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Potassium Heterogeneous Distribution in Soil and Its Uptake by *Zea mays* l.

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Potassium (K) is an essential nutrient on the growth and development of plants. This study investigated the uptake of potassium by *Zea mays* in heterogeneous soil distribution towards increasing the availability of this nutrient in plants, animals and human foods. A greenhouse pot experiment was conducted with *Zea mays* grown under control, (0mg/kg K added) homogeneous (100mg/kg K added), and heterogeneous (stimulated realistic heterogeneity) of K for 6 weeks after germination and initial establishment for 4 weeks. Shoots and root at harvest were analyzed using Atomic Absorption Spectrometer (AAS), Thermos Fisher Scientific Model 3000 ICE after acid digestion with Nitric acid. Data collected were analyzed using SPSS version 25 for windows, deploying appropriate statistical tools. The mean shoot K concentration in control, homogenous and heterogeneous treatment were 11460±250mg/kg, 1401±117mg/kg and 11188±222mg/kg respectively while the mean root K concentration in control, homogenous and heterogeneous treatment were 11581±96mg/kg, 12018±286mg/kg, and 8066.2±1468mg/kg respectively. There

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was a significant difference ($p<0.05$) in the root and shoot potassium concentrations between treatments. However, the root potassium concentration of the control treatment was two to three times as much as that of the homogenous and heterogeneous treatments. The homogenous shoot potassium concentration was the lowest 1401±117mg/kg and two times higher than that of the control and heterogeneous treatments which suggest low translocation of potassium from the roots to the shoot in homogenous soil condition. Potassium concentration on all treatments were 2 to 3 times as high the WHO standard limit which may pose health risk. However, the risk depends on the frequency of consumption and the plant part consumed. The concentration factor (CF) for control, homogeneous, and heterogeneous were 0.84, 0.69 and 0.10 respectively. The concentration factor (CF) did not differ between treatments. This study showed that this *Zea mays* plants uptake potassium from varying soil conditions and effectively translocate them to the above ground. This has implications for approving the availability of those nutrients in plants and animals.

Keywords: Potassium; heterogenous; uptake; Zea mays; distribution.

1. INTRODUCTION

Superficial fertilizer bands and no-till farming alter soil nutrient transport [1]. Roots grow and absorb more nutrients in nutrient-rich zones [2,3]. In phosphorus-deficient soils, roots produce organic and inorganic compounds that mobilize potassium from sparingly soluble sources [4]. Optimizes soil and plant potassium use (2008). Ma, Rengel although plant responses to soil nutrient and pollutant variability are well established, their regulatory systems are not.

Sizes of natural soil nutrients affect plant growth and dissemination [5]. Intraspecific competition, population dynamics, community structure, and ecosystem function are affected by soil nutrient fluctuations in plants [6]. Even with the same nutrients, diverse soils help plants [7]. In diverse contexts, foraging lets plants obtain more resources from resource-rich locations [8]. The average adult has 140g potassium. Most meals contain potassium, with nuts and seeds containing 1% and yeast extract or coffee 3–4%. Consume 3.5 g daily. Systemic potassium [9]. This cation enhances cell osmolality.

Nerve stimulation is its key function [9]. Plasma potassium is 3.5–5.0 mmol/L lower than intracellular potassium [9]. Plasma potassium management is multifaceted. Example: renal excretion [10]. The sodium/potassium-ATPase pump is vital [10].

Shoot allocation may alter root responses to fluctuating nutrient supply since root growth and carboxylate exudation need considerable potassium expenditure [11]. Barley root exudation and assimilation enhanced in potassium nitrate-enriched soil [12].

Potassium is essential to plants. Plant cells need potassium for osmoregulation, photosynthesis, electrical neutralisation, metabolite transport, and enzyme activation [13]. For 20%–33% of maize growth and development, potassium is applied less than nitrogen and phosphorus [14].

Roots absorb most nutrients. Root activity and form affect crop growth and soil nutrient absorption [15]. Nutritional stress affected root nutrient uptake [16]. Potassium-efficient rice genotypes absorb more, have larger roots, and have more root-soil contact [17].

