



## The use of comfrey as soil amendment to improve growth of maize and amaranth vegetable

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### Abstract

Being an organic material enriched with essential nutrients, comfrey plant (*Symphytum spp*) can be used as a soil amendment to improve soil characteristics and crop productivity. This study aimed to evaluate the potential of comfrey plant on growth and yield of maize (*Zea mays*) and amaranth (*Amaranthus spp*). Two pot experiments were conducted where in first experiment, maize was grown in soil amended with Comfrey leaves powder (CLP) at 0, 2, 4 and 8% (w/w) for 6 weeks and in second experiment, Amaranthus was grown in soil amended with Comfrey roots powder (CRP) at 0, 2 and 4 % (w/w) for 5 weeks. Application of 8% of CLP to the soil increased maize height significantly (by 29 cm,  $p = 0.045$ ) compared to maize in control treatment. Maize leaves number increased significantly (from 5 to 8 leaves,  $p = 0.001$ ) following soil amendment with 2% of CLP. Stem diameter increased significantly with increasing CLP from 0 - 4% (diameter from 0.7 to 1.2 cm,  $p < 0.001$ ) compared to control, further increase in CLP up to 8% had no further significant effect. Total maize plant biomass increased significantly (from 8.21 to 28.25 g,  $p < 0.001$ ) following the soil amendment with 0 - 8% of CLP. Soil amendment with 2% of CRP increased significantly Amaranthus shoot biomass (0.48 to 1.31 g,  $p = 0,048$ ) and total plant biomass (0.66 to 1.48 g,  $p = 0.018$ ), further increase in CRP had no further significant effect. Positive growth responses noted in both crops following soil amendment with comfrey could be linked to high nutrients composition noted in comfrey powders. From this study, the use of 2 to 8 % (w/w) comfrey powders is recommended to improve vegetative growth of amaranth and maize, however further studies on use of comfrey as soil amendment are highly recommended.

**Key words:** *Amaranth spp.*; *comfrey leaves and roots powders*; *comfrey plant*; *maize*; *soil amendment*

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## Introduction

Comfrey (*Symphytum spp*) is an herbaceous perennial herb plant, belonging to the family Boraginaceae and originating from Europe. Geographically, Comfrey is a plant with a wide climatic range from temperate to tropic (Harris, 1990). This plant has been named as a beneficial plant following its widest range of uses such as green manure, liquid fertilizer, compost activator, soil amendment, soil conditioner, a mulch, and medicinal uses (Harris, 1990; Howard *et al.*, 2018). Several studies have reported the potential use of this plant in improving soil productivity and crop yields particularly in temperate countries (countries of crop origin). Howard *et al.* (2018) noted a high concentration of K in comfrey plant and increased concentration of available K and N to the soil following mulching the soil with this plant in one growing season. Harris *et al.* (1989) reported the highest yield of radish and tomato crops following soil amendment with comfrey leaves and comfrey liquid fertilizer in comparison to commercial organic fertilizer.

The use of Comfrey plant (which are locally available materials in Tanzania) to improve soil productivity and crop yields in Tanzania is still limited. This is due to lack of information regarding their potential suitability.

Agriculture is the dominant sector in the Tanzanian economy providing livelihood, income and employment to over 80% of the population. The agriculture sector in Tanzania, which is predominantly crop based, is typically rain fed and is dominated by small holder or subsistence farmers, and Maize is one among the staple food grown in Tanzania. Besides the importance of the agriculture sector in the country, it is constrained by low productivity which is mainly due to poor soil fertility, climate change and variability, as well as poor production technologies (Tumbo *et al.*, 2011). Following intensive farming by small holder farmers, the fertility status of these soils has been declining due to inadequate replenishment of nutrients (Kalvig *et al.*, 2012) through important soil management practices such as manuring, liming and fertilization. Therefore, most agricultural soils in the country are highly degraded, with low reserves of important nutrients like N, K, S, Ca

and Mg (MAFSC, 2006).

