4 Total Nitrogen

The total nitrogen in 2Pcb:1Tp at 4WAP recorded a significant percentage increase of 38.7% as the highest among the media 4WAP but decrease by -2.0% at 8WAP. All the media recorded some amount of increment from 0WAP to 4WAP except the Tp which had a decrease value of -4% in total nitrogen 4WAP.There was however, a general percentage decrease in total nitrogen in all the media, the highest -38% was observed in 2Rhb:

3.5 Organic Matter Content

2Msb:1Tp recorded 23.0% increase in organic matter 4WAP which was the highest among the media and as well recorded the highest decrease in organic matter of -19.0 8 WAP. All the media had a percentage increase from 0WAP to 4WAP. Generally, there was a percentage decrease in organic matter from 4WAP to 8WAP, the highest was however observed in 2Msb:1Tp -19.0% (Fig. 4).

3.6 pH of the Different Media

pH of the various media did not increase significantly, but 2Msb:1Tp had a slight percentage increase of 6.0% as the highest among the media 4WAP, the rest also recorded some increment in pH 4WAP except Tp which recorded a decline in soil pH of -1.4 4WAP. There was a general decline in soil pH for all the media by eighth week after planting. The highest decrease observed in 2Pcb:1Tp of -7.7% at 8WAP. (Fig. 5).

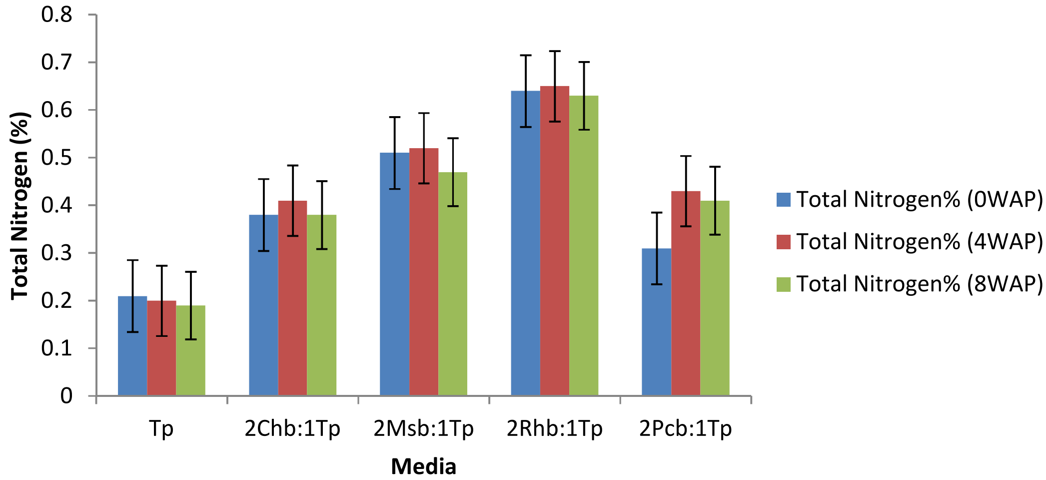

Fig. 3. Percentage total nitrogen content of the different media at 0WAP, 4WAP and 8WAP.