Bioavailable soil micronutrients affect soil fertility, quality, plant production, and ecology [18]. Nutritional potassium yields large, consistent, high-quality crops [18]. The crust, plants, and animals contain potassium [18]. Normal agriculture depletes potassium despite crops needing the same amount due to nutritional imbalance [19]. Underdeveloped countries' fertilisers have less potassium than crops [19].

Thus, potassium and soil fertility fall [19]. Potassium affects most biochemical and biophysiological processes and catalyses enzymes [19]. It turns photosynthetic components in fruits, grains, and tuberculi into fibres, proteins, lipids, and vitamins [20].

Reduced potassium affects plant photosynthesis and glucose distribution [20]. Potassium improves plant metabolism and disease resistance [20]. Soft tissues and high cell levels of low-molecular-weight compounds characterise nitrogen-supplemented low-potassium plants (Traner et al.). Parasites devour sugars and other low-molecular-weight cells, rendering soft tissues ineffective mechanical barriers [21]. Pets need potassium. Major electrolyte with Na+ and Cl-.

The body has 120 g of potassium, a positive cation in 98% of cells [21]. 420 mg in red cells and 4-5 mg K/100 ml in blood serum indicate potassium consumption [21]. Potassium affects cell metabolism and biochemistry [22]. Glucose and glicogen metabolism and aminoacid-based cell protein synthesis are its functions [22]. Daily potassium is needed for muscle growth, neurological, cardiovascular, and diuretic elimination [22].

Potassium regulates cells and environment [22]. Sodium-potassium pumps introduce chemicals to cell membranes. Protein and cell components are potassium-based [22].

Many plant and animal foods and drinks contain potassium. Many vegetables and fruits are good sources [23]. In many countries, vegetables are mainstays and decrease blood pressure [23].

Dietary fibre and vegetables may promote intestinal transit, decrease cholesterol, regulate blood glucose, and transport minerals and phytochemicals from the fibre matrix [23]. Increasing vegetable intake may lower saturated fats, trans fats, and high-calorie foods, improving diet [24]. To maximise health advantages, eat a variety of vegetables because each provides phytonutriceuticals (vitamins, minerals, dietary fibre, and phytochemicals) [24]. Growing crops needs potassium. Irrational fertilisation and compound index reduce soil potassium, inhibiting rhizosphere growth [25].

Environmental, plant physiology, soil, and agricultural techniques affect potassium (K) heterogeneity and uptake [26]. Potassium distribution research enhances soil management and the environment [26]. Plants absorb potassium, changing animal diets. Wildlife and livestock eat potassium-rich vegetation [23]. Understanding plant potassium absorption and food chain transport is crucial for animal health and productivity [20]. Humans need potassium for fluid, muscle, and brain homeostasis [20]. In well-nourished persons, potassium shortage is rare, however some groups or medical conditions require potassium monitoring. Crop potassium uptake study maintains food quality [20].

The main aim of this study is to investigate the relationship between uptake of potassium (K) by *Zea mays* and spatial distribution towards increasing the availability of this nutrient in plants, animals and human foods.

The Objectives of the study: To simulate heterogeneous distribution of potassium in growth medium to be used in a greenhouse pot experiment.

To grow *Zea mays* in greenhouse experiment in different spatial treatments (control 0 mglkg K added, homogenous (1000mg/kg added) and simulated realistic heterogeneous treatments using computer models.

To determine the concentration of K in roots and shoot of *Zea mays* after harvest
To determine the concentration factor (CF) of this plant between treatments in order to asses uptake.
To compare K concentration and uptake of plants between treatments.

2. METHODS

2.1 Experimental Design

Excel computer models and Robust ANOVA, a visual basic software based on FORTRAN and previous work, were used to simulate one heterogeneity model to create field site and historical field experiment heterogeneity levels. Pot variability, plant species, and mean K concentrations were measured by Solomon-Wisdom et al. [27].

Power analysis calculated the minimum replicates needed to detect a statistically significant treatment mean difference assuming normal distribution. Since the Kolmogorov Smirnov test showed normal distribution, seed germination data was used for power analysis.