Routine application of inorganic fertilizers is highly recommended to supply nutrients such as N, P and K to agricultural soils. However, due to lack of knowledge regarding the importance of soil fertilization by small scale farmers, high cost of inorganic fertilizers and low income of the small-scale farmers who dominate the agricultural sector in the country, the use of these fertilizers is still low.

Given the infertility and acidity of most Tanzanian soils, the low use of fertilizers by small scale farmers and the availability locally soil amendment material like comfrey plants within the country, the use of this organic material as soil amendment/conditioner could be a feasible technology to improve the soil fertility and crop production in Tanzania. However, recommendations for the agricultural use of this organic material should be based on sound knowledge of comfrey characteristics particularly the nutrients composition and, its effects on soil and growth and yield of crops. The current study was undertaken with the aim of evaluating the potential of using comfrey leaves and roots powders as soil amendment to improve growth of maize and biomass yield of amaranth vegetable in pot experiment, and the specific objectives were i) to evaluate the soil nutritional characteristics and the elemental composition of Comfrey leaves and roots powder with respect to its use as soil amendment ii) Evaluate the fertilizer effect of increasing concentrations of Comfrey leaves and roots powder on vegetative growth of maize and biomass yield amaranth vegetable.

## Materials and methods

### *Description of the Study Area*

This study was conducted at Sokoine University of Agriculture (SUA), Department of Soil and Geological Sciences (DSGS) screen house. SUA is located on the northern foot slopes of Uluguru mountains at approximately 6.8498° S and 37.6545° E and elevation of around 525 meters above sea level (Shaaban & Kisetu, 2014). The area receives moderate rainfall between 600 mm and 1000 mm annually, and temperatures ranging from 20°C to 32°C (Saria *et al.*, 2018). The rainfall pattern of the area is bimodal, the long rains usually begin in March to May while the short

rains usually begin on early October to early December. The soil of the study area is, well drained reddish-brown sandy clay loam originated from colluvial (Saria *et al.*, 2018).

#### ***Soil and comfrey plant samples collection***

Soil sample used in this experiment was collected from the Department of Soil and Geological Science (DSGS) farm at Sokoine University of Agriculture in April, 2022. Topsoil (0-20 cm depth) were collected from different points within the field then mixed together to make one composite sample. Soils were air dried and sieved (4 mm) to remove plant debris and gravel and to maintain the natural crumb structure. Sieved soils were then used for pot experiment.

Comfrey plant leave and root samples were collected in March, 2022 from three different points (fields) at Nyandira village (-6.85636° S and 37.67052° E) - Mgeta highlands (altitude 1600 m above sea level), Morogoro. Based on physical appearance particularly leaves orientation and stem colour, three groups of comfrey plants were identified in the field, and these were, broad leaved with purple stem, elongated leaves with purple stem and elongated leaves with white stem. Comfrey plant samples were collected without consideration of physical appearance differences. Comfrey samples were collected by uprooting the whole plants, then shoots and roots were separated by cutting with a knife. Shoots and roots comfrey samples were packed in boxes separately and transferred to Sokoine University of Agriculture, Soil and Geological Science laboratories for detailed chemical characterization. In the lab, comfrey shoot (leaves) samples were mixed together, air dried and then oven dried at 60°C, grinded and sieved at 2mm sieve mesh size to get the fine powder. Comfrey root samples were also mixed together air dried and then oven dried at 60°C, grinded and sieved at 2 mm sieve mesh size to get the fine powder.