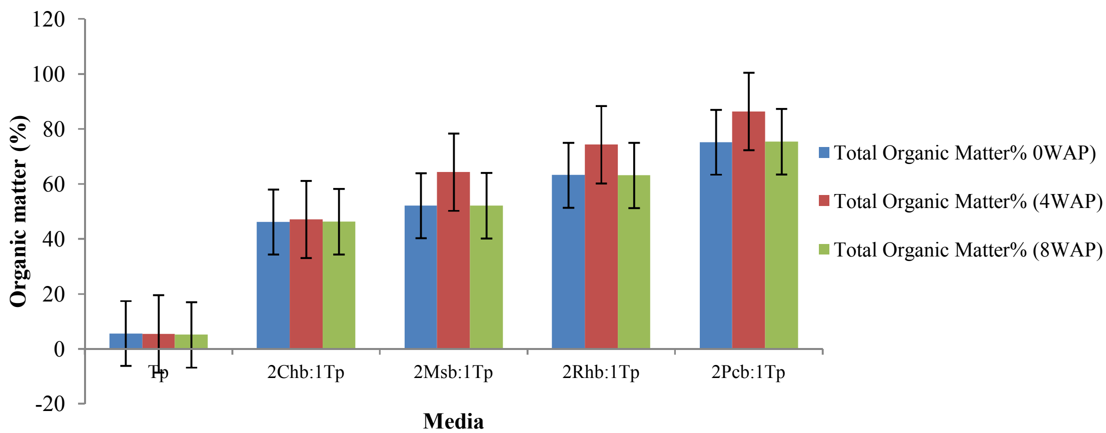

Fig. 4. Percentage organic matter content of the different media 0WAP, 4WAP and 8WAP

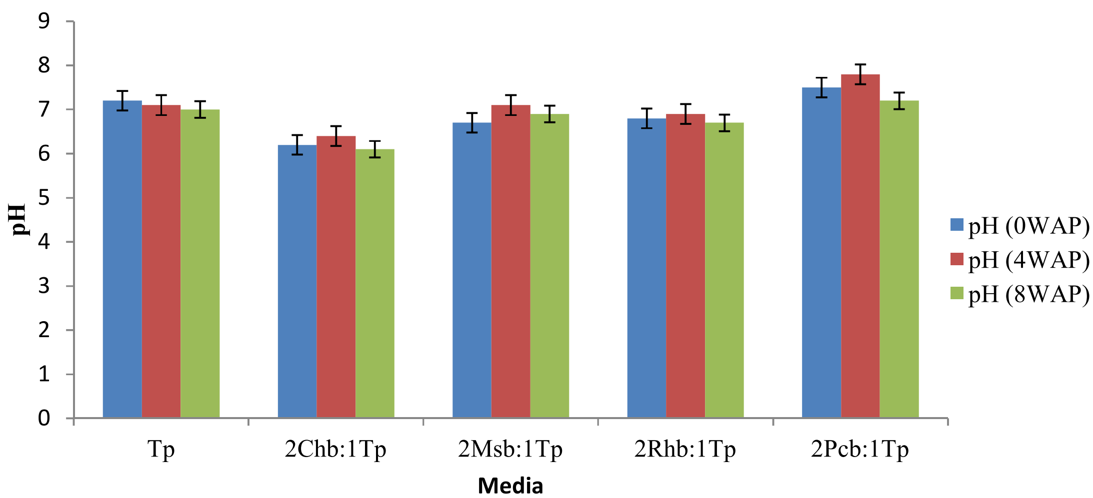

Fig. 5. pH of the different media 0WAP, 4WAP and 8WAP.

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3.7 Exchangeable Calcium Content

There was a significant percentage increase of 45.7% 0f calcium content in 2Pcb:1Tp which was the highest among the media at 4WAP and had a corresponding decrease of -27.5 at 8 WAP. The other media also recorded some increase in calcium content at 4WAP except the Tp which recorded a decrease in calcium content of -7.3% at 4WAP and a further decrease of -10.5% at 8WAP. There was however, a general decrease in calcium content 8WAP in all the media but the highest was observed in2Pcb:1Tp of 27.5%. (Fig. 6).

3.8 Exchangeable Potassium Content

The following media 2Rhb:1Tp, 2Pcb:1Tp and 2Chb:1Tp recorded percentage increase in exchangeable potassium of 48.4%, 44.0% and 26.0% respectively at 4WAP which was significantly different from the other media. 2Msb:1Tp recorded the least increase in exchangeable potassium of 9.0% at 4WAP. However, there was a general decrease in exchangeable potassium at 8WAP in all the media but the highest decrease of -32.0 was observed in 2Rhb:1Tp at 8WAP (Fig. 7).

