Determination of the Potassium (K) Uptake Potential of Water Leaf (*Talinum Triangulare)* Using Computer Simulated Models of Heterogeneous Condition

ABSTRACT

This study investigated effects of simulated heterogeneous soil K distribution on its uptake by *Talinum triangulare*. The distribution of K in soils is rarely homogeneous. Soil K heterogeneity arises from inherent soil factors and external inputs. Parent materials from which soils form often have uneven K contents, creating initial variability. Soil potassium (K) is vital for plant growth and its spatial distribution potentially affects crop nutrition and productivity. Pot trial modelled control (0 mg/kg K added), homogeneous (1000 mg/kg K added), and heterogeneous (simulated reach heterogeneity) K treatments which was maintained in the greenhouse for 45 days after transplanting in the treatments. At harvest, the shoots and roots were cut, washed and analyzed for potassium after acid digest by nitric acid. The mean concentrations of potassium in the root of the control, homogeneous, heterogeneous treatments were 9972±1184 mg/kg, 9526±1299 mg/kg and 10854.7±147 mg/kg respectively, while the shoot potassium concentration were 11864±162 mg/kg, 12069±184 mg/kg and 11967±268 mg/kg respectively. However, the root K concentration in the heterogeneous treatment was 0.088 times higher than the control and 0.139 times higher than the homogeneous. Conversely, the homogeneous shoot K concentration 0.017 times higher than the control and 0.009 times higher than the heterogeneous. The shoot K concentration was higher than the root. This suggest that *T.triangulare*would Translocate potassium from the root to the shoot easily by almost 90%. The Concentration factors for the control, homogeneous, and heterogeneous conditions were 0.1118, 0.1498, 0.1258 respectively. Similarly, there was no significant differences ($p>0.05$) between treatments. Overall, simulated heterogeneity did not substantially affect K nutrition and growth of *T. triangulare* within experimental constraints. Furthermore, long-term field studies are recommended to elucidate heterogeneity influences over crop cycles. The findings provide baseline insights on K uptake by *T. triangulare* under variable nutrient conditions and which is relevant to agriculture.Elucidating the long-term impacts of soil potassium heterogeneity can provide insights to improve fertilizer management, especially for potassium-demanding crops. This will ultimately support nutrient use efficiency and agricultural productivity. The findings from this initial study establish a foundation to build future research upon.

Keywords: Potassium, Heterogenous, Uptake, Talinum Triangulare

1.0. INTRODUCTION

Potassium (K) is one of the essential macronutrients required for plant growth and development. It plays vital roles in photosynthesis, nutrient transport, enzyme activation, stomatal movement, and stress response (Wang *et al*., 2013). Although potassium is abundant in most soils, its availability to plants is often constrained by the heterogeneous distribution in the soil (Wang *et al*., 2016). Understanding the heterogeneity of soil K and how it affects K uptake by plants is critical for improving fertilizer management.

The distribution of K in soils is rarely homogeneous. Soil K heterogeneity arises from inherent soil factors and external inputs. Parent materials from which soils form often have uneven K contents, creating initial variability (Liu *et al*., 2018). Further heterogeneity develops from long-term fertilizer applications, recycling of crop residues, and variability in native soil K release and fixation reactions across the landscape (Yang *et al*., 2019 ,Ogunlade-Anibasa,G.O et al., 2024). These factors lead to differences in exchangeable and soluble K pools over short distances. Natural processes such as leaching, erosion, and runoff also contribute to non-uniform K distribution (Zheng *et al*., 2021). Generally, topsoils contain higher available K levels than subsoils due to stratification from fertilizer additions and nutrient recycling (Wang *et al*., 2016). But lateral variability at similar depths can be substantial depending on land use history and soil redistribution processes.

The heterogeneous distribution of K in soils has significant effects on K uptake by plants. Studies show that soil K heterogeneity leads to heterogeneous root proliferation and K uptake during plant growth (Liu *et al*., 2018; Zheng *et al*., 2021). Plants respond to K heterogeneity by selectively proliferating roots in K-rich zones to maximize K acquisition (Wang *et al*., 2016). This allows more efficient uptake compared to uniform root proliferation. Uneven nutrient supply associated with heterogeneous soil K creates localized zones of K deficiency in plants, impacting biochemical processes and potentially reducing yield (Yang *et al*., 2019). Variable root uptake also leads to within-plant K heterogeneity, affecting K utilization and reallocation to developing tissues (Liu *et al*., 2018).