#### ***Soil and Comfrey leaves powder analysis***

The physical chemical properties of the soil were determined following the standard methods; soil texture was determined by hydrometer method (Moberg, 2001). Soil pH was measured potentiometrically (Okalebo *et al.*, 2002), Organic carbon was determined by Walkley and Black wet oxidation method (Okalebo *et al.*, 2002). Electrical conductivity was determined in 1:2.5 soil-water

suspensions using an electrical conductivity meter (Moberg, 2001). The exchangeable bases (Ca<sup>2+</sup>, Mg<sup>2+</sup>, Na<sup>+</sup> and K<sup>+</sup>) was determined by atomic absorption spectrophotometer (Moberg, 2001). Total nitrogen was determined by Kjeldahl method (Bremner, 1965), Total phosphorous was determined calorimetrically (Walker *et al.*, 1968) and extractable Phosphorous was determined by Bray's 1- Method. The physical chemical properties of the CLP and CRP were determined by the methods explained for soil above and the elemental composition of the CLP and CRP were determined following the microwave digestion of the Comfrey samples.

#### ***Experimental set up and design***

The soil sample was collected from the DSGS model farm. The soil was processed for pot application whereby it was air dried and well sieved with a 4mm sieve.

##### ***Experiment 1***

The experiment involved four concentrations of CLP 0, 2, 4, and 8% w/w on a dry weight basis. The equivalent fresh weights of 1000 g dry weight of soil were mixed thoroughly with each concentration of either CLP and then the mixture was used to fill the required number of plant pots. Four replicates of each comfrey treatment plus soil mixture were prepared. Each pot was watered with tap water and allowed to equilibrate for 24 hours before sowing the maize seed. Four seeds of maize (*Zea mays* var. ZAM SEED 405) were sown in each pot at a depth of about 2cm. The pots were arranged in glasshouse following a randomized complete block design (RCBD) considering and noting all possible sources of errors. Following germination, plants were thinned to two per pot. The pots were regularly watered with tap and maintained following all the required agronomic practices. Plants were fertilised with NPK 5 weeks after germination when symptoms of P deficiency occurred across all treatments. Plants were harvested after six weeks.

##### ***Experiment 2***

In this experiment, the experimental set up and maintenance were like that in experiment 1 except the soil here were amended with 0, 2 and 4% CRP concentrations. Amaranth seeds was bought from agro-dealers and broadcasted in pots of similar size like that of maize in experiment 1. After

germination, plants were thinned to 15 plants/pot. On the 4<sup>th</sup> week, NPK fertilizer (dissolved in water) was applied at equal dose across all treatment (including control) to boost the growth. Plants were harvested after five weeks.

### ***Plant harvesting***

#### *Experiment 1*

Before harvesting, number of leaves were counted and the plant height (from the stem/soil surface to the end of the shoot) were measured. The stem diameters were also determined after cutting the plants at the stem. Shoot biomass was also determined after harvesting the shoots per treatment and oven drying at 60°C until constant weight. The roots were extracted from the soil, washed thoroughly with tap water and oven dried at 60°C until constant weight. Then the total plant biomass was determined by weighing together the weight of shoot and roots per treatment.

#### *Experiment 2*

Amaranth shoot biomass yield was determined after uprooting all plants per each pot, washing roots thoroughly with tap water, and oven drying plants at 60°C until constant weight, then recording the total plant biomass weights per treatment.

### ***Statistical analysis***

Statistical analyses were performed using Genstat

17<sup>th</sup> Edition (VSN International, UK). A generalized one-way analysis of variance (ANOVA) was conducted on all parameters (soil, comfrey and plant growth data) using CLP/CRP as a factor. Normality was tested by plotting residuals against expected normal quantiles and post-hoc comparisons between means were based on Tukey's test at 0.05 probability level

### **Results**

#### ***Initial characteristics of experimental soils, and Comfrey leaves and roots powder***

The chemical characteristics and elemental composition of soils, and comfrey leaves and roots powder used in the experiment are presented in Table 1. The soil used was clayey and slightly acidic with pH value of 5.63. The highest total % N (2.7) was noted in CLO and the trend was CLP > CRP > experimental soil. The highest % C (43.85) was noted in CRP and the trend was CRP > CLP > experimental soil. CLP was enriched with the essential macro nutrients P, K, Ca and Mg, the general trend was CLP > CRP > experimental soil while the micronutrient Cu, Zn, Fe and Mn followed the trend CLP > experimental soil > CRP. K was the richest essential nutrients measured in comfrey leaves powder, with an elemental concentration of 19300 mg/kg, which was very high in comparison to that in experimental soil (0.0012 mg/kg).

