Maize trial site in Zimbabwe illustrating the effects of moisture stress and low soil fertility on crop growth.

Managing Nutrients for Climatic Resilience in African Smallholder Maize Production

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Soil nutrient management proves critical to increase maize yield under both current and projected climatic conditions. The yield benefits from nutrient management are further enhanced given an early maize planting date.

KEYWORDS:
climate change; APSIM; planting date; simulation modelling; *Zea mays*

ABBREVIATIONS AND NOTES:
N = nitrogen; P = phosphorus; K = potassium.

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A combination of climate change and declining soil fertility are major causes of low crop productivity in sub-Saharan Africa (SSA) (Mapfumo et al., 2013). Productivity of maize, the main cereal crop in the region, is predicted to decline by 30 to 60% by the end of 21st century due to rising temperatures and changing rainfall patterns (Rurinda et al., 2015; Traoré et al., 2017). Yet the demand for food is anticipated to rise as the population in Africa increases. There is a great concern that food deficits will worsen in SSA; thus, there is a growing need for crop and nutrient management technologies that are adapted for the region.

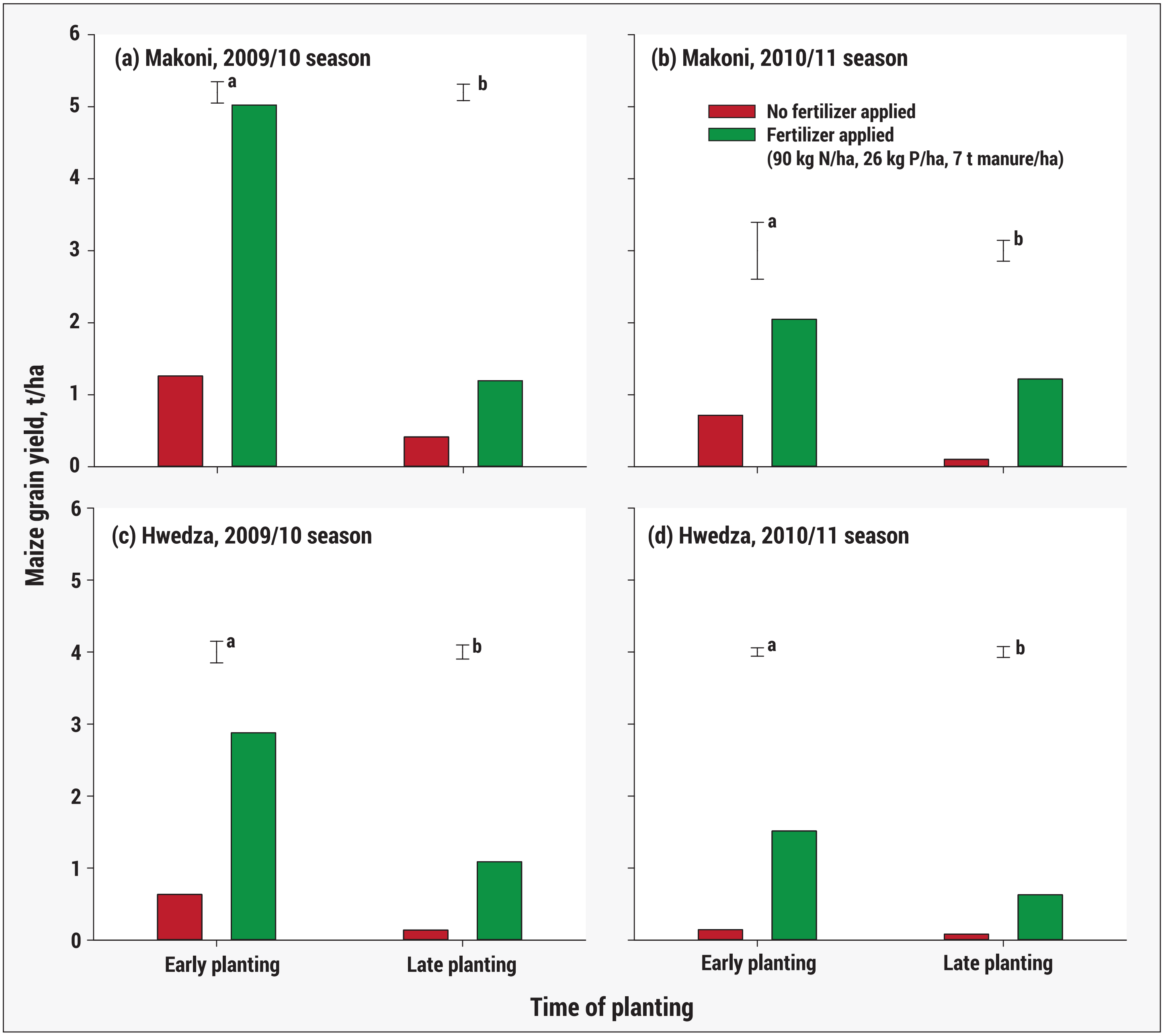

Figure 1. Maize grain yield in response to fertilizer use and planting date for two cropping seasons in Makoni and Hwedza districts, Zimbabwe. Error bars represent the standard error of the difference (SED) for a = time of planting, b = nutrient management.