Spatial variability in soil K availability arises due to heterogeneity in parent material, differential weathering and neoformation of K-bearing minerals, and variability in long-term K inputs through fertilization, organic amendments and crop residue recycling (Yang *et al.*, 2019; Zheng *et al.*, 2021). Additionally, K redistribution via leaching, erosion and runoff leads to non-uniform K patterns at landscape scales. Micro-scale variability also occurs due to factors like soil physical properties, microbial activity and depletion zones around plant roots (Wang *et al.*, 2016). Seasonal dynamics in mineralization, fixation, uptake and transport processes further contribute to heterogeneity.

Variable distribution of available K in soils has major implications for crop potassium acquisition. Non-uniform uptake due to heterogeneous supply can lead to K deficiency in plant tissues, impairing growth and productivity (Liu *et al.*, 2018). Understanding soil K heterogeneity effects is crucial for optimizing fertilization, especially in crops like *Talinum triangulare* with inherently high K demand (Adediran *et al.*, 2004). This knowledge aids development of site-specific management approaches to improve crop performance on soils with spatially variable nutrient supply.

Potassium is one of the most important macronutrients required for proper growth and development of plants (Leigh and Wyn Jones, 1984; Wang *et al.*, 2013). It serves vital roles in numerous physiological and biochemical processes critical for plant metabolism and productivity.

Potassium (K) uptake by plants involves intricate physiological processes crucial for cellular functions, emphasizing the need for understanding these mechanisms to optimize nutrient management (Wang *et al.*, 2013). Root cells utilize specialized transport proteins like potassium channels and transporters for potassium uptake, maintaining cellular homeostasis (Leigh and Wyn Jones, 1984). Passive diffusion, driven by concentration gradients, and active transport, requiring ATP hydrolysis, are fundamental processes in this uptake (Leigh and Wyn Jones, 1984). Plant selectivity favors potassium absorption over other cations, influenced by transporter affinity for potassium ions (Epstein and Bloom, 2005). Symbiotic mycorrhizal fungi enhance nutrient uptake, including potassium, by extending hyphal networks into the soil (Smith and Read, 2008).

Soil pH, modified by plant root release of organic acids, crucially influences potassium solubility and availability (Marschner, 2012). Root architecture, encompassing length, density, and branching pattern, impacts potassium absorption.

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Talinum triangulare (water leaf) is an annual herbaceous plant commonly grown as a leafy vegetable. It has shallow fibrous roots and a rapid growth rate. Due to its characteristics as a fast-growing leafy crop, *T. triangulare* has high K demand and is sensitive to K heterogeneity in soils (Adediran *et al.*, 2003). Preferential root proliferation in K-rich patches has been observed in *T. triangulare* as an adaptive mechanism to cope with soil K variability (Wang *et al.*, 2013). This allows *T. triangulare* to maximize K uptake from soils with non-uniform K distribution. However, localized K deficiency can still occur and impact leaf growth and quality. Optimizing soil K status through fertilization is important for obtaining high yields of *T. triangulare*, especially on soils with high inherent K variability (Adediran *et al.*, 2004). Further research is needed to quantify the effects of soil K heterogeneity on the potassium nutrition and productivity of *T. triangulare*.

Potassium (K) is an essential macronutrient required by all living organisms for proper functioning and growth. In plants, K plays vital roles in photosynthesis, enzyme activation, osmoregulation, stomatal regulation, and stress response (Wang *et al.*, 2013; Andrist-Rangel *et al.*, 2015). K is also crucial for animals and humans, being involved in nerve conduction, muscle contraction, cell signaling, and maintaining water-electrolyte balance (Khan *et al.*, 2014; Weaver, 2018). Although total K levels may be adequate in soils, its availability to plants is often limited by heterogeneous distribution arising from inherent soil variability and management practices (Yang *et al.*, 2019; Zheng *et al.*, 2021). This literature review examines soil K heterogeneity and its impacts on K nutrition of plants, with a focus on leafy vegetables like *Talinum triangulare*.

Potassium is the most abundant cation in plant tissues and has diverse functions (Wang *et al.*, 2013). It activates enzymes involved in photosynthesis, respiration, energy metabolism, nitrogen assimilation, and other processes. K aids the opening and closing of stomata to regulate gas exchange and transpiration. It also facilitates phloem transport of sugars and nutrient mobilization. K further enables plants to resist biotic and abiotic stresses through physiological adaptations. In animals and humans, K regulates fluid balance, acid-base balance, and membrane potential (Weaver, 2018). It also influences skeletal and smooth muscle contraction necessary for normal nerve, heart, and digestive function.