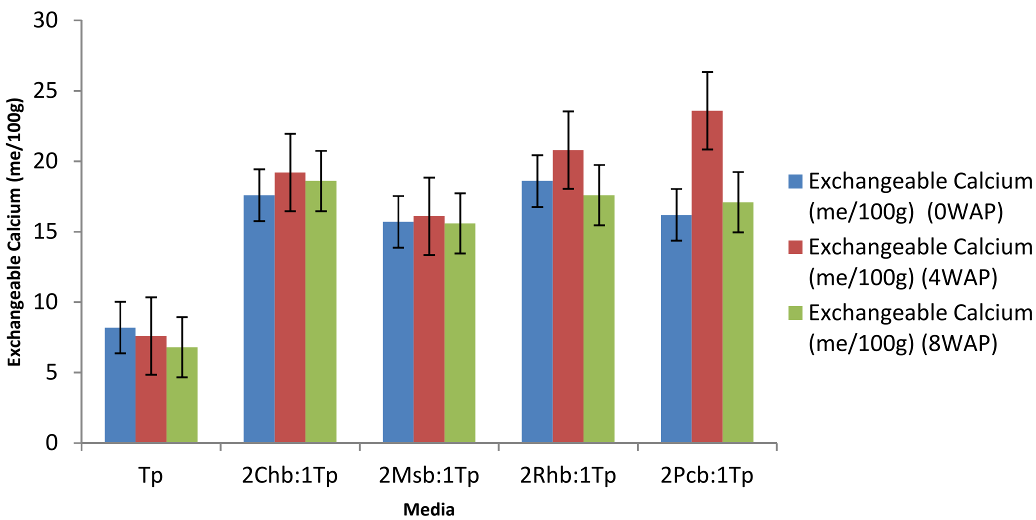

Fig. 6. Exchangeable calcium content of the different media 0WAP, 4WAP and 8WAP

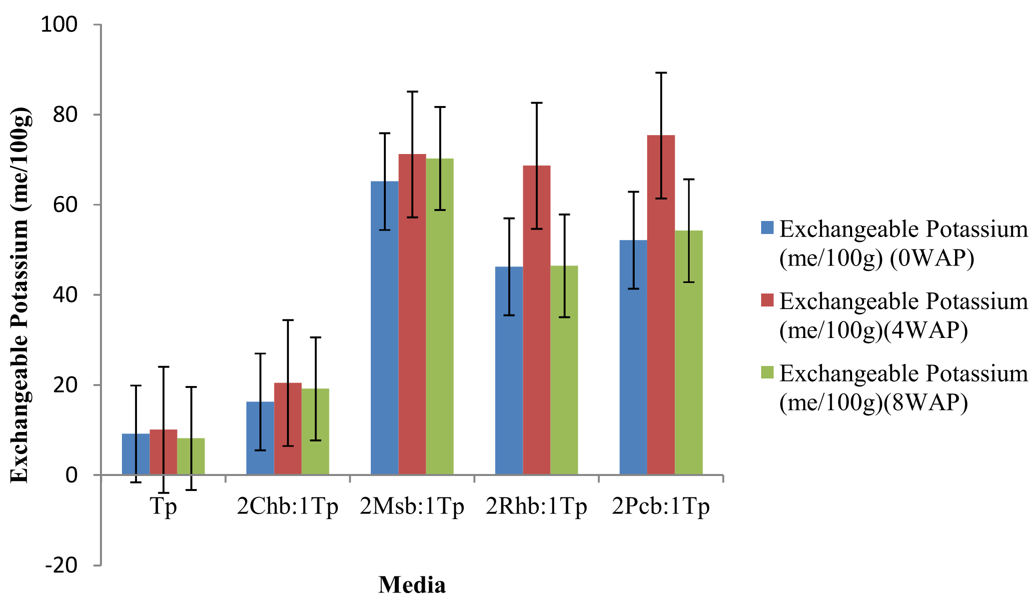

Fig. 7. Exchangeable potassium of the different media 0WAP, 4WAP and 8WAP

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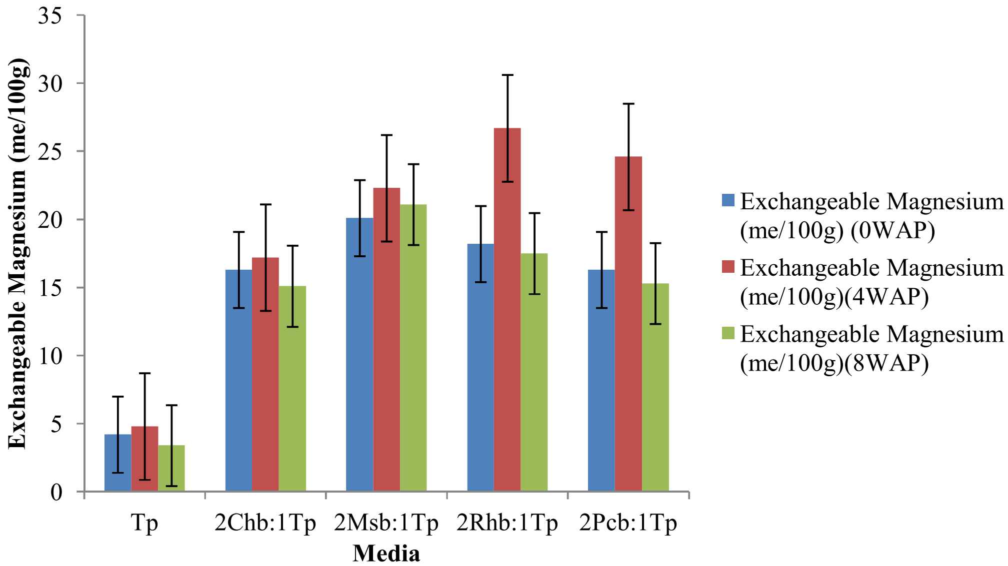

Fig. 8. Exchangeable magnesium of the different media 0WAP, 4WAP and 8WAP

3.9 Magnesium Content

2Pcb:1Tp and 2Rhb:1Tp had a significant percentage increase of exchangeable magnesium of 51.0% and 47.0% respectively at 4WAP. The lowest increase in exchangeable magnesium was observed in 2Chb:1Tp from 4WAP. All the media however recorded a downward trend in exchangeable magnesium at 8WAP. The highest decrease was -35.0 and observed in 2Rhb:1Tp. (Fig. 8).

3.10 Available Phosphorus Content

2Pcb:1Tp and 2Rhb:1Tp recorded an increment of 17.4% and 17.3% respectively at 4WAP significantly different from the other media. On the other hand, Tp, 2Chb:1Tp and 2Msb:1Tp recorded a decrease in available phosphorus at 4WAP. However, all the media recorded a decrease in available phosphorus 8WAP and the highest been -17.0 and observed in 2Rhb:1Rhb (Fig. 9).

3.11 Sprouting of *Bougainvillea glabra* and *Ficus benjamina* Cuttings

There were significant media and plant material type interactions for the number of days to cuttings sprouting (Table 1). *Bougainvillea glabra* cuttings in both 2Pcb:1Tp and 2Msb:1Tp took the shortest time to sprout, significantly earlier than the other treatment combinations. The longest time to sprouting was observed in *Bougainvillea glabra* cuttings in 2Chb:1Tp which was not different from that of *Bougainvillea glabra* cuttings in Tp. Between the media, sprouting occurred earliest in 2Pcb:1Tp though not significantly different from that in 2Msb:1Tp. The longest time to sprouting occurred in 2Chb:1Tp media which was similar to the time taken in Tp media. Among the plant cuttings, there were no differences in the time taken to sprout (Table 1).

