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ENHANCING GROWTH PERFORMANCE OF *CHROMOLAENA ODORATA* IN TWO SOIL SAMPLES BY USING COW MANURE AS AMENDMENT

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Abstract

A greenhouse experiment was conducted to study the effect of cow manure on the growth of *Chromolaena odorata* propagated for the purpose of phytoremediation of organic contaminant in soil. Cow manure was mixed separately with two soil types: clay soil and sandy-loam soils in a ratio of 9:1 (soil:manure) and put into 2 L PVC pots, the homogenized soil types were measured into 2 L PVC planting pots. Selected sprouting stem cuttings of *Chromolaena odorata* were transplanted into the pots containing the soil-manure mixture. Nutrient status of the soil was monitored weekly through the period of experimentation and the growth of the plants and biomass accumulation were measured. Control experiment was set up with manure. Survival of plants after transplanting was highest for cuttings transplanting after 3 weeks (95%) and 5 weeks (50%) of sprouting in the nursery. Profuse growth of plants in the both amended soil types were observed when compared with the control. Biomass accumulation was significantly higher in amended soils compared to the control. This study has shown that organic manure amendment to both soil types can enhance the growth and biomass accumulation of *Chromolaena odorata.* This is a good indication that the amendment could be beneficial in soil phytoremediation studies involving *C. odorata*.

Key words: Growth performances, Growth enhancement, *Chromolaena odorata,* Soil.

Introduction

Plants grow by absorbing nutrients from the soil. They do so due to the nature of the soil, available nutrients, prevailing environmental conditions, pH, and the particular plants in question (Kirmani *et al*., 2011). Depending on its location, soils are made up of combination of particles, which include; sand, silt, clay, and organic matter. Soil texture, which is also referred to as the makeup of the soil and soil pH, determines nutrient availability to plants (Robertson and Morgan, 1995). While texture determines how well nutrients and water are retained in soil, the pH tends to affect the availability of nutrients in the soil. At low pH, macronutrients are less available while micronutrients are relatively more available. An ideal soil should contain the required composition of nutrients for optimal growth of plants. However, this does not occur naturally due to variation in soil nutrients and texture thereby making some soils more productive than the other. Elevated level of nutrients in soil may result in toxicity of the nutrients to the plants. Generally, optimal water supply as well as nutrient are necessary for optimal plant growth (Munir *et al*., 2012; Fabunmi *et al*., 2012; Atagana *et al*., 2013).

Chromolaena odorata is an invasive shrub of South and Central American origin, but have been introduced to other parts of the world including Africa. *C. odorata* has been reported to have pharmacological and medicinal properties (Che Man, 2010; Taiwo *et al*., 2001; Atagana *et al*., 2013; Fazal *et al*., 2012). It has also been used in remediation of contaminated soils (Tanhan *et al*., 2007, 2011). *C. odorata* grows in a wide range of soil pH. It also prefers well-drained soil but its growth may be affected by water logging and salinity (Gareeb, 2007). *C. odorata* growing in waterlogged soil may be susceptible to infection by pathogen such as yellow leaves, black stem or die back (Mcfadyen, 1991). The plant enjoys nutrient-rich soil, however it survives in soil with poor nutrient but such growth may be retarded (Robinson, 2006). *C. odorata* thrives in an open and disturbed areas with appropriate light and a temperature range of between 20 and 37^{o}C (Gareeb, 2007). A key survival strategy of the plant is the total non-structural carbohydrates, which is its source of carbon stored in the root and is used for the survival of the plants especially at adverse conditions (Kizlowski, 1992). The amount of such reserves determines the plants ability to grow and reproduce (Robinson, 2006). It also enables the plant to survive competition with surrounding vegetation, support rapid invasion and certain stress conditions, thus have the ability to grow spontaneously in a variety of habitats (Sivagnanam & Swamy, 2010). For optimal yield of a plant, appropriate soil and nutrient conditions are necessary. The ability of a plant in a soil to function actively is dependent on favorable allocation of the limited resources available to the diverse life functions of the plant, which include maintenance, growth and reproduction. Therefore any species that tends to colonize a particular niche, should allocate more of its resources for rapid growth and reproduction (Sivagnanam & Swamy, 2010).

