UPLAND RICE YIELD RESPONSE TO SOIL MOISTURE VARIABILITY WITH DEPTH ACROSS FERRALSOLS AND GLEYSOLS IN WESTERN UGANDA

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ABSTRACT

Soil moisture is a vital factor in boosting rice productivity by influencing the growth of healthy plants. In mid-western districts like Kikuube where rainfall is unpredictable, maintaining optimal soil moisture differs between a bountiful harvest and crop failure. Effective soil moisture management leads to improved water use efficiency, allowing crops to withstand periods of drought. This study assessed upland yield response to soil moisture variations with soil depth in Ferralsols and Gleysols for two seasons: (August to December 2023 and March to June 2024). Twenty-four (24) access tubes were installed in six fields, each field having four (4); three (3) fields of Ferralsols and three (3) for Gleysols, from which soil moisture content was measured using the Diviner 2000 at 10 cm intervals to a 1m depth. Calibrated rain gauges were also installed in each field to measure the daily rainfall received. Soil physical properties such as texture, bulk density, infiltration rates, soil water holding capacity, field capacity, and permanent wilting point (PWP) were determined. In Ferralsols, the soil moisture decreased with an increase in depth whereas in Gleysols, the soil moisture increased with an increase in depth. The increase in soil moisture with an increase in depth is attributed to the contribution of capillary rise for Gleysols. Gleysols registered higher yields of 5,840kg ha^{-1} compared to 3,527kg ha^{-1} in the Ferralsols–during the March-June 2024 season which had a high rainfall variability. However, high yields (6,375 kg ha^{-1}) in Ferralsols were registered in the August-December 2023 growing season characterized by less rainfall variability. Both Ferralsols and Gleysols are suitable for upland rice production. Nevertheless, in high variability of rainfall, the continuous supply of water by capillarity in Gleysols meets the crop water requirements unlike in Ferralsols.

INTRODUCTION

Upland rice cultivation is a prevalent agricultural practice in many regions of the world (Gadal et al., 2019), including western Uganda, where it plays a crucial role in food security and income generation for smallholder farmers (Agric, 2023). This crop exhibits a complex yield response to soil moisture variability, particularly when grown in Ferralsols and Gleysols (Niang, 2019). These soil types are characterized by their unique properties and moisture dynamics and play a crucial role in the growth and productivity of upland rice. Ferralsols, typically found in tropical regions with high rainfall, are deeply weathered, leached soils with a high content of iron and aluminum oxides, which can significantly influence the water-holding capacity and, consequently, the moisture availability of rice plants (S. Michael, 2023). On the other hand, Gleysols are often located in low-lying areas and are prone to waterlogging due to poor drainage, affecting root development and nutrient uptake in rice crops (Bado et al., 2018). In western Uganda, the bimodal rainfall pattern contributes to the variability of soil moisture with depth, impacting the yield of upland rice across these soil types. During the rainy seasons, Ferralsols provide adequate moisture for rice growth, but the challenge arises in managing excess water in Gleysols to prevent detrimental effects on the crop (Ojara et al., 2024). Conversely, in the dry seasons, the retention of soil moisture becomes critical, especially in Ferralsols, to sustain the rice during periods of water scarcity. A Study (Singh et al., 2017) has shown that upland rice varieties exhibit different physiological responses to soil moisture stress, with some genotypes demonstrating tolerance by maintaining growth and yield under varying moisture regimes. The ability of rice plants to adapt to moisture stress is linked to traits such as root depth and density, which determine the extent of water uptake from different soil layers (Sandhu et al., 2016). In Ferralsols, deeper root systems can access moisture from lower soil horizons, while in Gleysols, rice varieties with a higher tolerance to waterlogged conditions may fare better.