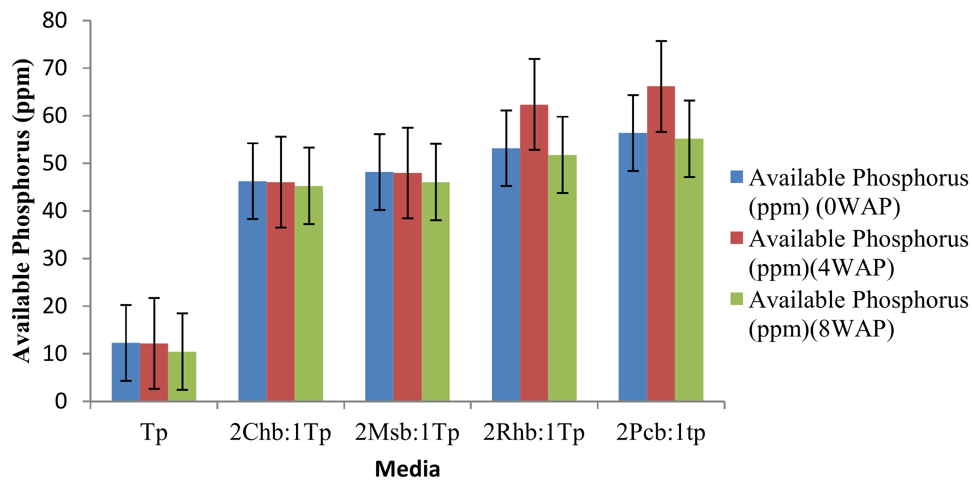

Fig. 9. Available phosphorus of the different media 0WAP, 4WAP and 8WAP

Table 1. Effects of media and plant type on the number of days to sprouting of cuttings

Media	Plant material		Mean
	Bougainvillea glabra	***Ficus benjamina***	
Tp	30.00ab	21.33c	25.67ab
2Chb:1Tp	31.00a	22.67c	26.83a
2Msb:1Tp	15.00d	25.67bc	20.34c
2Rhb:1Tp	23.33c	23.67c	23.50b
2Pcb:1Tp	15.00d	22.67c	18.84c
Mean	22.90a	23.20a	
Lsd (0.05) Media =3.11 ; plant type =1.37 ; Media x Plant material =5.21			

Plate 1. Sprouted *Bougainvillea glabra* cuttings in 2Pcb:1Tp (right) and 2Msb:1Tp (left)

3.12 Leaf Production of *Bougavillea glabra* and *Ficus Benjamina* Cuttings at 5 WAP

There were significant media and plant type interaction for the number of fully developed leaves at 5 WAP (Table 2). *Bougainvillea glabra* cuttings in 2Rhb:1Tp and 2Pcb:1Tp recorded the highest number of leaves 5 WAP, significantly different from the other treatment combinations. The least number of leaves fully developed 5 WAP was observed in both *Bougainvillea glabra* cuttings in Tp and 2Chb:1Tp. Between the media, the highest numbers of leaves fully developed were observed in the 2Rhb:1Tp media though not significantly different from that of 2Pcb:1Tp. The least number of leaves fully developed occurred in both 2Chb:1Tp and Tp. (Table 2). Among the plant cuttings, there were no significant differences in the number of leaves fully developed (Table 2).

3.13 Leaf Production of *Bougainvillea glabra* and *Ficus Benjamina* Cuttings at 6 WAP

There were significant media and plant type interaction for the number of fully developed leaves at 6 WAP (Table 3). *Bougainvillea glabra* cuttings in both 2Rhb:1Tp and 2Pcb:1Tp recorded the highest number of fully developed leaves 6 WAP, significantly different from the other media combinations. However, the least number of fully developed leaves was observed in *Bougainvillea glabra* cuttings in Tp but was not significantly different from *Bougainvillea glabra* cuttings in both 2Chb:1Tp and 2Msb:1Tp. Between the media, the highest number of fully developed leaves 6 WAP was recorded in 2Rhb:1Tp though not significantly different from 2Pcb:1Tp and 2Msb:1Tp. Whiles the lowest number of fully developed leaves 6 WAPS was observed in Tp which was not significantly different from 2Chb:1Tp media. Among the plant type cuttings, there were no significant differences in the number of leaves fully developed (Table 3).

3.14 Leaf Production of *Bougainvillea glabra* and *Ficus benjamina* Cuttings at 7 WAP

There were significant media and plant type interaction for the number of fully developed leaves at 7 WAP (Table 4). *Bougainvillea glabra* cuttings in both 2Msb:1Tp and 2Pcb:1Tp media recorded the highest number of fully developed leaves but not significantly different from 2Rhb:1Tp. The least number of fully developed leaves was observed in *Bougainvillea glabra* cuttings in 2Chb:1Tp media. Among the media, 2Rhb:1Tp and 2Msb:1Tp recorded the highest number of fully developed leave 7 WAP, whiles the lowest number of fully developed leaves was observed in 2Chb:1Tp. Among the plant types, there were no significant differences in the number of leaves fully developed.