A study in Zimbabwe made use of both on-farm trials and simulation modelling to quantify the yield response of maize to current and projected climatic conditions. Field experiments were conducted in eastern Zimbabwe within both sub-humid (Makoni District) and semi-arid (Hwedza) climatic zones. The study evaluated the effect of management practices such as cultivar choice, planting date, and fertilizer use. The long-term impact of these management options was assessed through crop simulation modelling using the Agricultural Production Systems Simulator (APSIM) (Keating et al., 2003). Three maize cultivars were sown in each of the early and late planting windows defined by stakeholders. Each of the three cultivar-planting date combinations received N, P, K, and manure combinations at either zero (no fertilizer applied), low (35 kg N/ha, 14 kg P/ha, 3 t manure/ha), or moderate (90 kg N/ha, 26 kg P/ha, 7 t manure/ha) fertilization rates. Three climate periods were selected to cover both near and long-term climatic conditions (i.e., 2010 to 2039; 2040 to 2069; 2070 to 2099) against a baseline period of 1976 to 2005. Future climate data for a Representative Concentration Pathway (RCP) was generated from an ensemble of five global circulation models. RCP 8.5 is a high concentration pathway with the highest greenhouse gas emissions for which radiative forcing reaches >8.5 watts/m^2 by the year 2100. RCP 8.5 combines assumptions about high population and relatively slow income growth with modest rates of technological change and energy intensity improvements, leading in the long-term to