Free-living soil bacteria that are beneficial to the environment are referred to as plant growth promoting rhizobacteria (PGPR). PGPRs are found in close contact with the root of plants. Bacteria are found in large numbers in the rhizosphere of plants. These bacteria occurs because of the availability of high level of nutrients, which include sugars, amino acids and organic acids exuded from the roots of plants. The exudates support the growth of bacteria and its metabolism. Plant Growth Promoting Rhizobacteria (PGPR) influences the growth and development of plants, this it does by preventing phytopathogenic organisms from invading the plants. Rhizosphere organisms also help plant growth through its metabolic activities by breaking down complex compounds and making metabolites available for plant absorption (Atagana *et al*., 2013).

The main objective of this study was to investigate the effect of the addition of cow manure in the growth medium of *C. odorata* with a view to measuring the effect of the amendment on the growth performance of the plant in two soil types.

Materials and Methods

Soil: Two soil types: a clay soil and a sandy loam soil were used for the experiments. The clay soil was collected from a grass field from a depth of up to 30 cm and the sandy loam soil from a soil mound at a construction site. The soil were homogenized by hand to remove pebbles, stones and gravels and air-dried. The hormogenized soils were put in cellophane bags before being stored at room temperature. Portions of the soil (250g) each were used for soil characterization. Cow dungs were collected from the Department of Veterinary Science University of Pretoria and characterized by an independent laboratory. The two soil types were separately mixed with cow manure in a ratio of 9:1 (w/w) (soil to manure).

Plant material: *C. odorata* plants were collected from the Department of Agriculture at the University of KwaZulu-Natal. Stem cuttings of the plant were propagated in soil beds without cow manure. The young plants were allowed to grow in the nursery before being used in the experiments.

Experimental procedure: Cuttings of young plants from the nursery were pruned and planted in the soil-manure mixture described in the section describing soil above. The cut surface of the stem was moistened with deionized water and then dipped into the rooting hormone (Atagana *et al*., 2013). The hormone treated plants were planted into the soil in the plastic bags described above. The experiments were set up in the greenhouse to allow new buds to sprout. The plants were watered to keep moisture at 70% field capacity and to protect the cuttings from shivering and dying. Sprouted cuttings were transplanted into 2 L PVC pots containing 2 kg of the soil-manure mixture after two weeks of propagation. The plants were maintained at 70% moisture and allowed to grow for six weeks in the greenhouse. Control samples were set-up containing equal weight of unhomogenized soil in pots. Soil mineral components, pH, growth rate of plants, survival rate, the age bracket of plants that support optimal transplant into the soil were monitored at interval of weeks. The experiment involved a factorial treatment model in complete randomized design; each soil sample was made in triplicates and was duplicated. So a total of thirty-six samples were set up, meaning that each soil samples has eighteen set ups. *C. odorata* cuttings were put in each PVC pot giving a total of about 60 pots.

The experiments were carried out for six weeks in the greenhouse at the University of South Africa Pretoria ($25^0$46’1”S, $28^0$12’2”E) and 1439 m above sea level (Anyasi, 2012). Soil samples were collected from the experiments weekly and analyzed for nutrients. Growth parameters measured were compared with those of the control. Soil texture was determined using the sedimentation and decantation method (Walpola & Arunakumara, 2011), pH was measured with the use of standard electrode pH measurement (Mettler Toledo pH meter FE20/FG2), and the method employed for total organic carbon (TOC) measurement was the Loss on Ignition (LOI) by (Anon., 2000). Total nitrogen was estimated colorimetrically using phenoldisulphonic acid, exchangeable potassium was measured using atomic absorption spectrophotometer (Blackmore *et al*., 1987). Soil phosphorus was extracted by borax method and determined using spectrophotometer (Dick & Tabatabai, 1977). Fluoro-boric acid dilation method with spectrophotometer was used to determine the content of calcium in the soil samples. In the analysis for metals, Inductively Coupled Plasma spectrometer (ICP) was employed while acid digestion (Aqua-regia) was used for extraction. Soil moisture content was determined through the gravimetrical method. Thermal needle probe procedure (single method) was used for the determination of thermal conductivity.

Statistical analysis: The results were subjected to one-way analysis of variance (ANOVA) to determine if there is statistical significance between the two soil samples and the parameters tested using SPSS version.