3.15 Rooted Cuttings of *Bougainvillea glabra* and *Ficus benjamina*

There were significant media and plant type interactions for the number of rooted cuttings (Table 5).*Bougainvillea glabra* cuttings in 2Msb:1Tp, 2Rhb:1Tp and 2Pcb:1Tp as well as *Ficus benjamina* in 2Msb:1Tp and 2Pcb:1Tp recorded the highest number of rooted cuttings. The least number of rooted cuttings was observed in *Bougainvillea glabra* in Tp. The highest number of rooted cuttings was recorded in 2Msb:1Tp and 2Pcb:1Tp between the media, whiles the lowest number of rooted cuttings was observed in 2Chb:1Tp which was not significantly different from Tp and 2Rhb:1Tp. Among the plant types, there were no significant differences in the number of rooted cuttings (Table 5).

Plate 2. Leaves fully developed of *Bougainvillea glabra* 5 WAP in 2Rhb:1Tp

Table 2. Effects of media and plant material type on the number of leaves fully developed of cuttings 5 weeks after planting (5 WAP)

Media	Plant material		Mean
	Bougainvillea glabra	*Ficus benjamina*	
100%Tp	1.00b	2.00ab	1.5b
2Chb:1Tp	1.00b	2.33ab	1.65ab
2Msb:1Tp	2.33ab	1.67ab	2.00ab
2Rhb:1Tp	3.00a	2.00ab	2.5a

2Pcb:1Tp	2.67a	2.33ab	2.5a
Mean	2.00a	2.06a	
Lsd (0.05)	Media =0.87 ; plant type =0.38 ; Media x Plant type =1.46		

Table 3. Effects of media and plant material type on the number of leaves fully developed of cuttings 6 weeks after planting (6 WAP)

Media	Plant material		Mean
	Bougainvillea glabra	***Ficus benjamina***	
Tp	2.00 b	3.00 ab	2.5c
2Chb:1Tp	2.33ab	3.33ab	2.83bc
2Msb:1Tp	3.67 a	3.00ab	3.34ab
2Rhb:1Tp	4.00 a	3.33ab	3.67a
2Pcb:1Tp	4.00 a	3.00 ab	3.50ab
Mean	3.20	3.31	
Lsd (0.05)	Media=0.80 plant type =0.35	Media x Plant type =1.35	

Table 4. Effects of media and plant material type on the number of leaves fully developed of cuttings 7 weeks after planting (7 WAP)

Media	Plant material		Mean
	Bougainvillea glabbra	***Ficus benjamina***	
Tp	4.00bc	4.67ab	4.33ab
2Chb:1Tp	3.00c	4.67ab	3.84b
2Msb:1Tp	5.67a	4.33b	5.00a
2Rhb:1Tp	5.00ab	5.00ab	5.00a
2Pcb:1Tp	5.67a	4.00bc	4.84a
Mean	4.67a	4.53a	
Lsd (0.05)	Media=0.73 ; plant type =0.73 ; Media x Plant type =1.22		

Plate 3. Fully developed leaves of *Bougainvillea glabra* 7 WAP in 2Pcb:1Tp

Table 5. Effects of media and plant type on the number of rooted cuttings

Media	Plant material		Mean
	Bougainvillea glabbra	***Ficus benjamina***	
Tp	1.00b	2.00a	1.50ab
2Cnb:1Tp	1.33ab	1.33ab	1.33b
2Msb:1Tp	2.00a	2.00a	2.00a
2Rhb:1Tp	2.00a	1.67ab	1.84ab

2Pcb:1Tp	2.00a	2.00a	2.00a
Mean	1.67a	1.80a	
Lsd (0.05) Media=0.57 plant type =0.25 Media x Plant type =0.96			

Plate 4. Rooted *Ficus benjamina* (right) and *Bougainvillea glabra* (left)