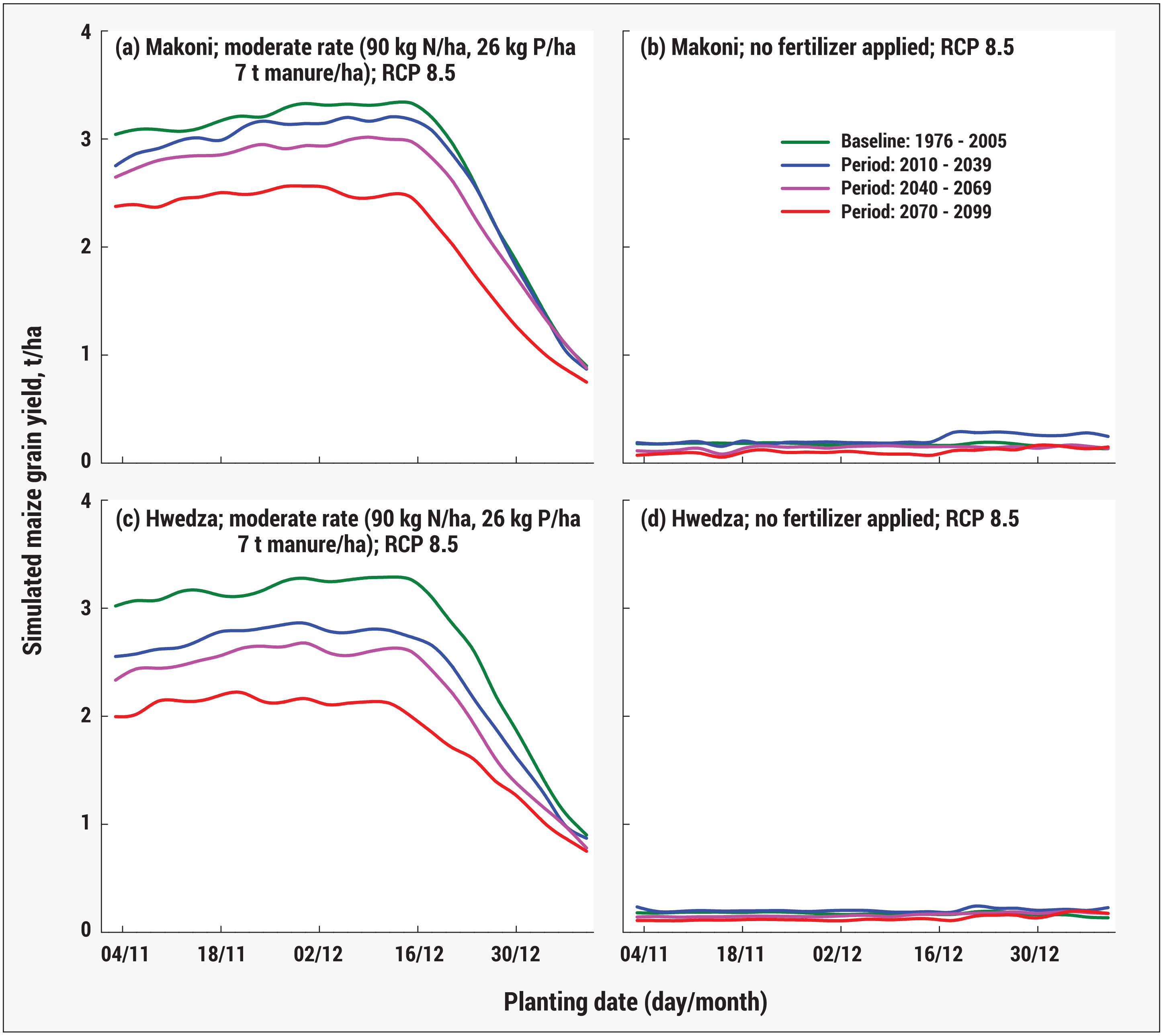

Figure 2. Simulated average seasonal maize yield distribution with planting date (cultivar SC401) under two fertilization rates. RCP 8.5 = Representative Concentration Pathway (8.5 watts/m^2).

high energy demand and greenhouse gas emissions in absence of climate change policies.

Nutrients, Climate Resilience, and Sustainable Cropping

Fertilizer and manure application increased maize grain yields threefold compared with the control (no nutrient application) under the current sub-humid (**Figure 1a** and **1b**) and semi-arid (**Figure 1c** and **1d**) climatic conditions. Likewise, results from the simulation modelling showed significant increases in grain yields with nutrient application under both current and projected climates (**Figure 2**). The similar results obtained between the on-farm experiments and the simulation modelling reinforces the continued importance of nutrient management for improved crop productivity in SSA, even under a changing climate.

Supporting Research Examples

In Sudano-Sahelian zone of West Africa, Traoré et al. (2014) reported that use of fertilizers at recommended rates could buffer losses in maize yield by up to 50% of the baseline yield under a changing climate. The study also concluded that fertilizer use on millet could offset the predicted yield losses and contribute to yield increases in the face of climate change and variability. In another large-scale study in SSA, Folberth et al. (2013) highlighted that increasing nutrient supply to rates commonly applied in high-input systems would allow for a tripling of maize yields from the current 1.4 t/ha to 4.5 t/ha.

Yield benefits from nutrient management further increased when maize was planted early (**Figure 1** and **2**).

Regardless of the amount of fertilizer applied, yield declined drastically when the planting of maize was delayed past mid-December, four weeks after the start of the rainy season. Across SSA, numerous studies have demonstrated that early planting is important for achieving optimal yields (Shumba et al., 1992). For this study, the differences in yield between cultivars were negligible under current and projected climates (data not shown). The range in time to maturity of the cultivars available on the market was too small to respond differently to the rainfall trends experienced.

Conclusion

Fertilizer and manure use increased maize yield under both current and projected changes in climatic conditions. The yield benefits of nutrient management were further increased when maize was planted within three weeks of the start of the rainy season. The results highlight the critical contribution of soil nutrient management and planting time to improved maize productivity and resilience to climate change in Zimbabwe and in similar maize-growing environments in SSA. **BC**

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