Simulating in situ heterogeneity is impossible. Pots cannot simulate regional nutrient variation. Only field sampling can assess it. Due to this potential complexity, the heterogeneity model was created to reproduce the in-situ heterogeneity of trace elements reported at this scale in field locations in an earlier study [28] with intermediate HF (1 to 3.22 at 20 m). At 1000 mg/kg mean concentration, all treatments replicated HF of 1.00, 1.25, 2.00, and 3.19. The simulation used the log-normal distribution from those field sites when GSD and HF rose. All treatments maintained 1000 mg/kg K C3. Establish seedlings swiftly without variation.

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

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 1b. Heterogeneous--GSD 0.1 Robust mean =1029; HF=1.2

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

2.2 Greenhouse Pot Trials

According to Anibasa [29]. The real marijuana study started with two nurseries. The seedlings have water leaf. A greenhouse held 10 Zea mays replicates for control, homogeneous, and heterogeneous treatments.

Solomon-Wisdom et al. [27] method. 15 rigid square pots (14 X14 cm, 17 cm deep) were detergent-washed and tagged with plant species and homogeneous, heterogeneous, and control treatments. The pots were divided into a 5 by 5 2-dimensional grid with 25 mm square, 170 mm deep compartments using homemade cell dividers made from 1 mm transparent polyethylene terepthalate glycol (PTEG) sheets This helped heterogeneity models.

After removal, thin PETG preserved heterogeneity by reducing column collapse. The growth media compartments had designated paper liners. Filling templates organised media and cells. Inert Sinclair Perlite (grain size 2.0-5.0 mm) was placed between paper liners and pot exteriors due to their non-vertical sidewalls. Model heterogeneous cells. Filling two pots ensured equal growth medium entered and distributed into cells. In bespoke containers, each cell received 100 cc of softly compressed growing medium. Add 50 ml and tap growing media again.

Completed pots were randomly placed in 3 rows and 3 columns on drip trays and benches.

Unspiked two-week-old seedlings were placed in capillary media. Apply tap water with a fine rose can. Less heterogeneity disruption. We checked growing media wetness. The growth media pH was tested. Each treatment centre received selected plant seedlings after two weeks of unspiked growth. The greenhouse had ten duplicates of each treatment under LED lights 30 (a 12-hour photoperiod) at 30-5C during six weeks.

Harvesting followed 60 days of growth. To compare growth between treatments, longest leaf length, number of true leaves, and height (to the nearest I mm) were measured at 14, 28, and harvest. For homogeneous, heterogeneous, and control root and shoot biomass (FW and DW), all pots were harvested to explore how heterogeneity influenced plant species. Per 3.2, all treatments' shoots and roots were gathered.

2.3 Chemical Analysis

Dirt that could alter metal concentrations was removed from shoots and roots. To determine K content, roots and shoots were fan-dried at 60°C for 48 hours after nitric and perchloric acid digestion, weighed, and evaluated with an Atomic Absorption Spectrometer (AAS) [30] advised 1 gramme (DW) biomass for chemical analysis, however data quality checks allow smaller amounts.

Growing media K concentration was evaluated. Regression linked nominal and real concentrations.

2.4 Seed Germination Experiment

This was done as described by Anibasa [29]. The pot trial was done in two stages According to Anibasa [29]. Cannabis research comprises seed germination and pharmacological testing. Maize was planted for control (TC), homogeneous (THO), and heterogeneous (THT) seed germination on a greenhouse-maintained nursery copy of Zea mays. In Anibasa [29], growing seeds is discussed in 3.3.1. Before germination, one seed tray was washed and sterilised with household bleach (1:9 water), rinsed with tap water, reverse osmosis water, and air-dried. Trays list plant names and dates.

Drain holes in the seed tray reduced post-seeding waterlogging.

Light density fine grade Sinclair® vermiculite (grain size 2.0-5.0 mm) with neutral pH 7 was equally soaked with tap water and placed 1cm below the seed tray rim before sowing. Per supplier instructions, little seeds were thinly dispersed over vermiculite. The huge tray with drain holes covered trays after sowing to permit light and air in and prevent medium drying and dampening.