**Table 1**

*Initial characteristics of experimental soil, and comfrey leaves and roots powder from Mgeta highlands, Morogoro, Tanzania.*

<b>Parameter</b>	<b>Experimental soil (SUA-DSGS farm)</b>	<b>Comfrey leaves powder</b>	<b>Comfrey roots powder</b>
Textural class	Clayey		
<b>Chemical properties</b>			
pH	5.63		
CEC (Cmol+/ kg)	14.05		
OC (%)	1.87	41.16	43.853
<b>Macro nutrients</b>			
N (%)	0.1	2.7	1.401
P (mg/kg)	0.15	4200	0.118
K (mg/kg)	0.0012	19300	0.603
Ca (mg/kg)	0.027	2900	0.081
Mg (mg/kg)	0.015	1800	0.058
<b>Micro nutrients (mg/kg)</b>			
Cu	0.8	17.9	0.003
Zn	0.46	37.3	0.004
Fe	49.6	1032.98	0.035
Mn	121.79	173.49	0.025

*Note: Values given are means of three replicates. OC = organic carbon; CEC = cation exchange capacity.*

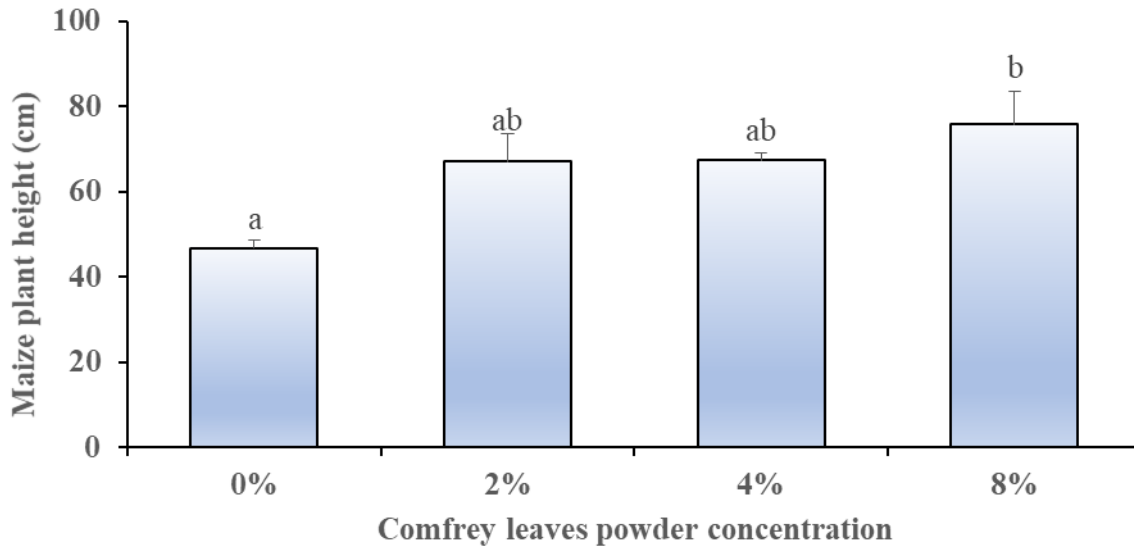
From the first experiment, vegetative growth parameters of maize grown in soil amended by different concentrations of comfrey leaves powder are presented in figures 1, 2, 3 and 4.

Application of 8% of CLP to the soil increased maize plant height significantly (by 29 cm,  $P = 0.045$ , Figure 1) in comparison to the height of maize grown in control treatment while other

comfrey powder concentrations did not show any significant effect in maize plant height. Generally, an increasing trend of maize plant height was noted in soil amended by 2 - 4% of comfrey leaves powder though this increase was not significant higher in comparison to control.

