EGU24-3544, updated on 27 Feb 2025
https://doi.org/10.5194/egusphere-egu24-3544
EGU General Assembly 2024

Sorghum water use efficiency and yield variations discerned by 13C isotopic technique under managed agricultural practices in Upper Eastern Kenya

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Current knowledge on using ^{13}C discrimination as an indirect measure of yield and water use efficiency (WUE) under different soil moisture conditions and soil fertility inputs in C4 crop species has considerable uncertainty. The objective of this study was to test for (i) the effect of selected soil water conservation measures and soil fertility inputs on sorghum yield, water use efficiency, and ^{13}C discrimination, (ii) evaluate the relationship between various measures of water use efficiency and ^{13}C discrimination, between sorghum yield and ^{13}C discrimination; (iii) sorghum stem diameter and WUE and, the use of stem diameter and ^{13}C discrimination as potential yield and WUE proxy. We implemented a field trial on-station for five seasons in the semi-arid areas of Upper Eastern Kenya. The experiment was designed in a randomized complete block design (RCBD) with three levels of nitrogen fertilization (120 kg ha^{-1}, 60 kg $ha^{-1,}$ and 30 kg ha^{-1}) application with four replications. The selected soil water conservation measures and soil fertility management were minimum tillage, mulching, tied ridging, and Managing Beneficial Interactions in Legume Intercrops (MBILI) along a control (no input). Water use efficiency was determined using carbon discrimination analysis and gravimetric technique. The leaves and post-harvest grain samples were analyzed for %N, %C, and $\delta^{13}C$ on an Isotope Ratio Mass Spectrometer (IRMS). A clear and significant ($p \leq 0.05$) treatment effect was observed on the ^{13}C isotopic discrimination and sorghum yield and growth attributes over the five seasons. The highest (4.85 Mg ha^{-1}) grain yield was observed with minimum tillage with crop residue treatment. The $\delta^{13}C$ values ranged from -13.14to -11.86‰for the sorghum grain. Treatments under minimum tillage with residue and tied ridges and the MBILI intercrop had significantly ($p \leq 0.05$) higher sorghum grain yield, WUE, stem diameter, chlorophyll content, and high $\delta^{13}C$ values. The ^{13}C discrimination was significantly ($p \leq 0.05$) associated with yield, WUE, stem diameter, and leaf chlorophyll. In the treatment with high N rate, the equation relating ^{13}C discrimination to yield was Yield (Mg ha^{-1}) = $1.4822\delta^{13}C + 20.879$; $R^2 = 0.3518$. A significant positive relationship ($R^2 = 0.31$) was observed between grain N fertilizer use efficiency and grain $\delta^{13}C$ in sorghum harvested from plots with high N rate treatments. There was also a correlation ($R^2 = 0.341$; $p=0.001$) between WUE and sorghum stem diameter. Based on these results, we conclude that grain ^{13}C discrimination values at maturity and stem diameter are a potential complementary criterion for assessing sorghum yield performance and WUE under

different soil moisture and nutrient availability conditions. Therefore, it can be deduced that minimum tillage with crop residue with a high fertilizer application rate (120N/ha) improves sorghum grain yield, WUE, and higher grain $\delta^{13}C$ values. The high grain $\delta^{13}C$ values observed with minimum tillage with crop residue over the five seasons indicate that plants suffered less water stress under minimum tillage with crop residue treatment. Therefore, grain $\delta^{13}C$ discrimination and stem diameter can be used as water use efficiency proxy with C4 crops like sorghum.