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RESEARCH ARTICLE

ASSESSMENT OF GROWTH AND DEVELOPMENT OF COMMON BEANS IRRIGATED WITH TREATED WASTEWATER

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ABSTRACT

The low level of common beans production in Tanzania has been attributed partly to low levels of soil plant-available phosphorus. In view of that, a screen house experiment was conducted to recover phosphorus from treated wastewater and to assess its effects on growth parameters of common beans. Three irrigation treatments (T0: freshwater, T1: freshwater and fertiliser, T2: treated wastewater) were used. The experiment was laid out in a Completely Randomized Design with 20 replications. Results showed that Treated wastewater significantly ($P < 0.05$) improved days to 50% flowering and maturity compared to other treatments. Beans irrigated with treated wastewater also had significantly higher ($P < 0.05$) height, number of branches, number of pods and number of leaves than in T0 and T1. Maximum dry weight was also obtained from treated wastewater treatment compared to the other treatments. The study indicated that treated wastewater could be used in common beans production.

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INTRODUCTION

In many countries, waste water is used as an alternative water source in the agriculture sector, replacing the high-quality water required for human consumption (Toze, 2006). According to FAO (2010), agricultural water and wastewater usage globally, accounts for approximately 70% of water use on average. By contributing to food and water security, wastewater irrigation can alleviate strain on water resources by providing a reliable year-round source of water with sufficient nutrients for crop growth (Dickin *et al.,* 2016). Wastewater is considered as an enormous nutrient source for irrigated plants (Rattan *et al.,* 2005), holding valuable nutrients needed for plant growth, and has excellent fertilization potential for agricultural crops. Treated domestic and municipal wastewaters contain macronutrients such as nitrogen, phosphorous and potassium, and micronutrients such as calcium and magnesium, all of which are vital to plant and soil health. As reported by Finley (2008), wastewater use can supplement or even replace commercial fertilizer inputs. Common bean (*Phaseolus vulgaris* L.) is among the most important food grain legume crops in Tanzania. The country ranks among the top 20 in global bean production (Ndakidemi *et al*., 2006).

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However, most of bean production is carried out by smallholder farmers for their own consumption, with an average 20% surplus being marketed (Hillocks *et al.*, 2006). In recent years, bean consumption has increased because of increased population pressures both in rural and urban areas, and escalation of the cost of living. However, production of common bean has remained low and does not meet the increasing demand. The average yield is 741 kg/ha, compared with a potential yield of about 1500-3000 kg/ha (Hillocks *et al.*, 2006). Phosphorus (P) is considered as the first limiting plant nutrient for bean production (CIAT, 1998). Common bean requires P to enhance energy for its metabolic activities. The crop possesses high requirements for P and is hence sensitive to low plant-available P in soils (Boutraa, 2009). The low level of production in Sub-Sahara Africa (SSA) has been attributed partly to low levels of soil plant-available P (Beebe *et al.*, 2013). The amount of available P in soils is largely insufficient to meet the demand of most legumes and thus there is widespread P deficiency in pulse crops. Based on soil analytical data, 65-80% of the bean producing areas in SSA are deficient in plant-available P (Broughton *et al.*, 2003), thus reducing common bean yield by over 60% (Acosta-Díaz *et al.*, 2009). One way to overcome P deficiency is through recovering P from wastewater, to provide both irrigation water and nutrients required for crop growth. Wastewater that has been treated is a resource that can be used for productive uses in agriculture because it contains P that contributes to promotion of plant growth. Its reuse can deliver positive benefits to farming communities and municipalities (FAO, 1992). Therefore, this study was conducted to recover phosphorus from treated wastewater and acquire information on the influence of the recovered P on growth and development of common beans.

MATERIALS AND METHODS

Pot experiments were carried out in a screen house to study the effects of treated wastewater on growth parameters and development of common beans. The experiment was laid out in a Completely Randomized Design with three irrigation treatments and 20 replications. The treatments were:

T0: irrigation with freshwater;
T1: irrigation with freshwater and fertiliser;
T2: irrigation with treated wastewater.