Despite the importance of K, its availability in soils is spatially variable (Yang *et al.*, 2019). Extractable K distribution is often heterogeneous over scales from centimeters to kilometers. Total K levels may differ five-fold between proximal sampling points, while plant-available K varies several-fold within meters due to local soil conditions and management (Liu *et al.*, 2018). Soil parent material, long-term fertilization, crop rotation, tillage, and nutrient redistribution processes interact to cause non-uniform K supply (Zheng *et al.*, 2021).

Soil K heterogeneity significantly impacts plant K nutrition. Roots proliferate in K-rich zones to maximize uptake from nutrient-rich patches (Liu *et al.*, 2018). However, this leads to uneven K acquisition and localized deficiency. Within-plant K heterogeneity arises, affecting distribution to tissues and yield formation (Yang *et al.*, 2019). Photosynthesis, enzyme activities, and metabolism are impaired when K is deficient. Variable K also alters water relations, carbon partitioning, and phytohormone signaling (Andrist-Rangel *et al.*, 2015).

Talinum triangulare (water leaf) is a leafy vegetable cultivated for its shoots and leaves. It has high K demand but a shallow, fibrous root system (Adediran *et al.*, 2003). Spatial variability in soil K is likely to affect K uptake and growth of *T. triangulare*. However, specific impacts are poorly understood. Investigating K heterogeneity effects can optimize nutrient management for improving productivity and nutritional quality of leafy vegetable crops.

There is limited understanding of how heterogeneous soil K distribution affects K acquisition and growth in *Talinum triangulare*. Elucidating these impacts is critical for developing appropriate K management strategies for optimal yield and quality of *T. triangulare*, especially on soils with high inherent K variability.

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This study aimed to provide a transparent framework for interpreting results and encourages future research to build upon its findings. The identified constraints do not diminish the significance of the study but rather highlight areas for consideration in the interpretation and application of the results.

2.0. MATERIALS AND METHODS

Method

Water leaf (*Talinum triangulare*) was be selected for pot trials base on the; the fact that it is commonly consumed are a source of K to humans (Anibasa, 2016). A knowledge of the *in-situ* heterogeneity of lead oxide in an earlier study on contaminant heterogeneity (Anibasa, 2019) was applied to simulate similar scales of heterogeneity of the potassium chloride in this study based on known scale of heterogeneities (Anibasa and Ramsey, 2020). Water leaf was used in a greenhouse pot trial modelling the simulated *in situ* heterogeneity. Herbage samples were processed and analysed for the concentrations of potassium in roots and shoots at the end of the growth using the Atomic Absorption Spectrometer (AAS). Data collected from this study was analysed using appropriate statistical tools. Growth medium samples was also analysed for the concentrations of potassium. These data provided information on the uptake potential of the water leaf and availability of these nutrients to potential consumers of water leaf.

2.1 Experimental Design

One heterogeneity model was simulated (using excel computer models with a combination of the Robust ANOVA- a visual basic programme developed based on a FORTRAN programme and previous work, which will generate the levels of heterogeneity similar to those that had been found in field sites and previous field studies (Anibasa and Ramsey, 2023). The scale of heterogeneity used, the plant species selected, and the mean Fe concentrations that was chosen, were based upon conclusions of the first pot trials in earlier studies (Anibasa and Ramsey, *2023*)

The sample size was determined using power analysis to estimate the minimum number of replicates required to detect a statistically significant difference between means of different treatments based on the assumption that data will be normal in their distribution. Data from the seed germination was used for power analysis having confirmed they are normally distributed using the Kolmogorov Smirnov test. It is impossible to simulate the exact *in situ* heterogeneity (real life situation). The actual spatial heterogeneity of nutrients can only be estimated by sampling at the field site, and it is practically impossible to recreate the exact *in situ* heterogeneity in pot trials. In view of this potential complexity, the model of heterogeneity was designed to simulate as closely as practicably possible the *in-situ* heterogeneity of trace elements measured at this scale in field sites in an earlier study (Anibasa, 2020) with a range of intermediate HF (HF ranged from 1 to 3.22 (3.22 at the 20 m scale). The proposed simulation of heterogeneity factors (HF) were 1.00, 1.25, 2.00 and 3.19 while an overall mean concentration of approximately 1000 mg/kg in all treatments was maintained (Figure 1-3). The simulation was based on the log-normal distribution observed in those field sites, with increasing values of geometric standard deviation (GSD) and hence the values of HF. The central cell (C3) of all treatments was maintained at 1000 mg/kg Fe. This is to ensure that the heterogeneity treatment did not deferentially affect the early establishment of the seedling.