**Figure 1**

*Effects of Comfrey leaves powder on maize plant height*



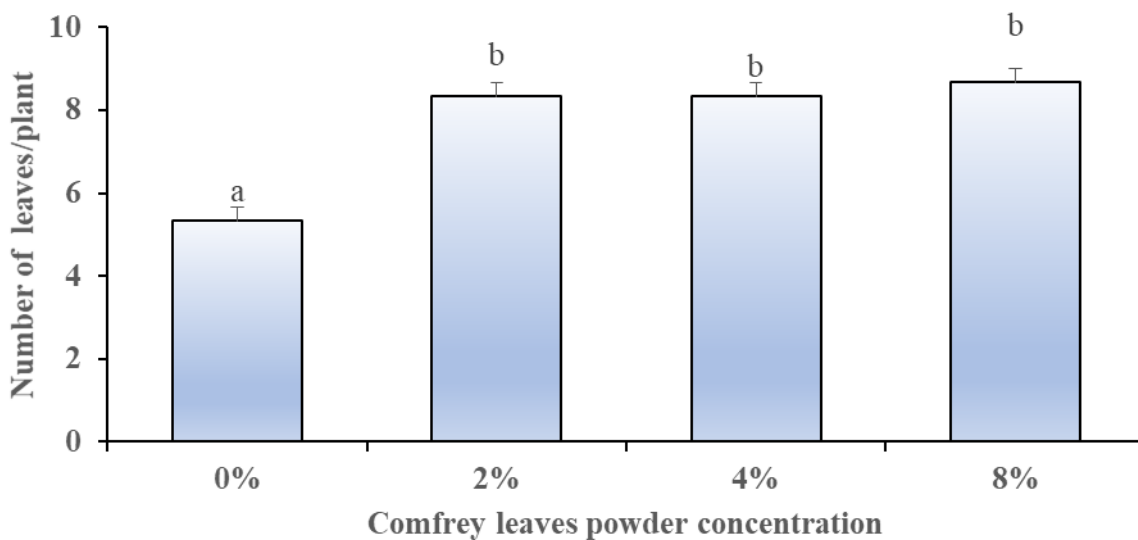
*Note: Columns with the same letters are not significantly different according to Tukey's multiple comparison test,  $p < 0.045$ . Comfrey leaves were collected from Mgeta highlands, Morogoro, Tanzania*

Soil amendment with 2% of comfrey powder increased the number of maize leaves significantly (from 5 to 8 leaves,  $P = 0.001$ , Figure 2), while further increase in comfrey powder

concentration did not further increase significantly the number of leaves.

**Figure 2**

*Number of leaves/plants for maize grown in soils amended by different concentration of Comfrey leaves powder.*



*Note: Columns with the same letters are not significantly different according to Tukey's multiple comparison test,  $p = 0.001$ . Comfrey leaves were collected from Mgeta highlands, Morogoro, Tanzania*

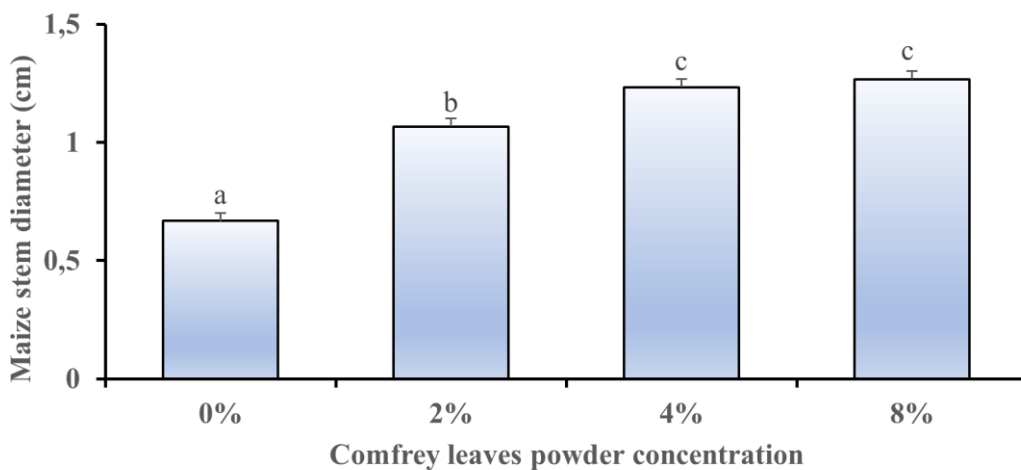
Maize plant stem diameter was found to increase significantly (diameter from 0.7 to 1.2 cm,  $p < 0.001$ , figure 3) with an increasing concentration of comfrey leaves powder from 2 to 4% in comparison to the stem diameter of plants grown in control, while further increase in comfrey concentration up to 8% did not show and further