Pots of treatment T1 were irrigated with fresh water and supplied with fertilizer, those of treatment T2 were irrigated with treated wastewater while pots of treatment T0 were used as control and irrigated with freshwater without fertilizer application. Pots (13 cm in diameter and 10 cm in depth) were used. Common beans (*Phaseolus vulgaris* L.) of a local variety, was used in the experiment. All pots contained 8cm deep of air dried soil in which the seeds were sown. 3 g of NPK fertilizer (15-9-20) equivalent to 30 kg P ha^{-1} was added (and mixed well) to soils in pots of T1 before sowing. Some key properties of the soil used in the experiment are presented in Table 1. Plants were thinned during the first two weeks after sowing to leave one plant per pot. Irrigation started at the first day after sowing. On a daily basis, T0 and T1 received 0.5 L of fresh water while T2 was irrigated with 0.5 L of treated waste water. Some key parameters of fresh water and treated wastewater were determined using procedures described by EPA (1982). All standard local cultural practices were followed throughout the growth period.

Table 1. Some properties of the soil used in the experiment

Parameter	Unit	Sandy loam (depth: 0-30 cm)
EC	dS/m	0.52
pH	-Log[H^+]	7.3
Available P	mg/kg	17.5
Available K	mg/kg	290.6
Available N	%	1.0
Organic matter	%	1.1

Days to 50% emergence was recorded as the number of days from sowing to when 50% of the plants emerged in each plot. Similarly, days to 50% flowering was recorded as the number of days from planting to when 50% of the plants produced flowers and 50% maturity was recorded as the number of days from planting to when 50% of the plants showed yellowing of pods. At maturity, data on plant height, number of leaves per plant, number of branches per plant and number of pods per plant were taken from ten randomly selected plants in each treatment. Plant height of 10 randomly selected plants per treatment was measured with the help of a meter ruler, from the base of the plant to the apical bud of the plant and expressed in centimetres. Mean height of the 10 plants were considered as the height per plant. The number of leaves per plant was recorded by counting number of branches from 10 random plants per treatment and the mean was taken as number of leaves per plant. Similar procedure was followed to obtain number of pods and branches per plant in which means of number of pods and branches of 10 randomly selected plants were considered as number of pods per plant and number of branches per plant respectively. Biomass in terms of dry weight was measured at harvest. Ten randomly selected plants from each treatment were carefully uprooted to obtain whole plant, washed with distilled water to remove unwanted materials and soil from roots. The samples were dried in an oven at 70°C for 24 hours and weighed for dry matter determination. The mean dry weights of the 10 plants per treatment were taken as dry weight per plant.

Statistical Analysis

Analysis of Variance (ANOVA) was carried out on the data obtained by using QI Macros 2016 Tool in Ms Excel 2007. Means were compared using LSD at a probability level of 5%.

RESULTS

Characteristics of treated wastewater and freshwater used in the study

The characteristics of treated wastewater and freshwater used in the study are shown in Table 2. Treated wastewater contained considerable amounts of nutrients needed to promote plant growth, such as P as well as other macronutrients i.e. potassium and nitrogen compared with freshwater. Together, the nutrients play important role in the promotion of growth and yield of common beans.

Table 2. Properties of treated wastewater and freshwater used in the experiment

Parameter	Unit	Treated wastewater	Freshwater
Temperature	^0C	25.2	25.2
pH		7.84	7.8
TSS	mg/l	14	3.7
Conductivity	dS/m	1.27	0.49
NO_3	mg/l	20	8.7
PO_4	mg/l	4.2	0.02
K	mg/l	8	1.2

Days to 50% emergence, flowering and maturity of common beans under different treatments

The results for days to 50% emergence, flowering and maturity are shown in Table 3. There was no significant difference among treatments on days to 50% emergence as all plants emerged before 7 days as shown in Table 3. However, the results showed that effect of Treatment had significant ($P < 0.05$) effect on days to 50% flowering and on days to 50% maturity. T2 was earlier (42.4 days) to flower while T0 took the highest number of days (50.3). More number of days to maturity (78.4 days) was recorded for T0 and less (71.2 days) for T2.