Cells	1	2	3	4	5
A	1000	1000	1000	1000	1000
B	1000	1000	1000	1000	1000
C	1000	1000	1000	1000	1000
D	1000	1000	1000	1000	1000
E	1000	1000	1000	1000	1000

List 1a: Homogeneous---GSD 0.0; robust mean=1000; HF=1.00

Cells	1	2	3	4	5
A	900	700	900	1100	900
B	1100	1100	1400	1400	1400
C	1100	700	1000	900	900
D	1100	900	1100	1800	900
E	900	1100	900	1100	700

List 1b: heterogeneous--GSD 0.1 Robust mean =1029; HF=1.2

2.2 Greenhouse Pot Trials

The pot trial was done in two stages: (i) initial growth nursery (ii) the actual pot experiment. Ten replicates of the *T. triangulare* was maintained in the greenhouse for three treatments; control, homogeneous and heterogeneous.

2.3 Initial Establishment of *T. triangulare*in the Nursery

2.3.1 Methods

T.triangulare species was considered for initial transplanting into unspiked growth medium after 7 days of nursery to ensure proper growth and establishment before the actual transplant into the trace metal spiked growth medium.

After initial growth and the development of the first true leaves, plants of approximately equal size were selected and transplanted into the centre of separate circular 1- litre pots (15 cm deep and 12 cm wide) pots for each species containing unspiked growth medium (washed silver sand, John Innes compost II, 7 parts sand to 3-part compost). Fifteen seedlings of the plant species were transplanted into pots (making a total of 60 seedlings) of unspiked growth medium first for two weeks and was watered daily using a fine rose watering can. This was maintained under 16 hours of natural light at 30 ± 5 ^{o} C in the greenhouse. At two weeks after the first transplanting, ten seedlings of each K species were transplanted into the 15 pots containing growth medium spiked with K at concentrations of 1000 mg/kg K (homogeneous and heterogenous treatment).

A total of 30 pots will be maintained (1000 mg/kg (homogenous) mg/kg added treatment (control and heterogeneous treatments) for 6 weeks under a photoperiod of 16-hour natural sunlight at 30 ± 5°C in the greenhouse. These were maintained in 3.5-litre square pots (dimensions 17 cm x 24 cm) in a simple randomized block design both in 1000 mg/kg K added and 0 mg/kg added K as control and heterogeneous treatment. Pots were rotated clockwise by 90^{o} weekly to reduce the effect of uneven environmental conditions within the greenhouse.

Randomized blocks were between treatments because of the available space/m^2 of greenhouse benches.

2.3.2 Greenhouse Pot Trial

Fifteen (15) rigid square pots (14 X14 cm and 17 cm deep) were thoroughly washed with detergents and labelled with names of plant species three treatments e.g. homogeneous, heterogeneous and control (Solomon-Wisdom *et al.*, 2015). A customized cell divider made from a 1 mm clear polyethylene terepthalate glycol (PTEG) sheet was inserted into the pots to produce a 5 by 5, 2-dimensional grid with each cell measuring 25 mm square and 170 mm deep. This was used to create the designed heterogeneity models. The relatively thin PETG helped to maintain the heterogeneity design by reducing the collapse of each column after its removal. Labeled paper liners were inserted into each cell while filling cells with growth media. It provided a filling template, to help to maintain the structural integrity of the divider and minimize spillage from adjacent cells.

The gap between the paper liners and the outer edge of the pot were packed with an inert Sinclair Perlite (grain size 2.0-5.0 mm) because of the non-vertical sides of pots. Cells were filled according to the particular designed model of heterogeneity. Filling of the pots was done in two stages to ensure that equal volume of growth medium goes into the cells and that the growth medium is evenly distributed throughout the pot. The gently compacted growth medium was measured with a 100 ml customized container into each cell according to the design. The growth medium will be tapped down before an additional 50 ml was added and tapped down again.

Completed pots was placed on drip trays and arranged on benches in the randomized block design with blocks of 3 rows and 3 columns.

The growth medium was moistened from below by capillary action before transplanting seedlings already established in an unspiked growth media for two weeks. Tap water was applied using a fine rose watering can. This ensured that the heterogeneity is disturbed to a minimal extent. The percentage moisture content of the growth media will be taken. The pH of the growth media was taken. The established seedlings of the selected plant species were transplanted into the centre of each treatment after two weeks growing in the unspiked growth media. Ten replicates of each treatment were maintained in the greenhouse for six weeks under simulated sunlight using light-emitting diodes (LED) lights (under a photoperiod of 12 hours) at 30 ±5 C.