3.16 Root Length of *Bougainvillea glabra* and *Ficus benjamina*

There were significant media and plant material type interaction for root length (cm) per cuttings (Table 6). The recorded the longest root length (cm) though not significantly different from 2Pcb:1Tp media but significantly different from Tp and 2Chb:1Tp media. The least root length was recorded in Tp, which was similar to that of 2Chb:1Tp media. Between the media, the highest number of cuttings rooted was observed in both 2Msb:1Tp and 2Rhb:1Tp media respectively, though not significantly different from 2Pcb:1Tp. The least cuttings rooted were recorded in 2Chb:1Tp, though not also significantly different from Tp media. Between the media, the longest root length was recorded in Msb:1Tp and 2Rhb:1Tp, whiles the least root length was observed in 2Chb:1Tp (1.35) which was not significantly different from Tp. Among the plant cuttings, there were no significant differences in the number of cuttings rooted of *Bougainvillea glabbra*, (Table 6).

Table 6. Effects of media and plant material type on root length (cm) per cuttings

Media	Plant material		Mean
	Bougainvillea glabbra	***Ficus benjamina***	
Tp	1.20c	2.03ab	1.62ab
2Chb:1Tp	1.17c	1.53ab	1.35b
2Msb:1Tp	2.33a	1.67abc	2.00a
2Rhb:1Tp	2.33a	1.63abc	2.00a
2Pcb:1Tp	2.17ab	1.70abc	1.94a
Mean	1.84a	1.71a	
Lsd (0.05) Media=0.44 ; plant type =0.19 ; Media x Plant type =0.73			

4. DISCUSSION

According to the results obtained 2Rhb:1Tp performed better in increasing the water holding capacity. This is in agreement with Ruehr (2007) that biochar increases the ability of soil to hold water especially in soils with poor water holding capacity like sandy soils [14]. This is achieved in two ways; firstly, a large portion of biochar particles are of suitable size to slow or block the movement of water through soil. Secondly, biochar has a very high porosity, which provides a very large surface area for intermolecular attraction forces to work between the biochar and water molecules. This gives biochar the capacity to act like a sponge and soak up water and keep it attached to the particle. Over time this stored water will be gradually be released into the soil where it can be absorbed by plant roots. However, the differences in water holding capacity of the various biochar may be due to the fact that not all biochar is the same. The raw material and the temperature influencing pyrolysis can affect its porosity and chemical properties [15]. It is also reported by Jessica and Peter that biochar additions to soils that are infertile increases porosity, through the nature of its particle size and shape, and since biochar particularly have porous internal structure [16]. Besides, increased soil porosity, increases the surface area of soil. The high surface area, porous and often hydrophobic nature of biochar makes it an ideal surface for the sorption of hydrophobic organic compounds [17,18]. Biochar produced from different feedstock and under different conditions exhibits a range of physical and chemical properties [19,20]. Which will have impacts upon nutrient leaching once it is applied to soil. The total nitrogen in 2Pcb:1Tp recorded a significant percentage increase from 0WAP to 4WAP but decreased from the 4WAP to 8WAP due to the fact that soil-applied biochar particles harbour microorganisms including bacteria and mycorrhizal fungi. Such organisms often have a great impact on plant nutrition for example, through the mineralization of organic N into forms available to plants or susceptible to volatilization, and through improved P and Mg nutrition via extensive fungal hyphal systems. Steiner *et al*, (2008) established that biochar can operate as an absorber lowering nitrogen leaching and increasing the rate at which nitrogen is used [21]. The general reduction of total N from 4WAP to 8WAP may either be due its leaching or volatilization as reported by Saito et al. [22]. Soil organic matter increased in 2Msb:1Tp, 2Pcb:1Tp and 2Rhb:1Tp from 0WAP to the 4WAP due to the highly porous, high surface area, variable charge organic material that has the potential to increase soil water-holding capacity, cation exchange capacity (CEC), and surface sorption ability and base saturation when added to soil [23]. There was however a reduction in organic matter content in all the treatments on the 4WAP to the 8WAP due to the availability of soil microbes and enzymes. The results of this study confirm the findings of Verheijen et al. who reported similarly that biochar can increase and decreased the availability of soil organic matter to microbes and enzymes [24]. At 4WAP there was a percentage increase in soil pH in the entire treatments except the control which was slightly alkaline could be attributed to its high surface area and porosity which eventually increases the soil CEC. According to Chan *et al*., (2007) biochar application improves soil pH thus reducing lime requirements [25]. Bagreev et al. also reported that, pH of biochar can range between 4 and 12 depending on the conditions for pyrolysis and the nature of feedstock used [26]. Soil analysis at 4WAP for exchangeable calcium, indicated an increase in all the treatments except the control indicating the plants use it for metabolic processes. The ash in biochar contains plant nutrients, mostly bases such as Ca, Mg, P and micronutrients such as manganese (Mn). The mineral elements contained in biomass will mostly be found in biochar ash, with the notable exception of nitrogen (N). During the pyrolysis process, significant proportions of biomass N are lost by volatilization [25]. The results indicated that, 2Rhb:1Tp, 2Pcb:1Tp and 2Chb:1Tp increase exchangeable potassium at 4WAP. This is affirmed by Lehmann et al. *(*2003) who reported that, soil K can increase due to the high content of K in biochar prior to its use as soil amendment [7]. Moreover, the results of the current study agrees with the findings of Chan et al. (2007) who reported that, the type of biomass and pyrolysis temperature can affect the availability of major nutrients [25]. Media analysis at 4WAP showed a percentage increase in exchangeable magnesium in all the treatments due to type of biomass used to char the biochar and the pyrolysis temperature could also affect the nutrients availability. Chan and Xu (2009) stated that, biochar ash contains plant nutrients, mostly bases such as calcium, phosphorus and magnesium [27]. However, media analysis 8WAP showed a percentage decrease in all the treatments and this may be due to plants cuttings using it for metabolic activities. Available phosphorus had a percentage increase in all the treatments 4WAP probably due to the fact that availability of nutrients in biochar is dependent on the biomass type and the pyrolysis temperature at which the biochar is created. This also affirms findings by Nigussie et al. that available phosphorus was made available in the soil due to the presence of high P in the feedstock used [28]. There were significant difference between media and plant material type interaction for days to root emergence of *Bougainvilea glabra* air-layers.This could be due to the high water holding capacity, air-porosity and other major nutrients necessary for roots development. According to Hartmann and Kester continuing availability of moisture, sufficient supply of oxygen (aeration) and moderate temperature in the part of the stem where roots are be formed can affect the formation of roots on layers [29].