Effect of treatment on plant height, number of branches, number of pods and number of leaves

The treatments had significant ($P < 0.05$) effect on plant height at maturity (Table 4). T2 gave the highest mean plant height of 82.4 cm while T0 gave the lowest mean plant height of 54.1 cm indicating higher growth potential of common beans irrigated with treated wastewater.

Table 3. Days to 50% emergence, 50% flowering and 50% maturity of common beans under different Treatments

Treatment	Days to 50% emergence	Days to 50% flowering	Days to 50% maturity
T0:fresh water	6.3	50.3	78.4
T1:fresh water and fertilizer	5.9	44.8	72.3
T2:treated wastewater	5	42.4	71.2
LSD (5%)	NS	4.19	2.52

Also, treatment had a significant ($P < 0.05$) effect on number of branches per plant (Table 3). The mean number of branches per plant was the highest (6.2cm) in T2 and lowest (4.5cm) in T0. The treatments showed significant ($P < 0.05$) effect on number of pods per plant (Table 4). The highest mean number of pods per plant (15.6) was obtained for T2 while the lowest was recorded for T0 (8.6). The treatment had a significant effect ($P < 0.05$) on number of leaves per plant (Table 4). T2 had the highest number of leaves per plant (6.2) while T0 had the lowest number of leaves per plant (4.6).

Table 4. Effect of treatment on plant height, number of leaves, number of branches and number of pods of common beans

Treatment	Plant height (cm)	No. of leaves	No. of branches	No. of pods
T0:fresh water	54.1	4.6	4.5	8.6
T1:fresh water and fertilizer	64.3	6.1	5	12.9
T2:treated wastewater	82.4	6.7	6.2	15.6
LSD (5%)	12.10	1.29	1.19	3.34

Effect of treatment on dry matter yield

The results for dry matter production under different treatments are shown in Fig. 1. The results indicate that plants grown in T2 produced significantly higher ($P < 0.05$) dry matter yield than in T0 and T1. The maximum (54.4 g plant^{-1}) dry matter was recorded in T2 while the minimum (40 g plant^{-1}) was recorded in the control treatment (T0).

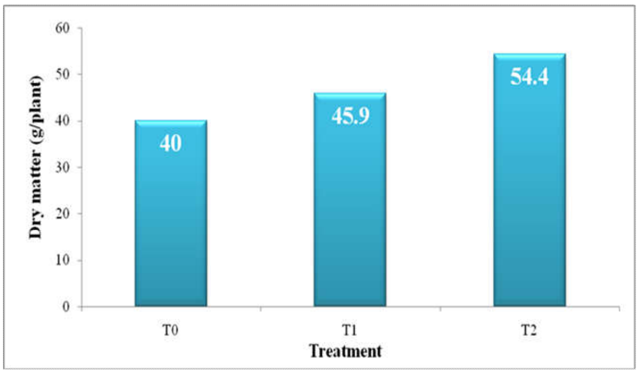

Figure 1. Effect of treatment on dry matter yield of common beans

DISCUSSION

Characteristics of treated wastewater, freshwater and soil used in the study

Treated wastewater had optimum pH and EC for irrigation based on Food and Agriculture Organization standards (FAO, 1992). Furthermore, the treated wastewater was enriched with considerable amount of nutrients that are considered essential for maintaining soil fertility and enhancing plant growth and productivity. Phosphorus which is an essential nutrient and a constituent of macromolecular structures was also present (4.2 mg L^{-1}). The soil used in the experiment was P deficient, containing only 17 mg kg^{-1} P. According to Mourice and Tryphone (2012), soils are considered deficient in P if the soil plant-available P contents are less than 40 mg kg^{-1} P determined by Bray-1 method. This can be due to prolonged degradation by erosion and repeated removal in crop harvest without replacement of the removed P.