In the greenhouse, they germinated in 16 hours of natural light at 20C + 5°C.

Post-germination tray removal. The dry seed tray top was gently watered with a fine spray watering can without resetting the seeds. This surface was usually moist.

Planting Zea mays unspiked was thought. Before transplanting into trace metal spiked growth media, wait 7 days after germination to allow proper development.

After germination and the first true leaves appeared, seedlings of roughly the same size were transplanted into the centre of circular 1-litre pots (15 cm deep and 12 cm wide) for each species with unspiked growth material.

The species' 30 seedlings were transplanted into 15 unspiked growth media pots and watered daily with a fine rose watering can for two weeks. The investigation was conducted in a greenhouse with 16 hours of natural light at 30±5°C. Each species put 10 seedlings into 15 pots with 1000 mg/kg K-spiked growth medium heterogeneously two weeks later.

During 16 hours of sunlight at 30±5°C, 30 pots got 1000 mg/kg homogeneous and heterogenous additional treatment. Simple randomised block design introduced 1000 mg/kg K and 0 mg/kg K to 3.5-litre square pots (17 cm x 24 cm greenhouse) with heterogeneous treatment.

Rotating pots clockwise weekly minimized greenhouse unevenness. We used random blocks for greenhouse bench space and variety treatments.

Shoot harvesting involved cut stems 0.01 mm above ground and root screening for dirt. Repeated tap water washing and 48-hour 60°C drying removed harvested plant dirt. AAS assessed herbage ground K for nitric and perchloric acid digestion.

2.5 Sample Digestion

Matuisewiz (2003) discussed sample digestion. Samples were filtered with a 0.45µm membrane filter and kept at 40°C until analysis. 0.5 ml Zea mays sample and 25 ml aqua-regia digested 3 hours at 120oC. For Atomic Absorption Spectrometer analysis, digested samples were prepared in 25ml of deionized water using Whatman filter papers.

2.6 Quality Control

The batch comprised reagent blanks, duplicate samples, and IAENF L.-certified reference materials to check contamination, precision, and bias. A spectrometer measures sample and blank trace. Concentrations were mg/kg.

Examined data using Minitab 18 and Windows SPSS 25. Kolmogorov-Smirnov assessed data normality, while ANOVA and RANOVA assessed variable significance.

Different statistical methods were employed to examine and model study data.

Total plant trace metals varied by species/varieties, shoot, root, and metal. Analysis of plant K uptake and concentration. Several harvest effects were found. Plants on metal spiked media were harvested after six weeks. After nitric and perchloric acid açid digestion, AAS (PerkinElmer AA Analyst 400) evaluated shoot and root metal content in dried and milled plant materials.

2.7 Quantification of Plant Uptake

According to Anibasa [29]. The concentration factor (CF) assesses plant soil metal absorption [31]. Chemical concentration ratio of living tissue to surrounds [32]. Some research uses other words. Baker [33], Safae et al. [31], and Akinci [34] use concentration factor phytoextraction or bioaccumulation.

Plant airborne, subterranean, and soil trace metal concentrations are compared metal concentration (both expressed on a dry weight (DW) basis), and expressed mathematically as (Rotkittkhun *et al.,* 2006).

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

$$\mathrm{CF_{Total}} = \frac{\text{Cshoot and root}}{\text{Csoil}} \tag{1}$$

Where,

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

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

$$\mathrm{CF_{Shoot}} = \frac{\text{Concentration of trace metals in shoots and roots } \frac{\text{mg}}{\text{kg}} \text{ DW}}{\text{Concentration of trace metals in soil } \frac{\text{mg}}{\text{kg}} \text{ DW}} \tag{2}$$

$$\mathrm{CF_{Root}} = \frac{\text{Concentration of trace metals in shoots and roots } \frac{\text{mg}}{\text{kg}} \text{ DW}}{\text{Concentration of trace metals in soil } \frac{\text{mg}}{\text{kg}} \text{ DW}} \tag{3}$$