These conditions can be provided by using loose rooting medium with high water holding capacity such as sphagnum moss. According to Mialoundama et al., *Dacryodes edulis* was identified as a difficult species to be multiplied vegetatively after several failures to propagate it through cuttings and grafting but the air layering method produced successful results [30].

5. CONCLUSIONS

Even though there is a high demand for *Bougainvillea glabra* and *Ficus benjamina* in the landscape industry in Ghana for both their functional and beautification purposes, it is difficult for nursery operators to meet these demands. In the experiment, the used of readily available feedstock such as *paspalum* clippings, rice husk, maize stover and coconut husk to produce biochar for the propagation of these plants significantly improved the propagation of these plants by both semi-hardwood cuttings and air-layering. However, the air-layering experiment was more successful in propagating both *Bougainvillea glabra* and *Ficus benjamina* in all the biochar treatments applied. All the biochar media formulated were able to initiate rooting in both *Bougainvillea glabra* and *Ficus benjamina* air-layers. However, the 2Msb:1Tp and 2Pcb:1Tp were also highly successful in promoting early rooting in both *Bougainvillea glabra* and *Ficus benjamina* air layers. Biochar as a soil amendment adds up the Cation Exchange Capacity (CEC) of the soil which representation of the soils ability to retain nutrients in the soil to be taken up by plants. Biochar application improved both the physical and chemical properties of the soil such as; water holding capacity, air-porosity, total nitrogen, organic matter content, soil pH, exchangeable calcium, exchangeable potassium, exchangeable magnesium and available phosphorous than the control. However, the 2Rhb:1Tp, 2Pcb:1Tp and 2Msb:1Tp improved the both the physical and chemical properties of the media significantly.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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