Results and Discussion

Textural analysis: The two soil samples used were clay soil and sandy loam respectively as shown in Table 1. In 1, the percentage of silt and sand varied from 9.5 to 18.5, these values were very low compared to the percentage of clay, which was 72 %. On the other hand, the percentages of clay and silt in soil 2 were very slight compared to the sand substitute, 19.5 and 15 compared to 65.5 of sand, although the value was not sufficient to describe the texture as sand when compared with textural triangle. Soil texture influences the growth of plants by its direct effects on the aeration of the soil, water infiltration, cation exchange capacity (CEC), and erodibility of the soil. Infiltration and permeability are rapid in sandy soil, very slow in clayey soil and intermediate in loamy soil. Soils that are granular, with a large diversity of particle size have many large and small pores. These are desirable characteristics for a good plant yield. Therefore, soil texture is a very good factor, which should be considered in managing plant growth.

Soil pH: The initial pHs of the soil before addition of the manure were 7.89 and 6.72 for the two soils S1 and S2 respectively. When the manure was added, the pH changed to 7.83 and 6.73 for the respective soils. This shift in pH continued progressively towards neutrality with the plants throughout the duration of the experiment until it got to 7.75 and 7.13 respectively at the sixth week of the experiment (Table 2). This could be explained with the fact the organic manure was gradually being sorbed into the soil matrix hence continued to shift the soil pH. It is reported that plants are most comfortable at neutral pH even though some plants could survive a more acidic or more alkaline soil (Grime, 1979). The availability of most elements in soil is influenced by the soil pH regime, and literature has it that at low pH macronutrients becomes less available while micronutrients are relatively more available and vice versa (Walpola *et al*., 2011). The presence of cow dung manure in a soil contaminated with spent engine oil was found to raise the pH of the soil which was initially at acidic level and organic manure reduces the pH of an alkaline soil that is grown with *C. odorata* (Jebril & Yahaya, 2010; Olla *et al*., 2013; Javeed & Zamir, 2013). Organic matter causes hydrogen ion (H^+) metal cations from the cation exchange complex of soil components thereby causing metals to be released from sesquinoxides and variably charge soils to which they have been chemisorbed (Homegren, 2000). Organic matter is also influence by the pH hence causing the retention of contaminants in soil solution during low pH. The pH of the water supplied in the greenhouse was measured to be 7.7 and falls within the US Environmental Protection Agency (USEPA)'s range for safe drinking water (Anon., 2004).

Table 1. Percentage (m/m) of clay, silk and sand in the uncontaminated soil samples collected from the greenhouse site.

Factor	Unit of measurement	Values	
		Soil 1	Soil 2
Clay	%wt	72.0	19.5
Silt	%wt	18.5	15.0
Sand	%wt	9.5	65.5
Texture		Clay	Sandy loam

Soil 1 = Clay, Soil 2 = Sandy loam

Table 2. pH values of soil and water samples as was used in the greenhouse.

pH in days	Tap water	Soil 1	Soil 2
U S		7.89	6.72
Day 1	7.70	7.89	6.72
Week 1		7.83	6.73
Week 2		7.83	6.77
Week 3		7.81	6.86
Week 4		7.77	6.94
Week 5		7.75	6.99
Week 6		7.75	7.13

Soil 1 = Clay, Soil 2 = Sandy loam, US = Unhomogenized soil

Total organic carbon (TOC): Before the mixture of the homogenized soil with organic manure, the initial total organic carbons measured in percentage weight of the soil were 5.80 and 0.41 for the two soil samples respectively. After homogenization with organic manure, the soil was increased to 6.35 and 0.43 for both clay and sandy-loam soil respectively. These values also increased progressively till the six weeks of experimentation (Table 3). Soil TOC is related to soil organic carbon (SOM), and so the ease and speed with which soil organic carbon (SOC) which is the carbon stored in SOM becomes available is related to SOM fraction in which it resides. SOC is one of the most constituent of the soil due to its capacity to affects plants growth as both a source of energy and a trigger for nutrient availability through mineralization (Walpola & Arunakumara, 2011). A direct effect of soil with poor SOC is reduced microbial biomass activity and nutrient mineralization due to shortage of energy sources (Tanhan *et al*., 2007). In this experiment, organic manure was seen to have increased the TOC value of the soil compared to the control which remained almost the same at those intervals.