3. RESULTS

3.1 Potassium Concentration of *Zea Mays* Roots and Shoots between Treatments

The comparison of potassium concentration of *Zea mays* roots between treatments are as shown in Fig. 1. The comparison of potassium concentration of *Zea mays* shoot between treatments are as shown in Fig. 2. The mean root potassium concentrations in the control, homogeneous and heterogenous treatments were 11581±96mg/kg, 12018±286mg/kg, and 8066.2±1468mg/kg respectively. The mean shoot potassium concentrations after control, homogenous and heterogenous treatments were 11460±250mg/kg, 1401±117mg/kg and 11188±222mg/kg respectively. There was a significant difference ($p<0.05$) in root and shoot potassium concentrations between treatments. Both root and shoot potassium concentrations were 12-26 times above the WHO tolerable limit of 4.700mg/kg as shown in Table 1.

3.2 Comparison of the Mean Root and Shoot, Potassium Concentration

The control treatment shows relatively high potassium concentrations in both roots and shoots compared to the other treatments i.e. the control treatment has higher potassium concentrations both in the roots and shoots compared to the homogeneous and heterogeneous treatments as shown in Fig. 3. The homogeneous treatment has higher potassium concentration in the roots compared to the shoots, which may have likely involved uniform conditions or uniform application of potassium. The potassium concentration in both roots and shoots is lower compared to the control treatment, with values of 12018±286mg/kg for roots and 1401±117mg/kg for shoots. This may indicate that under homogeneous conditions, the plant may tendencies to take up more K. The heterogeneous treatment shows a higher potassium concentration in the shoots compared to the roots. This suggests that the distribution of distribution of Potassium favours its translocation to the shoot varied significantly between treatments.

In general, there was a significant difference in potassium uptake or accumulation between the different treatments, with the control treatment showing the highest levels. This could indicates that the natural soil is horizontally rich in potassium. However, the controlled most significantly differ from the heterogeneous treatment which implies that the heterogeneity plays a key role in uptake of metals by plants.

3.3 Comparison of the Concentration Factor (Cf)

Concentration factor (CF) were 0.84, 0.69 and 0.10 in the control, homogenous, and heterogeneous respectively. The total concentration factor of the homogeneous treatment is about 0.69 % of the total concentration of the control treatment. The

Table 1. Comparison of *Zea Mays* Roots and Shoot Potassium Concentration between Treatments

Treatment	Potassium mg/kg (Mean±SEM)
Root	
Control	11581±96
Homogenous	12018±286
Heterogenous	8066.2±1468
Shoot	
Control	11460±250
Homogenous	1401±117
Heterogenous	11188±222
WHO	4.700mg/kg [35]

Key:
SEM = Standard error of the mean
WHO = World Health Organization

concentration factor of the heterogeneous treatment is about 0.10 % of the total concentration of the control treatment. The concentration factor of the control treatment is 0.84% of the total concentration. The concentration factor was the highest in the control and about 20% higher than the homogenous and heterogeneous treatments.

Comparison of the shoot and root concentration factors as shown in (Fig. 3). Showed that shoot had 20-30% higher K concentration than the root except in the homogenous treatment. About 90% of the K in the root is translocated to the shot and in heterogeneous soil condition rise and in heterogeneous soil conditions.