increase in maize stem diameter.

The total maize plant biomass (shoot + root) increased significantly from 8.21 to 28.25 g ( $p < 0.001$ , figure 4) with increasing CLP concentrations from 0 - 8%.

**Figure 3**

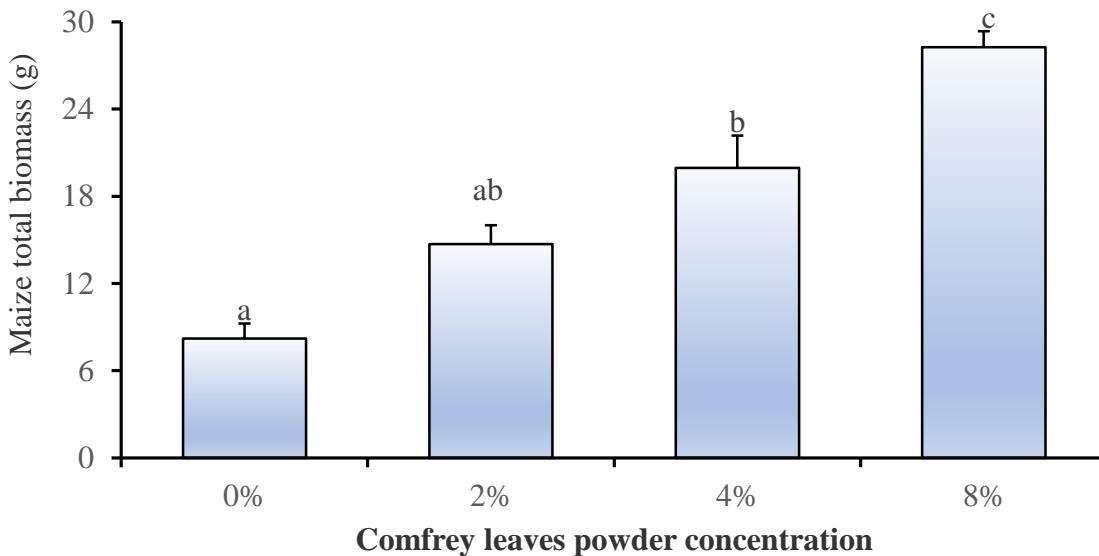
*Effects of Comfrey leaves powder on maize stem diameter*



Note: Columns with the same letters are not significantly different according to Tukey's multiple comparison test,  $p < 0.001$ . Comfrey leaves were collected from Mgeta highlands, Morogoro, Tanzania