Soil total nitrogen (STN): From the analysis of the soil types, the initial mean percentage value of the nitrogen in the original two soil types were 0.069 in the clay soil and 0.023 in sandy-loam soil. When the organic manure was added it increases the value of STN to 0.074 and 0.026 respectively. Such value increased to 0.080 and 0.030 at the end of the experiment. It was observed that STN and TOC increased in the same order, this could perhaps be attributed to the ability of the SOM constitute of the organic manure being able to fix nitrogen in the soil when it was mixed with the soil. Increase in soil organic matter increases the amount of nitrogen in the soil as microorganism can harbour the soil with optimum quantity of SOM. Soil nitrogen which is usually available in the form of nitrite (NO_3^{-1}), is an important element for plants growth. It is found in plants proteins, chlorophyll, nucleic acids, and other plants structure (Anon, 2009). Therefore higher healthy and increased yield of plants is a good indication of adequate level of nitrogen in the soil. However, rapids changes in the level of nitrogen in the soil do occur as a result of leaching of the elements from soil especially in coarse soil (Wheet, 2004). Increased nitrogen and phosphorus has been linked with increased soil SOM which results to increased microbial immobilization as well as increased nutrient input from atmospheric precipitation (Tripathy & Sing, 1992; Berg, 2000; Jebril &Yahaya, 2010; Olla *et al*., 2013).

Table 3. Physico-chemical characteristics of soil.

Intervals	TOC (ppm)		STN (%)		STP (ppm)		STK (ppm)		STC (ppm)	
	Soil 1	Soil 2	Soil 1	Soil 2	Soil 1	Soil 2	Soil 1	Soil 2	Soil 1	Soil 2
U S	5.80	0.41	0.069	0.023	8.63	4.15	16.60	2.98	83.00	60.72
Day 1	6.35	0.46	0.074	0.026	9.00	4.22	15.52	2.93	83.01	61.00
Week 1	6.29	0.46	0.072	0.019	9.13	4.17	15.47	2.78	83.00	61.12
Week 2	6.33	0.47	0.075	0.019	9.16	4.18	15.44	2.76	83.29	61.16
Week 3	6.36	0.49	0.076	0.023	9.31	4.18	15.39	2.76	83.37	61.21
Week4	6.37	0.49	0.079	0.025	9.33	4.23	15.30	2.62	83.59	61.34
Week 5	6.41	0.53	0.080	0.027	9.37	4.24	15.33	2.60	83.72	61.39
Week 6	6.42	0.56	0.080	0.030	9.37	4.25	15.28	2.60	84.08	61.70

Soil 1 = Clay, Soil 2 = Sandy loam, TOC = Total organic carbon, STN = Soil total nitrogen, STK = Soil total potassium, STC = Soil total calcium, U S = Unhomogenized soil

Soil total phosphorus (STP): The determination of phosphorus in the original soil indicated an initial value of 8.63 and 4.15 for the two respective soils. After the homogenization with organic manure, STP increased to 9.00 and 4.22 respectively. There was also relative increase in STP throughout the duration of the experiment. Phosphorus (P) is a naturally occurring element in the environment; hence it can usually be found in every living organism as well as in soil therefore organic manures are a good sink for it (Daniels *et al*., 1998).

Total potassium in the soil (STK): The total concentrations of potassium in the original soils were 16.60 and 2.98 for the respective clay and sandy-loam soils. Such concentration got reduced after the homogenization to 15.50 and 2.90 respectively (Table 3). These concentrations of potassium were reduced also through the six weeks of experimentation although at irregular interval within the two soils. This decrease in the concentration of STK could not be unravelled but is synonymous with the result of Mba (2008). Potassium is quite abundant in soils; its range is dependent on the soil type. With all the concentration of potassium in the soil, only small parts is present in water-soluble and exchangeable forms, and are sparsely available for plant uptake (Anon, 2005). Literature has it that sandy soils have the lowest STK, while clay and alluvial soils have the highest, a good description of the soils used in this experiment (Isaak & Nair, 2005; Norgrove *et al*., 2008).

Soil total calcium (STC): At the beginning of the experiment, initial concentration of calcium of unhomogenized soil samples were 83.00 and 60.72 ppm respectively for the two types of soil. After homogenization with organic manure, the concentration of the calcium in the clay only made a shift to 83.01 while that in the sandy-loam was 61.00 ppm respectively. Such trend in increment was observed for the six weeks of growth with *C. odorata*. Valuable biological processes in the soil are depended upon the stabilizing effects of elements in the soil without which the process of nitrification would be detrimental to soil organisms (Devendra *et al*., 1998; Wheet, 2004; Housa & Mekoa, 2008). Soils low in humus and clay, usually gives higher values of calcium than those with higher concentrations of colloidal clay and organic matter unless the component of calcium is replaced with hydrogen ion. It is reported that in a cultivated soil, the quantity of calcium in the soil is dependent on amongst other factors, with the concentration of nitrates and phosphates (Isaak & Nair, 2005).