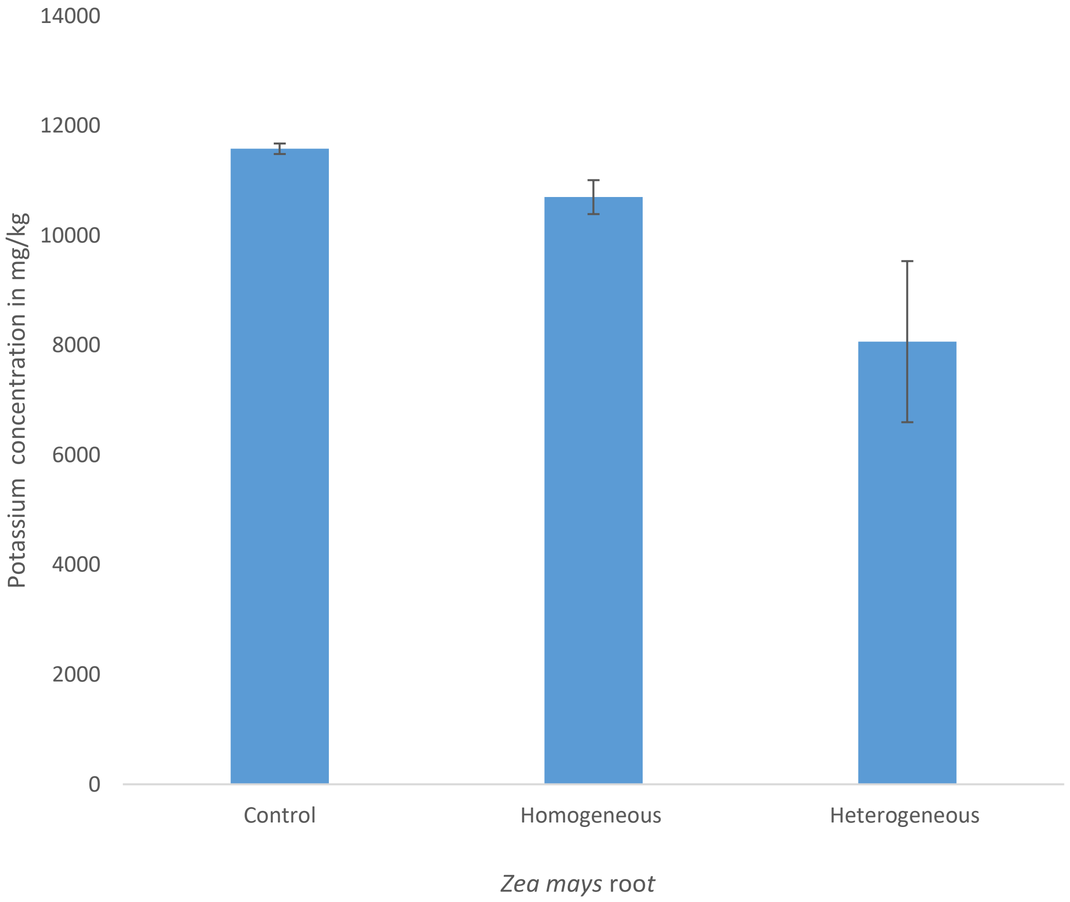

Fig. 1. Comparison of the potassium concentration of *Zea Mays* roots between treatments
Error bars represent 2 standard errors on the mean