**Figure 4**

*Effect of Comfrey leaves powder on total maize biomass (shoot + root)*



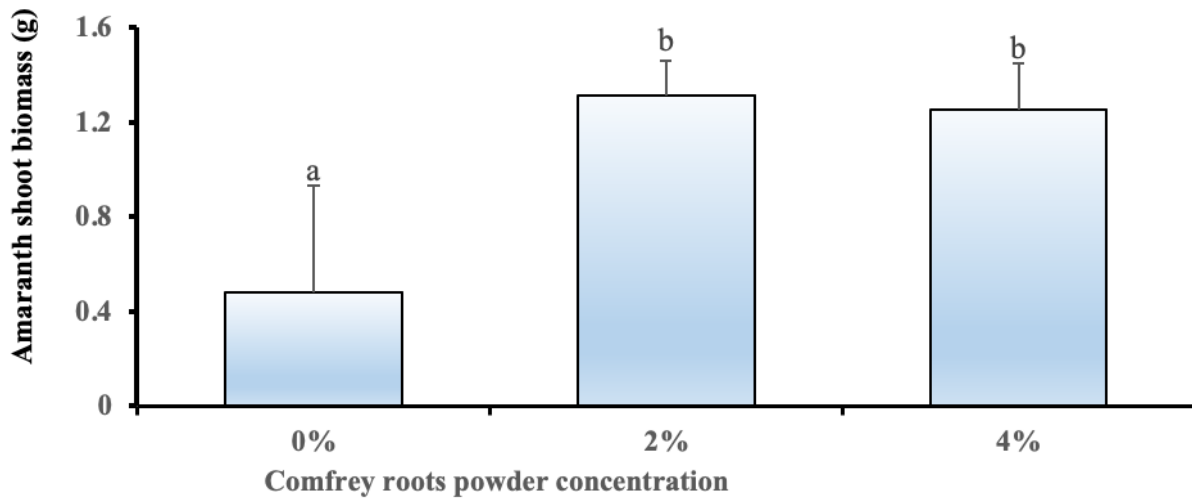
Note: Columns with the same letters are not significantly different according to Tukey's multiple comparison test,  $p < 0.001$ . Comfrey leaves were collected from Mgeta highlands, Morogoro, Tanzania

From the second experiment, soil amendment with 2% of comfrey roots powder increased significantly ( $P = 0.018$ , figure 5) the shoot biomass of Amaranthus vegetable, while further increase in comfrey roots powder concentration did not further increase significantly the shoot biomass. The total Amaranthus biomass (shoot + roots) increased significantly ( $p < 0.048$ , figure 6)

following the application of 2% of comfrey roots powder in comparison to total shoot biomass of Amaranthus grown in un amended soil (control). Further increase in comfrey roots powder concentration up to 4% did not show any further increase in Amaranthus total shoot biomass.

**Figure 5:**

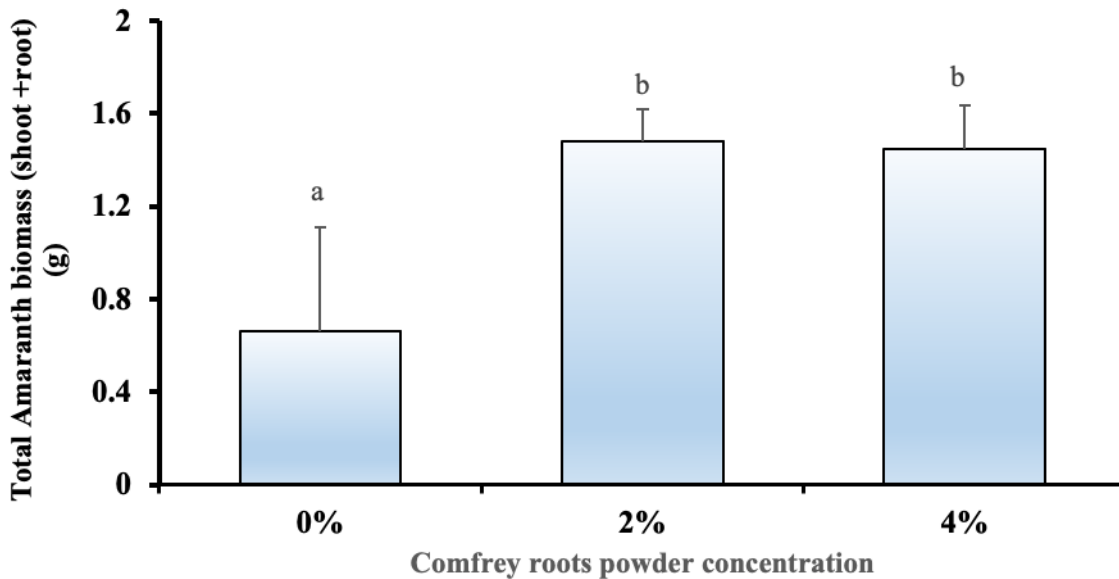
*Effects of Comfrey roots powder on shoot biomass yield for Amaranthus vegetable*