Metals: The concentration of micronutrients in fresh soil samples were in this order Mg<Mn<Fe<Pb<Cu<Zn, in clayey soil 1 while in soil 2 there were in this order Mg<Fe<Mn<Zn<Pb<Cu. These were reduced almost at equal proportion when the organic manure was mixed with the soil except with Magnesium that was reduced more appreciably than the rest. The composite reduction in the concentration of the microelements was as a result of the sink of the organic manures into the soil and the interest in trying to optimize the content of the nutrients in the soil. Microelements are required in minute concentrations by plants and tend to be toxic to plants and microorganism when there are increased (Al-Yemeni & Hashim, 2006; Escarre *et el*., 2011). Based on this postulation, organic manures will always act towards the optimization of the concentration of the elements in the soil. The concentration of the minerals in the clayey soil was greater than that in the sandy-loam. Table 4 shows the concentration of individual minerals in the analyzed soil.

Moisture content of the soil and thermal conductivity: This is referred to as the quantity of water retained in a material such as soil. One of the determinant factors for high moisture content of a soil is the quantity of organic matter. The ability of the soil to retain its moisture content is achieved through any activity that helps to increase the structure of the soil, by a way of increasing the saturation level of the soil (Ambika, 2002; Amin *et al*., 2012). Therefore it is explained that moisture content determines the thermal conductivity of the soil as it was reported in Tables 5 and 6. In this experiment, clay tends to have high moisture content because of the colloidal particle that tends to be closely parked. Therefore increase in the quantity of organics in the soil increase the moisture content, thermal conductivity and equally density. The concentration of the moisture content, density and thermal conductivity are in the ration of 1:1:2. These factors were reduced at the addition of organic manures. Percentage moisture, density and thermal conductivity in soil 2 were greater than in soil 1, unlike in other factors that were measured.

Table 4. Mineral content (ppm) of soil types used in the greenhouse.

Intervals	Cu (ppm)		Fe (ppm)		Mg (ppm)		Mn (ppm)		Pb (ppm)		Zn (ppm)	
	Soil 1	Soil 2	Soil 1	Soil 2	Soil 1	Soil 2	Soil 1	Soil 2	Soil 1	Soil 2	Soil 1	Soil 2
U S	35.89	0.54	59.01	78.00	112.9	88.7	77.05	11.32	46.65	1.71	20.82	3.54
Day 1	35.20	0.50	58.50	77.70	112.0	88.3	76.10	10.30	46.20	1.20	20.10	3.16
Week 1	35.14	0.50	58.55	77.56	112.0	88.3	76.07	10.31	46.19	1.19	20.12	3.13
Week 2	35.09	0.53	58.52	77.51	111.6	88.0	76.07	10.31	46.13	1.19	20.13	3.13
Week 3	35.03	0.51	58.00	77.45	111.3	87.6	76.05	10.28	46.12	1.18	20.12	3.12
Week 4	34.87	0.48	58.00	77.41	110.5	87.2	76.04	10.19	46.06	1.15	20.12	3.07
Week 5	34.72	0.46	57.89	77.27	110.0	86.9	76.04	10.17	46.01	1.11	20.09	3.05
Week 6	34.77	0.43	57.88	77.11	109.9	86.1	76.05	10.15	45.87	1.04	20.07	2.91

Soil 1 = Clay, Soil 2 = Sandy loam, Cu = Copper, Fe = Iron, Mg = Magnesium, Mn = Manganese, Pb = Lead, Zn = Zinc, U S = Unhomogenized soil

Table 5. Percentage amount of dry weight and moisture content of the soil types used in the study.

Soil samples	Initial weight	Final weight	% dry weight
Clay	5.025	4.782	95.2
Sandy loam	5.052	4.717	93.4

Table 6. Moisture content, density and thermal conductivities of soil types used in the greenhouse.