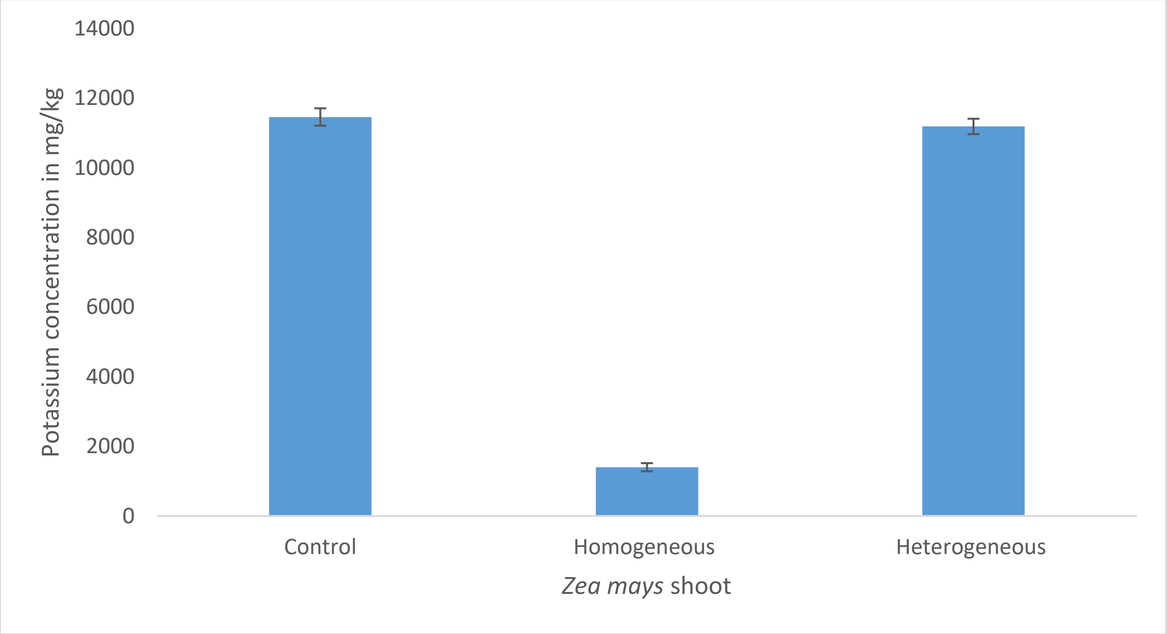

Fig. 2. Comparison of the potassium concentration of *Zea Mays* shoot between treatments
Error bars represent 2 standard errors on the mean

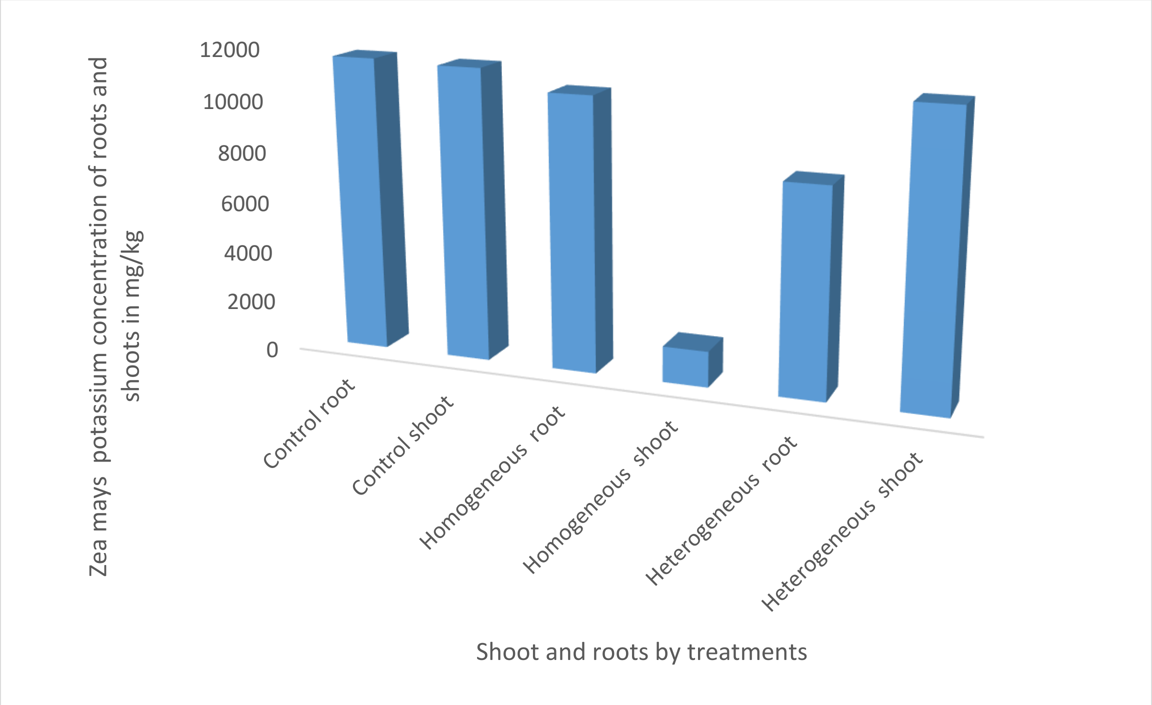

Fig. 3. Comparison of the mean root, and shoot, potassium concentrations between treatments

4. DISCUSSION

Potassium (K) is an essential nutrient on the growth and development for maize (*Zea Mays* L.). In this current study the results showed significant differences in potassium uptake between the control, homogeneous, and heterogeneous treatments for *Zea mays* with less uptake on the homogenous treatment.