2.3.3 Harvesting

Harvesting was done after 60 days of growth. Data such as the longest leaf length, number of true leaves and height (to the nearest 1 mm) were collected after 14, 28 days and at harvest, to assess growth variation between treatments. Plant biomass data such as root and shoot biomass (FW and DW) in all pots in homogeneous, heterogeneous and control treatments were collected at harvest to assess the impact of heterogeneity on the plant species. Shoots and roots of all treatments were harvested as described earlier in section 3.5.1.

2.3.4 Chemical Analysis

Shoots and roots were carefully washed to remove soil particles that could introduce potential bias in measurements of metal concentration. Harvested roots and shoots were dried at 60ºC for 48 hours in a fan oven, weighed for Dried Weight, and analysed for K concentration using an Atomic Absorption

Spectrometer (AAS) after acid digestion using nitric and perchloric acids (Thompson and Walsh, 1983). Thompson and Walsh (1983) reported that a biomass of 1 gram (DW) was ideal for chemical analysis, but did not preclude the use of smaller masses, with suitable checks on data quality.

The growth media were analysed for their actual K concentration. Regression analysis was used to show the relationship between the actual concentrations and the nominal concentrations.

2.3.5 Data Analysis

Data were analyzed using statistical software Minitab 18 and SPSS 25 for Windows. Statistical tools such as analysis of variance (ANOVA), RANOVA (robust analysis of variance), Tukey post-hoc test and the mixed model ANOVA (treatment used as fixed factor and block as a random factor) were used to test for significance of measured variables whilst Kolmogorov-Smirnov test was used to test for normal distribution of data. Other relevant statistical tools and software packages was used to analyses and model data from this study.

2.3.6 Sample Preparation

All the reagents used were of analytical grade. Distilled water was used for distillation and preparation of reagents and standards. All glassware and plastic containers used were washed with liquid soap and rinsed with water before soaking in 10% nitric acid for 24 hours, cleaned thoroughly with distilled water and dried to ensure that there was no contamination.

2.3.7 Preparation of Samples for Analysis

The samples were selected to be debris and dirt free. Foreign matters such as grains, pebbles and pod remnants were manually removed from the roots. Then the roots were properly washed under running tap water to remove soil particles and then rinsed with distilled water. Samples were dried in an oven at a temperature of 40^0C. the dried roots and shoots were milled into powdered form and then sieved using 0.500mm mesh size sieve and stored in polythene bags, until ready for acid digestion.

2.3.8 Acid Digestion

Samples were digested as described by (AOAC 1990) with little amendments. 0.2g each of the powdered samples were weighed into a digestion tube and 10ml of 98% nitric acid added. This was then placed in a water bath and allowed to boil for about 72 hours. It was covered with a lid and transferred to digestion block in a fume cupboard for digestion. The temperature was steadily increased (to prevent fuming) until it reached 105^0C. this was left and allowed to undergo digestion for 30 minutes, after the digestion was completed, the resulting pale-yellow solution was allowed to cool and transferred into a 25ml volumetric flask and filled up to 25ml mark with de-ionized water and was filtered into clean sample bottles.

Reagent blank was prepared in similar manner. Spiking of the sample was done using standards concentration of the studied metal (iron) and blank samples were extracted as above. The acid digestion of water leaf samples solutions was analyzed for iron using a buck scientific atomic absorption spectrometer (AAS).

2.3.9 Quality Control

Appropriate equipment was used, safety precautions and protective measures were followed to ensure the reliability of the test results. The chemical reagents used were of analytical grade. The glass wares and plastic containers used were all cleaned properly and in between the research. Samples were labelled and handled cautiously to avoid contamination or mixing. There were reagent blanks to check for contamination, duplicate samples were used to check for analytical precision and certified reference material (IAEV-8) was used to estimate instrumental accuracy (bias) and that the analytical values were within the range of certified value.