Intervals	% Moisture content		Density (g/cm^3)		Thermal conductivity ($W\ m^{-1}K^{-1}$)	
	Soil 1	Soil 2	Soil 1	Soil 2	Soil 1	Soil 2
U S	5.1	6.9	1.14	1.17	0.15	0.27
Day 1	4.8	6.6	1.25	1.33	0.19	0.39
Week 1	4.8	6.4	1.33	1.36	0.31	0.41
Week 2	4.6	6.4	1.39	1.21	0.27	0.41
Week 3	4.5	6.4	1.43	1.38	0.28	0.42
Week 4	4.6	6.5	1.44	1.43	0.29	0.42
Week 5	4.6	6.4	1.47	1.50	0.29	0.43
Week 6	4.7	6.4	1.52	1.52	0.30	0.42

Soil 1 = Clay, Soil 2 = Sandy loam, U S = Unhomogenized soil

Table 7. Components of water used in the greenhouse.

Analyses in mg/l	Sample identification Water sample	SANS 241-2006 (Maximum limits for class 1 water)
Sample number	925	
pH Value at 25°C	7.5	5.0-9.5
Electrical Conductivity in Ms/m at 25°C	26.5	150
Nitrate as N	1.5	10
Chloride as Cl	36	200
Sulphate SO_4	11	400
Sodium as Na	13	200
Potassium as K	<1.0	50
Calcium as Ca	14	150
Magnesium as Mg	14	70
Aluminium as Al	<0.100	0.300
Antimony as Sb	<0.010	0.010
Arsenic as As	<0.010	0.010
Cadmium as Cd	<0.005	0.005
Chromium as Cr	<0.025	0.100
Cobalt as Co	<0.025	0.500
Copper as Cu	<0.025	1.00
Iron as Fe	0.177	0.200
Lead as Pb	<0.020	0.020
Manganese as Mn	<0.025	0.100
Mercury as Hg	<0.001	0.001
Nickel as Ni	<0.025	0.150
Selenium as Se	<0.020	0.020
Zinc as Zn	0.192	5.00
Vanadium as V	<0.025	0.200

Propagation of the weed in the greenhouse: The propagation period took in total, eight weeks and that ran successively within the period as the plants were seen to thrive with an average growth percentage of above 90 % within the trials. This was unlike the growth observed with the control soil. This is shown in Fig. 1 as growth chart. The components of the animal manure are reported in Table 7 while the components of water are presented in Table 8. The addition of organic manure and the increase in growth of the plant might be attributed to rapid mineralization of N and steady supply of N from the manure as well. This might have met the N requirement of the plant at critical stages. Farm yard/compost or organic manure acts as nutrient reservoir and upon decomposition produces organic acids, thereby enabling the absorbed ions to be slowly released during entire growth period to ensure optimal growth and replenishment of plants (Robertson and Morgan, 1995; Anyasi, 2012).

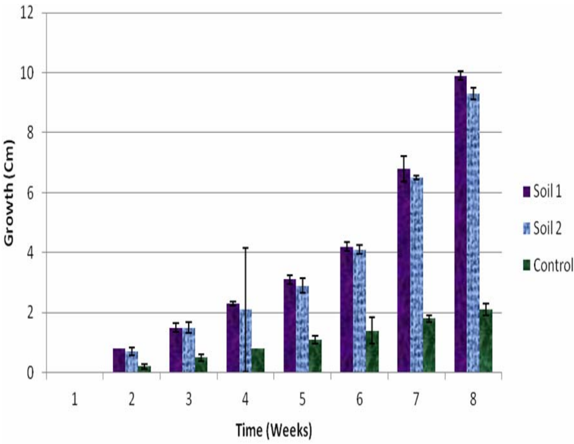

Fig. 1. Growth chart (GR value) of soil types mixed with organic manure as was used in the greenhouse for the trial propagation of *C. odorata* (values are average of 3 S.E.).

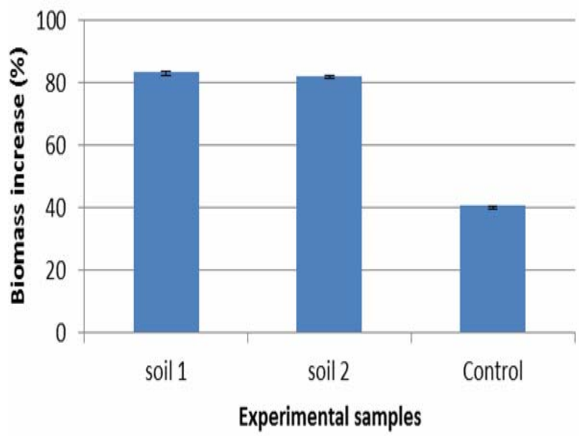

Fig. 2. Biomass accumulation (%) in *C. odorata* in two soils and control (values are average of 3 S.E)

Table 8. Components of animal manure as used in the greenhouse.