The root activity is commonly regarded as importantly physiological metabolism of root system, indicating absorption ability of root system in soil. Due to higher root activity, crops still could obtain adequate nutrient to maintain development and growth in spite of nutrition deficiency in soil (Lynch, 2005). In this study, the root and shot activity were promoted and uptake concentrations in the homogenous of potassium was explained.

The homogenous treatment had the lowest root K concentration of 12018±286which was about 20-30% lower than the heterogeneous and the control. The shoot potassium concentration in the homogenous treatment was the lowest (1401±117mglkg) which was 10-20% lower than heterogeneous and control. This suggests that the homogenous soil condition is unrealistic for potassium uptake in these plants.

The heterogeneous and control treatments are similar, showing that potassium-rich soil and plants prefer heterogeneous potassium distribution. Root and shoot concentrations were 12-26 times the plant guideline limit of 4.700mg/kg daily [35]. Reduced potassium consumption should be researched for crop quality and yield. Understanding nitrogen intake, plant development, soil management, and fertiliser helps boost crop yields. This study emphasizes potassium's importance for maize growth and sustainable soil management for nutrient uptake.

Farmers may adjust their fertilization strategies to account for uneven potassium distribution by adopting precision agricultural techniques. These methods allow for the targeted application of potassium fertilizers, ensuring that nutrients are delivered more effectively to areas where they are most needed. For instance, banding or localized placement of potassium fertilizers can create a more heterogeneous nutrient distribution in the soil, which can enhance potassium uptake and improve crop growth [36].

Effective potassium management has significant environmental impact. Improving potassium uptake efficiency in crops can decrease the need for frequent fertilization, thereby reducing the energy and resources required for fertilizer production and transportation. This contributes to the overall sustainability of agricultural practices and supports long-term soil health, which is crucial for maintaining productive farmland for future generations.

5. CONCLUSION

It examined how Zea mays absorbed soil potassium heterogeneity. K uptake varied substantially between homogeneous, heterogeneous, and control treatments. Treatment total K uptake factors were comparable. Maize potassium uptake research shows how soil variability improves plant growth and nutrient absorption. Data reveal homogeneous soil reduces crop potassium uptake and root and shoot concentrations. This emphasizes soil nutrient optimization and agricultural productivity studies. Farmer knowledge of soil, nitrogen, and plant growth improves farming and food security.

These findings can be used to enhance K management in maize cultivation by encouraging the use of soil management practices that create heterogeneous K distribution. For example, farmers could adopt precision agriculture techniques to apply K fertilizers more strategically, ensuring that potassium is available where and when the plants need it most. This approach could improve crop yields and reduce the need for excessive fertilizer use, contributing to more sustainable farming practices.

Future research could explore the long-term effects of soil potassium heterogeneity on maize crop yield and overall soil health. Specifically, studies might investigate how prolonged exposure to heterogeneous K distribution influences microbial activity and nutrient cycling in the soil. Additionally, research could focus on the interaction between potassium heterogeneity and other essential nutrients, such as nitrogen and phosphorus, to understand the broader implications for crop performance and sustainability in diverse soil environments. Understanding these dynamics over multiple growing seasons would provide valuable insights into optimizing fertilizer application and improving long-term agricultural productivity.

6. RECOMMENDATIONS

Based on this study, the following are recommended:

Further work on heterogeneous distribution of soil and uptake of other elements by plants especially food crop should be encouraged.

Enlightenment of Potassium fertilization of crops can be useful in agricultural food production.

Further work on study sites that represent a range of soil textures, structures, and fertility levels, as well as different land uses such as agricultural fields, forests, grasslands, and urban areas. This diversity will help capture the full range of soil uptake dynamics.

Collaboration with farmers, land managers, policymakers, and other stakeholders to identify research priorities and ensure the relevance and applicability of study findings.

Understanding of the study of heterogeneous distribution of soil uptake and its implications for soil fertility, nutrient cycling, ecosystem function, and land management practices. This knowledge is essential for promoting sustainable soil management and enhancing agricultural productivity in diverse landscapes.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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