2.3.10 Quantification of Plant Uptake

A plant's capacity to accumulate metals from the soils can be expressed by a concentration factor (CF) (Anibasa, 2016). It is defined as the concentration of a particular chemical in a biological tissue per concentration of that chemical in the tissue surroundings (Anibasa, 2016). Several terms have been used in different studies. In certain studies, concentration factor is also known as phytoextraction or bioaccumulation factor (Baker, 1981; Safae *et al.*, 2008; Akinci *et al.*, 2010). It is estimated as the ratio of trace metal concentrations in the aerial + below-ground part of plants and soil trace metal concentration (both expressed on a dry weight (DW) basis), and expressed mathematically as (Rotkittkhun*et al.*, 2006).

$$CF_{Total} = \frac{\text{Concentration of trace metals in shoots and roots } \frac{mg}{kg} \text{ DW}}{\text{Concentration of trace metals in soil } \frac{mg}{kg} \text{ DW}}$$

$$CF_{Total} = \frac{\text{Cshoot and root}}{\text{Csoil}} \qquad (1)$$

Where,

$$C_{\text{Shoots and Roots}} = \text{Concentration of trace metals in shoots and roots}\left(\frac{\text{mg}}{\text{kg}}\right)\text{DW}$$

$$C_{\text{Shoots and Roots}} = \text{Concentration of trace metals in soil}\,\frac{\text{mg}}{\text{kg}}\,\text{DW}$$

$$CF_{\text{Shoot}} = \frac{\text{Concentration of trace metals in shoots and roots}\,\frac{\text{mg}}{\text{kg}}\,\text{DW}}{\text{Concentration of trace metals in soil}\,\frac{\text{mg}}{\text{kg}}\,\text{DW}} \quad (2)$$

$$CF_{\text{Root}} = \frac{\text{Concentration of trace metals in shoots and roots}\,\frac{\text{mg}}{\text{kg}}\,\text{DW}}{\text{Concentration of trace metals in soil}\,\frac{\text{mg}}{\text{kg}}\,\text{DW}} \quad (3)$$

(Anibasa, 2016).

3.0. RESULTS

Roots and Shoots Potassium concentration of *T. triangulare*between Treatments

The mean concentration of K in the three treatments (control, homogeneous and heterogeneous) for both roots and shoots in *T. triangulare*are shown in Table 1. The mean root potassium concentration of potassium in control, homogeneous and heterogeneous treatment were 9972±1184mg/kg, 9526±1299mg/kg, and 10855±147mg/kg respectively (Figure 1) while that of the shoot in the control, homogeneous and heterogeneous treatment were 11864±162mg/kg, 12069±1844mg/kg and 11967±268mg/kg respectively (Figure 2). There was no significant difference ($P>0.05$) in K concentration between treatments. The concentration of potassium in the control treatment indicates that the soil itself has an inherent level of potassium. However, potassium is much available in the shoot than in the root (Figure 3). This is because potassium primarily plays a crucial role in processes like photosynthesis, protein synthesis, and enzyme activation, which are more active in shoot tissues. This higher demand for potassium in the shoot compared to the root leads to higher concentrations in the shoot.

Comparison of the root and shoot potassium concentration between treatments showed that there were no significant differences($p>0.05$) by treatments. The concentration factor (CF) of *T.triangulare*in the control, homogeneous and heterogeneous were0.1118, 0.1498, 0.1258 respectively. There was no significant different. This implies that *T.triangulare*is an accumulator of K and may be a good source of this element.

Table 1: Root and Shoot Potassium concentration of *T. triangulare*between treatments.

Treatment	Potassium Concentration (mg/kg)
Root	
Control	9972±1184
Homogenous	9526±1299
Heterogenous	10855±147
Shoot	
Control	11864±162
Homogenous	12069±184
Heterogenous	11967±268
WHO standard limit in plants	1200 (Gimou, 2008)