Analyses in mg/l	Sample identification			
	Horse manure		Cow manure	
Sample number	8894		8896	
Extract method	Distilled water		Distilled water	
Mass used (g)	5.16		6.20	
Volume used (ml)	100		100	
Units	Mg/l	Mg/kg	Mg/l	Mg/kg
Carbon in %	52.7	--	54.9	--
Total nitrogen	81	1570	109	1758
Total phosphate as P	50	969	46	742

Biomass accumulation: The accumulation of biomass which was taken as the difference in biomass measurement between the final biomass and the initial biomass and expressed in percentage is reported in Fig. 2. Highest mean biomass increase was measured in the soil 1 with 83.42% with strong contention with soil 2 with 82.18%. The control experiment was measured to be 40.67 which are significant at 95% degree of freedom. Biomass increase is a synonymous factor in phytoremediation studies because for plant to be able to withstand the phytotoxicity of a contaminant in the soil and cause a possible remediation of the contaminant, there ought to be rapid biomass accumulation in that plant (Berrow and Burridge, 1991, Mba, 2008). Therefore since organic manure was able to enhance biomass accumulation of C. odorata compared to the control, it should be taken as an enhancer in phytoremediation studies.

The soil types 1 and 2 were seen to maintain the normal growth curve (GR value) which was seen to be hyperbolic in nature when extrapolated, while the control samples maintained very low values in their growth curve. The nature of the curve in soil sample 1 and 2 is synonymous with the exponential of the *C. odorata* at developmental (Logarithmic) phase. The two soils 1 and 2 though started at different values in their first week of growth, have equal growth length at the second week, this continued through the third week until week six. However, soil type 1 maintained a greater growth level which could be attributed to having the prefared nutrient requirements for plants growth than soil 2, though the difference was not significant at 0.05 degree of freedom. In determining the rate of survival (RS value) of the weed on different soil samples, sample 1 maintained a percentage survival of 100, sample two contended with about 70 % while the control survived below 20% (Table 9).

In comparing the survival rate of the plant at growth interval of 3, 5, and 7 weeks of growth after sprouting, plants after 3 weeks of growth were seen as the best stage prior to propagation to transplant as survival at this stage was about 96% as given in Table 10. This means that almost all the plants in the entire set of experiment survived. However, plants in 5 and 7 weeks survived at 50 and 25% in the respective weeks. This means that transplanting of *C. odorata* from the nursery can effectively be done between the 3 to 5 weeks after sprouting; this according to Pujar *et al*, (2006) is the vegetative stage of the plants growth and supports re-growth after any kind of stress to the plants. Generally, plants growth depends on cell division followed by cell elongation, these primary physiological processes are involved in growth of plants (Davender *et al*., 1998). Cell division belongs to the logarithmic growth phase which was found to increase exponentially with time according to the study of Devender *et al*., (1998), at this period, plants are found to direct all of its stored energy for growth and repair. After the logarithmic phase comes the linear phase which is the cell elongation stage, here high exponential growth is witnessed even more than the logarithmic phase, where the body parts is usually replenished hence plants do find it difficult to survive unfavorable condition at the stage (Pujar *et al*., 2006).

Table 9. Survival rate (RS value) of *C. odorata* propagated in soil types 1 and 2 with control in the greenhouse.

Plants samples	Soil sample 1	Soil sample 2	Control
1	X	X	_
2	X	X	_
3	X	X	X
4	X	_	_
5	X	X	_
6	X	_	_
7	X	_	_
8	X	X	_
9	X	X	_
10	X	_	_
11	X	X	_
12	X	X	X
Percentage survival (%)	100.00	66.67	16.67

(x = Survival, – = Non-survival) (values are average of three replicates)

Table 10. Comparison of the survival rate of *C. odorata* plantlets at different age intervals in soil during transplanting in the greenhouse.