Days to 50% emergence, flowering and maturity of common beans under different treatments

In all treatments, common beans emerged before 7 days. This can be a result of availability of adequate moisture in the soil required to initiate the germination process since P has no direct role prior to seedling emergence. T2 had shorter days for 50% flowering and maturity than both T0 and T1. The good performance of T2 can be due to high nutrient concentrations of P, N and K in treated wastewater. Common beans are known to take longer to reach maturity with limited P supply. According to Onweremadu (2008), soils irrigated with wastewater have higher organic matter, available P and total N as compared to clean water-irrigated soil. High nutrient accumulation in the soil makes easy the access of plants to the high nutrient concentrations (macro and micro elements) and increases their growth and fertility leading to increased cytokinins synthesis and supply of photosynthates for flower formation. Phosphorus deficiency is related to the reduction in foliar expansion a decrease in the number of leaves and loss in photosynthetic efficiency.

Effect of treatment on plant height, number of branches, pods and leaves

Osman *et al*., (2006) noted that irrigation of crops with untreated or treated wastewater caused stimulation in the measured growth parameters of common beans (*Phaseolus vulgaris*). Our results showed that treated wastewater significantly improved height of common beans. This is in agreement with Alemu and Hameed (2017), who reported that the height of common beans irrigated with wastewater was higher than those irrigated with freshwater. Ali *et al*., (2011) on the other hand, studied castor beans and reported that, plant height of plants irrigated with treated wastewater was superior to those irrigated with freshwater. Availability of nitrogen in effluent plays an important role and stimulates the growth of stem resulting into high height (Khan *et al.,* 2003). The highest number of pods in T2 (15.6) compared to T0 (8.6) and T1 (12.9) can be attributed to its highest mean plant height which provided space for more pods to grow. Higher number of branches per plant in T2 (6.2) compared to T0 (4.5) and T1 (5) might be due to availability of P in wastewater. P plays a major role in cell division activity, leading to the increase in number of branches. According to the results, T2 had the highest number of leaves (6.2) while T0 had the lowest (4.6). This is due to nutrients present in the effluent. According to Khan *et al*., (2003), the availability of nitrogen stimulates the growth of new leaves. However, Gardner *et al*., (1985) argued that the increase of number of leaves in crops irrigated with treated wastewater is a result of increased concentration of other essential nutrients such as P and K that increases leaf number and leaf area by increasing cell size and number. Furthermore, P deficiency results into a decrease in the number of leaves, as seen in T0.

Effect of treatment on dry matter yield

Our results (Fig. 1) showed that common beans irrigated with treated wastewater had maximum (54.4 g $plant^{-1}$) dry matter yield compared to other treatments. A similar observation was made by Nelisen *et al*., (1989). In their study, they obtained higher dry matter yields of *Phaseolus vulgaris* L. irrigated with treated wastewater compared to yields obtained using water from a well. Saffari and Saffari (2013) recorded maximum fresh and dry yields of beans from wastewater treatment compared to the control/freshwater treatment. They concluded that irrigation with treated wastewater improves soil properties, plant growth and yield without any contamination in soil and toxicity in plants. Furthermore, AI-Nahidh and Gomah (1991) found that the application of treated sewage water enhanced the crop yield of wheat, while irrigating corn with wastewater in all the growth stages caused the most biological yield of the crop. According to EI-Gammal (2003), the increase in plant growth and productivity is associated with the presence of high levels of essential nutrients such as phosphorus, nitrogen and potassium in treated wastewater.

Conclusion

Results of this study showed that treated wastewater can improve growth parameters of common beans as compared to application of freshwater with fertilizer or freshwater alone. The treated wastewater used in the experiment was shown to be an effective fertilizer and provided good yield of common bean crop. Treated wastewater has least impacts on the environment and human health and contains sufficient nutrients needed by crops hence saving the cost of buying inorganic fertilizer. Therefore, treated wastewater could be used for ensuring a sustainable supply of phosphorus for production of common beans and other crops as well.

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