MATERIALS AND METHODS

Two seasons were considered in this study (August to December 2023 and February to June 2024). Six experimental plots on both Ferralsols (3) and Gleysols (3) were set up in Kikuube District. For each plot, four fertilizer treatments were applied. These included full package fertilizer recommendation (20kg N/ha + 30kg K/ha of DAP at planting, 20kg N/ha (Urea) + 40kg K/ha (MoP) at tillering and 20 kg N/ha (Urea) + 40kg K/ha (MoP) at panicle formation), half package (10kg N/ha + 15kg K/ha of DAP at planting, 10kg N/ha (Urea) + 20kg K/ha (MoP) at tillering and 10 kg N/ha (Urea) + 20kg K/ha (MOP) at panicle formation), quarter package (5kg N/ha + 7.5kg K/ha of DAP at planting, 5kg N/ha (Urea) + 10kg K/ha (MoP) at tillering and 5 kg N/ha (Urea) + 10kg K/ha (MoP) at panicle formation), and the Farmer management practices (Control). In each plot, four access tubes and one fabricated rain gauge were installed for reading soil moisture data by the Diviner 2000 at an interval of 10 cm to 100cm depth and recording on-site daily rainfall respectively. The Diviner 2000 was first calibrated to local soil conditions, likewise, fabricated rain gauges were also calibrated using the standard rain gauge at Makerere University Weather Station (the ratio of the value of the standard rain gauge to the value of the fabricated rain gauge) forming the calibration factor. Soil moisture data was read at least four times a week at an interval of one day. Weed management was done effectively from the time of planting by application of Butanil-S as a pre-emergence herbicide at the time of sowing and Butanil N70 + Butanil 2-4D as post-emergence herbicides. Pest management was also done using Roket type of pesticide only where there were cases of pests. The general rice yield was considered for this study as presented in the results below.

RESULTS AND DISCUSSION

Yield

There is a variation of upland rice production in the two soil types in Kikuube district. In both seasons 2023B, Ferralsols exhibited a higher yield (6,375kg/ha) than Gleysols (5,714kg/ha) whereas, in season 2024A, Gleysols had a higher yield (5,840kg/ha) than Ferralsols (3,527kg/ha). However, the variation in yields in both soil types and seasons is insignificant at $p<0.05$ (Figure 1).

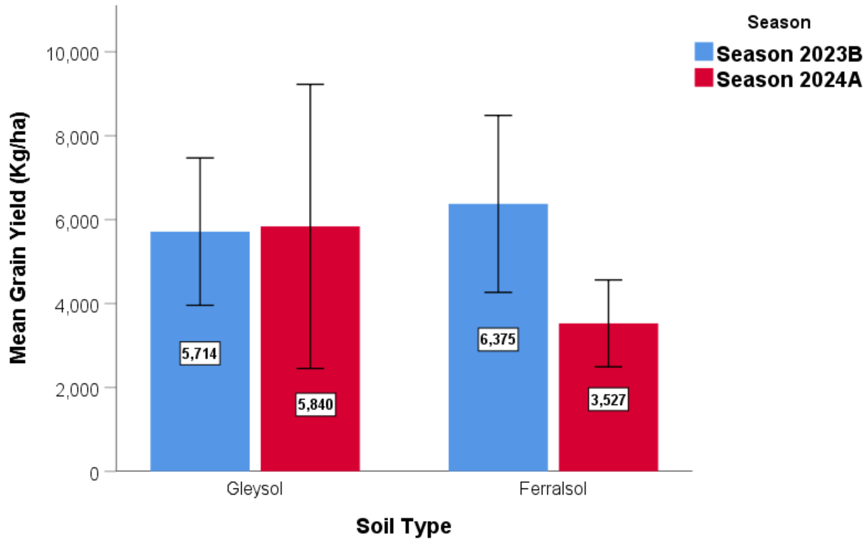


Figure 1. Rice yield for two seasons.