Plants samples	3 Weeks old	5 Weeks old	7 Weeks old
1	–	X	X
2	X	–	–
3	X	–	–
4	X	–	–
5	X	X	–
6	X	X	–
7	X	–	–
8	X	–	X
9	X	–	X
10	X	X	–
11	X	X	–
12	X	–	–
Percentage survival (%)	95.67	50.00	25.00

(x = Survival, – = Non-survival) (values are average of three replicates)

In this green house propagation of *C. odorata*, prevailing environmental conditions that include temperature and pressure was used and therefore requires that nutrient conditions be taking note of. Various studies has confirmed the ability of *C. odorata* to thrive in a wide range of soil types with soil fertilizer being less important to their growth and invasion (Wen *et al*., 2000; Huang *et al*., 2000; Wang *et al*., 2003; Vanderwoude *et al*., 2005; Zhang & Wen, 2009). However, this present study has elucidated the fact that soil-nutrient distribution is an important factor that enables the plant invasiveness. Light, water and nutrients are the basic resources that help to regulate the plants survival, growth as well as its distribution in its ecosystem. According to previous studies, *C. odorata* is light favouring species though drought could sometimes affects its growth (Wen *et al*., 2000; Wang *et al*., 2003; Yang *et al*., 2005; Fatima *et al*., 2014). Plants under great light intensity suffer a lot more drastic reduction in assimilation of CO_2 especially when subjected to drought stress (Holmgren, 2000). This according to the study could lead to photo-inhibition, as compared with plants under covered condition. In the present study, there was direct exposure to sunlight and other atmospheric conditions; water was constantly supplied to a moisture content of 70% which is optimal for the growth of *C. odorata*. Nutrients also were in correct order and could not inhibit the plants growth and therefore will help to argue the fact that *C. odorata* does not just invade any particular type of soil but the one that posses its absolute nutrient requirement; a witness to the variation of its invasion (Chandrasekaram & Swamy, 2010).

Nutrients behavior in the soils and the ability of plants to absorb them depend on the organic matter content of the soil as well as the pH (Alloway, 1995; Okoye *et al*., 2008). This behavior so to say, varied according to the nature of the nutrients, the physico-chemical properties of soil and the plants species (Tuzen, 2003; Kidd *et al.*, 2007). The soil organic matter could be derived from the total organic carbon values which were 6.35 and 0.46% for clay and sandy loam soils respectively, by multiplying the TOC values by the conversion factors which is 1.724. Therefore, organic matter content of the soil samples was 10.95 and 0.79 ppm respectively. The value was within the range for optimal growth of plants. Nutrients availability in the soil harboring *C. odorata* however manages the response factor of the weed since nutrients for example carbon, enables the plant to carry out various physiological activities. For instance, the ability of plants to delineate its biomass into shoot, root, reproduction or fruiting is aided by the physical and perhaps the chemical condition of the soil.

Chromolaena odorata does not require a particular type of soil for its growth but tends to survive in any kind of environment it finds its way (Housa & Mekoa, 2008). Therefore it can easily be inferred that nutrient make up of a soil does not really determined the kind of growth exhibited by *C. odorata* but only as a part of other effects (Chandrasekaran & Swamy, 2010). The soil types 1 and 2 as was used in the experiment though have variations of nutrient constituents, texture, and ability to retain water, but were able to support the growth of *C. odorata*. Therefore, it can be argued that though *C. odorata* have been reported to grow in any particular type of soil, that there is still specificity in its invasion. For instance in South Africa, the weed can only be found invading the KwaZulu-Natal area which is known to be highly fertile and have comparatively good rainfall thereby making agriculture central to its economy (www.southafrica.info/geography/kwazulunatal). It means that there is particular interest to the geography of the soil in that area. However, there is need that the physico-chemical characteristics of soil that is to be used in any laboratory study be known so it can be used to describe the phenomena that would be studied and to provide information as to whether soil amendment is required.

Conclusion

The growth of *C. odorata* was enhanced by the addition of organic manure into the two soil types as compared to the control experiment. There was increase in the concentrations of macronutrients as well as moisture content and the thermal conductivity of the two soil types. However, the presence of organic manure resulted in the decrease in the concentrations of micronutrients compared to the control. Based on the discussions, it is concluded that the amendment of the soil types lead to the enhancement in growth of plant, and this is significant in phytoremediation studies since effective phytoremediation entails optimal increase in plants biomass so as to enable absorption of contaminants from soil. The variation in the concentration of various elements measured in the two soil types resulted in the difference in growth of the plants. However, both soil types were able to support the growth of the plants throughout the experimental period hence could be employed in the phytoremediation of soil pollution.

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