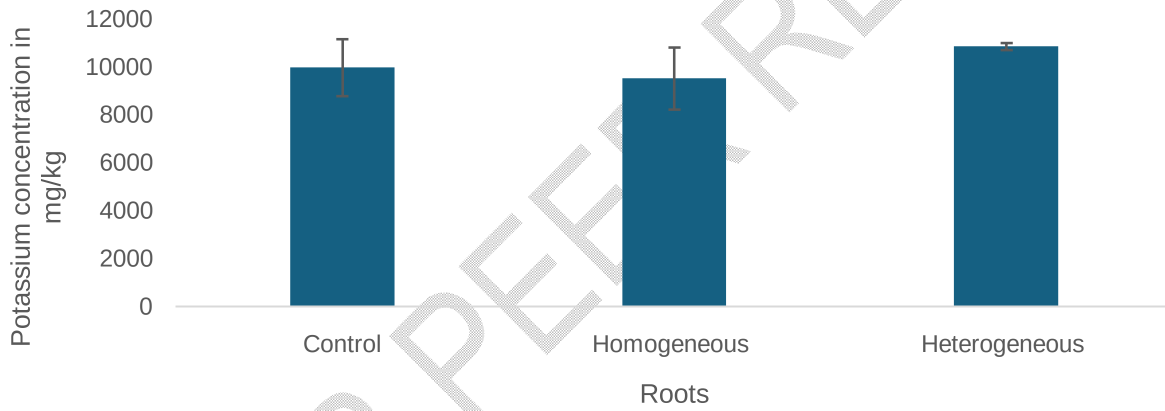

Figure 1: Comparison of the root Potassium concentration between treatments

Error bars represent 2 standard errors on the mean

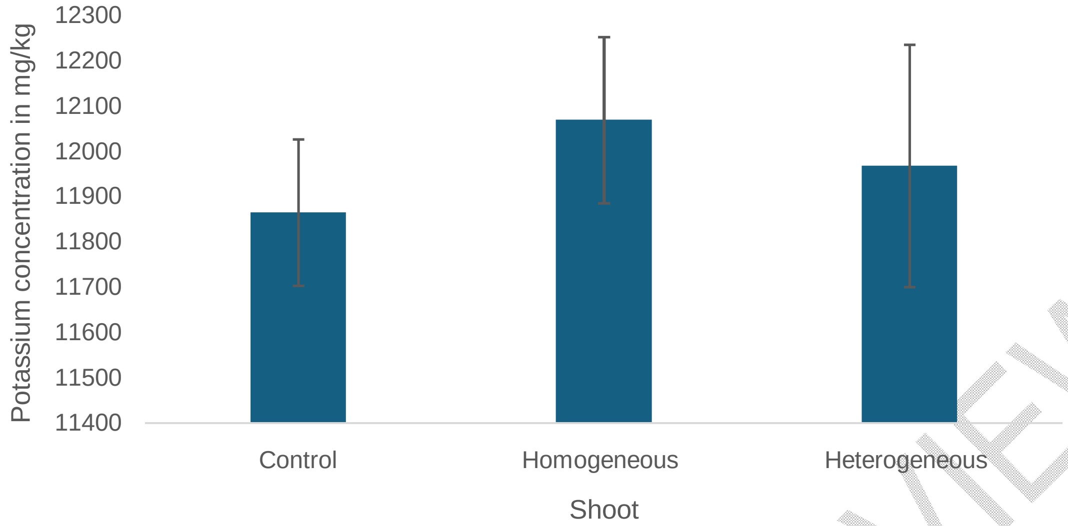

Figure 2: Comparison of the shoot potassium concentration between treatments

Error bars represent 2 standard errors on the mean

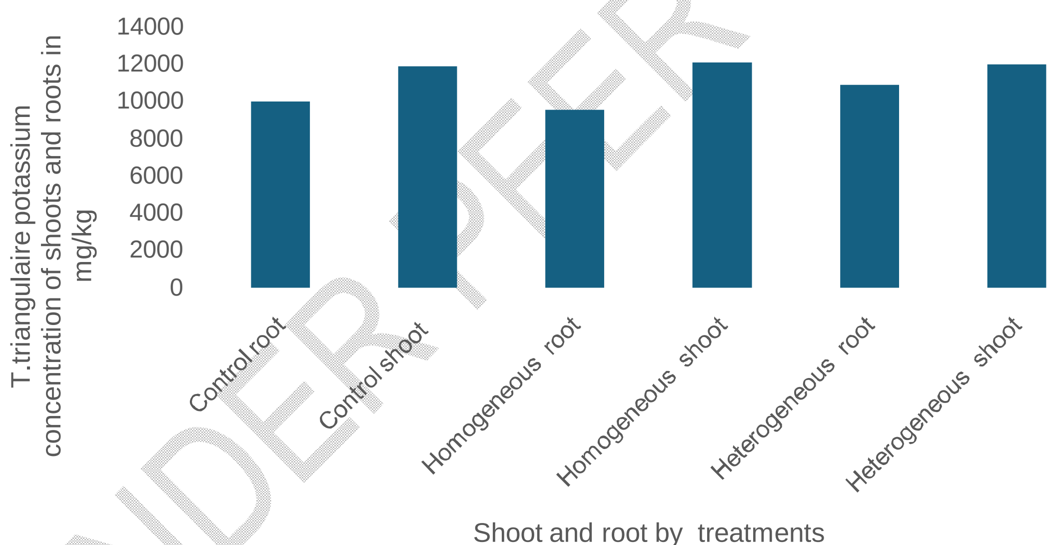

Figure 3: Comparism of the shoot and root concentrations between treatments

4.0.DISCUSSION

The results of this study provide insights into the effects of heterogeneous potassium distribution on potassium uptake and nutrition of *Talinum triangulare*. The potassium concentrations measured in the roots and shoots of *T.*

*triangulare*grown under the control, homogeneous, and heterogeneous treatments did not show statistically significant differences. This suggests that varying the spatial distribution of soil potassium within the tested ranges did not substantially impact overall potassium acquisition and partitioning to plant tissues in *T. triangulare*.