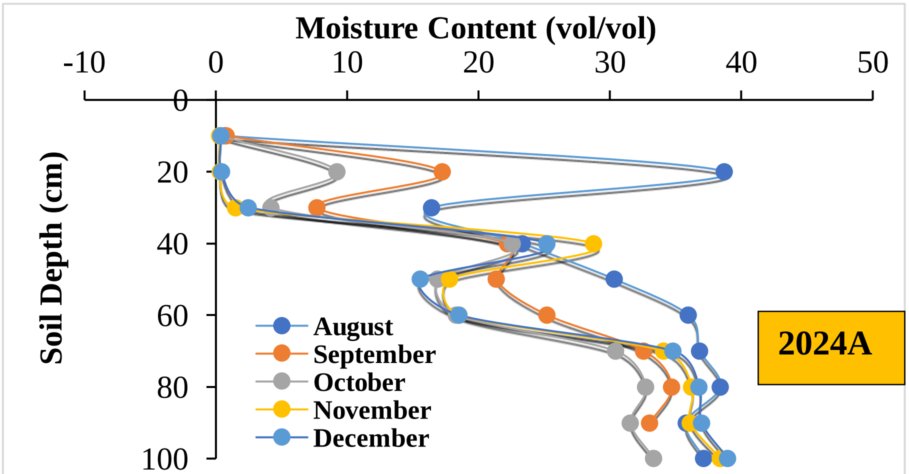
Soil moisture variation

Generally, soil moisture decreased with an increase in depth in Ferralsols whereas in Gleysols, the soil moisture content increased with an increase in soil depth (Figures 2 and 3 respectively).

DISCUSSION

Ferralsols and Gleysols are two distinct soil types that exhibit unique moisture variation profiles due to their inherent properties. The presence of micro-aggregates in Ferralsols enhances moisture storage at field capacity, which is crucial for crops like upland rice that rely on consistent moisture availability for optimal growth. The variation in soil moisture with depth (Increase with depth) Figure 2(A) in Gleysols significantly impacts the root development of upland rice, as the roots are not able to penetrate deeply enough to access the moisture in lower layers during drier periods. The effect of soil moisture on upland rice yield is profound since it is typically grown in rain-fed conditions, highly sensitive to soil moisture variability. Studies have shown that soil moisture stress during critical growth stages, such as panicle development, severely impacts the growth and yield of upland rice. For instance, improved upland rice varieties like NAMCHE 5 have demonstrated excellent performance under limited soil moisture conditions through early heading and maturity, contributing to higher grain yield. This is mainly due to their ability to produce heavier straw yield, an abundant number of productive tillers, higher filled spikelets, and heavier weight of seeds, which collectively enhance the harvest index and adjust to the soil moisture conditions. Furthermore, climate variability has been found to influence soil moisture levels and, consequently, rice production. Rain-fed upland rice systems are more vulnerable to these variations than irrigated paddy rice, with about 10% of the variance in rice production anomalies on a national level co-varying with soil moisture changes.

(A)



(B)

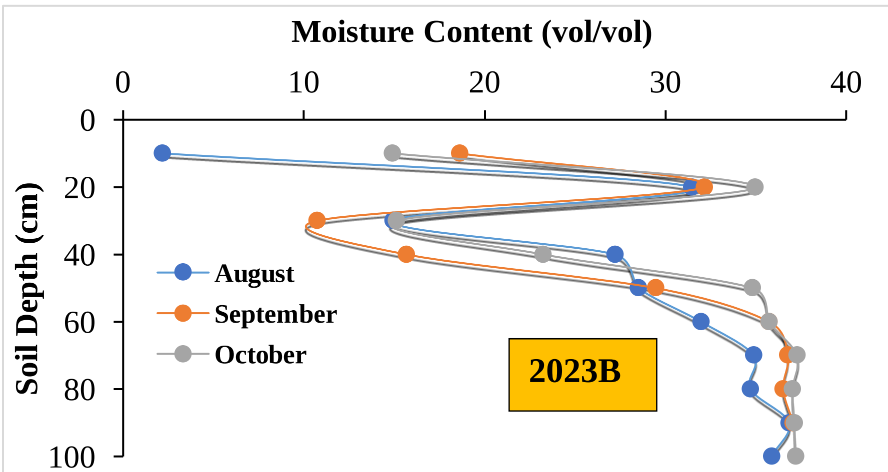


Figure 2. Variation of soil moisture with depth; (A) Gleysols (B) Ferralsols.

CONCLUSION

Understanding the dynamics of soil moisture in Ferralsols and Gleysols is essential for predicting and managing the yield of upland rice, which is a staple food for millions of people worldwide. Effective water management strategies, including the selection of rice varieties with drought tolerance and the timing of planting to coincide with optimal soil moisture conditions, are critical for sustaining rice production in the face of changing climate patterns and soil moisture regimes.

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