Note: Columns with the same letters are not significantly different according to Tukey's multiple comparison test,  $p < 0.018$ . *Comfrey roots were collected from Mgeta highlands, Morogoro, Tanzania*

**Figure 6**

*Effects of Comfrey roots powder on total biomass yield (shoot+root) of Amaranthus vegetable*



Note: Columns with the same letters are not significantly different according to Tukey's multiple comparison test,  $p < 0.048$ . *Comfrey roots were collected from Mgeta highlands, Morogoro, Tanzania*

## Discussion

The comfrey used in this experiment was enriched by essential plant nutrients and K was the highest in concentration (19300 mg/kg). Similar findings regarding the enrichment of K and other essential nutrients in comfrey leaf were reported earlier by Howard *et al.*, (2018), and Govere *et al.*, (2018). The enrichment of nutrients in comfrey plants have been linked to the extensive rooting system of this plant which allows exploration of more nutrients from the soil where it grows (Gwilym, 2010 and Oster *et al.*, 2021). Due to the presence of higher nutrient concentrations in Comfrey leaves powder, application of this material to the soil enhances the fertility status of the soil.

The positive results noted in both vegetative growth of maize, and biomass yield of Amaranthus vegetable following the soil amendment with comfrey plant powders (leaves and roots) could be linked to high nutrients composition of comfrey leaf and root powders noted particularly potassium, nitrogen and phosphorous. Hills *et al.* (1995) reported high

content of nitrogen, phosphorus and potassium in comfrey which was linked to deep rooting system of comfrey plant. Howard *et al.* (2018) noted a high concentration of K in and increased concentration of available K and N to the soil following mulching the soil with comfrey just in one growing season. Govere *et al.* (2018) noted enrichment of K in liquid fertilizer made from comfrey. Based on physical appearance of maize and Amaranthus vegetable from both experiments, plants were growing vigorously with deep green colour particularly in the last weeks of experiments in pots amended with comfrey powders (roots and leaves) than in controls (un amended soils) implying the good supply of nitrogen from comfrey powders to the plants. Harris *et al.*, (1990) reported a significant increase in available forms of N (nitrate and ammonia) in the soil amendment with comfrey plants which could be easily absorbed by plants thus influencing the plant growth. Moreover, the increase in total plant biomass (root and shoot) could be linked to high carbon content of the added comfrey leaf and root powders which likely improved the physical soil conditions such as soil structure, aeration and crop rootability in clayey soil (an experimental soil).

## Conclusion

Based on the elemental composition of comfrey leave and root powders and enrichment of K noted in comfrey, and being an organic material, comfrey can be used as soil amendment to supplement nutrients and improve the physical characteristics of the soil. The positive results noted in both vegetative growth and biomass yield of maize and amaranths vegetable respectively following soil amendment with comfrey from 2 - 8% (w/w) supports the use of comfrey as soil amendment to improve crop growth.

## Recommendations

Following enrichment of K in comfrey, and positive results noted in both vegetative growth and biomass yield of maize and amaranths vegetable respectively in soil amendment with comfrey, the application of 2 - 8% (w/w) of comfrey powders is recommend. However, studies to investigate the effect of comfrey powders on changes in soil characteristics, on growth and yield of maize, and amaranths and application of higher rates than 8% are highly recommended.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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