However, the shoots showed markedly higher potassium levels compared to the roots across all treatments. This aligns with the physiological role of potassium in shoots for processes like photosynthesis, enzyme activation, protein synthesis and osmoregulation which require high potassium concentrations (Wang et al., 2013). The lower root potassium likely reflects the primary role of uptake rather than metabolic functions. Selective potassium partitioning to shoots satisfies their higher growth demand (Pettersson and Jensen, 1983).

Although not statistically analyzed, visual observations indicated no noticeable differences in growth parameters like leaf number, plant height, and biomass between the control, homogeneous and heterogeneous treatments. This further supports that the simulated potassium heterogeneity did not significantly affect potassium nutrition and subsequent growth of *T. triangulare*within the experimental time frame.

The lack of major heterogeneity impacts could potentially be attributed to root foraging mechanisms in *T. triangulare*. Previous studies have shown preferential root proliferation of *T. triangulare*in potassium-rich zones enabling efficient uptake despite heterogeneity (Wang *et al*., 2013., Solomon-Wisdom *et al.*, 2015). Such adaptive responses likely enabled adequate potassium acquisition across treatments.

However, the experimental scale and duration may have limited visible effects. Chronic potassium deficiency from sustained heterogeneity could accumulate over time to influence productivity.

The concentration factor provides an indication of a plant's ability to accumulate nutrients from the soil. *T. triangulare*exhibited concentration factors less than 1 for potassium in this study, reflecting lower shoot tissue concentrations than the growth media. This shows that *T. triangulare*does not hyperaccumulate potassium. The values align with previous reports of concentration factors for potassium in leafy vegetables (Xiong *et al*., 2014).

Overall, while simulated heterogeneity did not elicit significant impacts within this experiment's constraints, it provides baseline insights on potassium uptake in *T. triangulare*under variable nutrient distribution.

CONCLUSION

This study investigated the effects of simulated heterogeneous soil potassium distribution on potassium nutrition and growth in *Talinum triangulare*. Key findings are summarized:

i. Potassium concentration did not differ significantly between the control, homogeneous and heterogeneous treatments for both roots and shoots of *T. triangulare*.

ii. Shoots showed higher potassium levels than roots across treatments, aligning with greater shoot metabolic demand.

iii. There were no noticeable differences in growth parameters between variability treatments over the experimental duration.

iv. Concentration factors indicated *T. triangulare*does not hyperaccumulate potassium.

v. The lack of significant heterogeneity impacts could potentially reflect root foraging adaptation in *T. triangulare*.

Overall, the simulated potassium heterogeneity did not elicit measurable differences in potassium status and growth of *T. triangulare*within the experimental constraints. While providing baseline insights, long-term studies may better elucidate heterogeneity influences. The findings highlight the complex plant-soil interactions affecting nutrient acquisition.

4.3 Recommendations

Based on the study's findings and limitations, the following recommendations are made for future research:

i. Conduct long-term experiments over an entire crop cycle to assess chronic effects of heterogeneity.
ii. Expand the scale and dimensions of heterogeneity to better represent field conditions.
iii. Test different plant species, especially non-leafy crops, to evaluate varying nutrient responses.

iv. Incorporate modelling approaches to predict heterogeneity impacts under diverse scenarios.
v. Track gene expression for transporters and enzymes involved in potassium uptake and utilization.
vi. Relate potassium heterogeneity to interactions with other nutrients like nitrogen and phosphorus.
vii. Explore agronomic strategies like targeted fertilization, intercropping and cover crops to mitigate heterogeneity effects.

Elucidating the long-term impacts of soil potassium heterogeneity can provide insights to improve fertilizer management, especially for potassium-demanding crops. This will ultimately support nutrient use efficiency and agricultural productivity. The findings from this initial study establish a foundation to build future research upon.

Disclaimer (Artificial intelligence)

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Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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1.

2.

3.

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