#7785 COMPARATIVE FERTILIZATION EFFECTS ON MAIZE PRODUCTIVITY UNDER CONSERVATION AND CONVENTIONAL TILLAGE ON SANDY SOILS IN A SMALLHOLDER CROPPING SYSTEM IN ZIMBABWE

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ABSTRACT

Low crop yields, food insecurity and abject rural poverty continue to be rampant in much of Southern Africa. Components of conservation agriculture (CA) are being widely promoted in southern Africa as one of the strategies to increase food security and mitigate rural poverty, despite there being scarce empirical evidence on their efficacy on degraded soils. This research aimed to assess the effects of tillage systems on maize grain yields under rain-fed conditions across a soil organic matter gradient using on-farm trials set-up in Eastern Zimbabwe. The effects of three tillage systems were compared, that is a) conventional tillage (CT), b) basins-based CA (B-CA), and c) furrow-based CA (F-CA) on sandy soils with soil organic carbon (SOC) ranging from 0.18-0.89% and clay content from 60 -150 g kg^{-1}. Fields were tagged using a Geography Positioning System (GPS) and mapped to improve nutrient targeting across seasons. An on-farm study was established with thirty farms, each with two fields previously selected as either rich or poor by host farmers as a nutrient omission trial using nitrogen (N), phosphorus (P), potassium (K), cattle manure (M) and their combinations. Host farmers' local soil fertility rating of poor and rich fields was validated by lab-based results which showed that poor fields had SOC <0.4%, were more acidic, had lower amounts of exchangeable bases (Mg, Ca, K), available P and total N. Whilst no significant tillage effects were observed in the first year, nutrient management significantly increased maize yields across the three years ($P<0.001$). Maize grain yields increased from 0.3 Mg ha^{-1} for unfertilized control to 4.1 Mg ha^{-1} for the NPKSM treatment. Maize grain yields were significantly higher under B-CA compared to both F-CA and CT in the second year ($P <0.01$), responding to improved targeting of fertilizers using basins. Maize grain yields were consistently larger for SOC rich fields. Response to N increased with increase in soil fertility, suggesting higher N use efficiency for soils with higher SOC. An amalgamated approach to nutrient management using both organic and inorganic nutrient sources is vital to ensure maize productivity on poor soils in agro-ecologies receiving unreliable rainfall.

Keywords: conservation agriculture, soil organic carbon (SOC), nutrient targeting, tillage practice

INTRODUCTION

Hunger and poverty that continues to ravish sub-Saharan Africa (SSA) is mainly a result of poor maize grain yields by farmers averaging less than 1 Mg ha^{-1}. Agricultural crop production is primarily rain-fed, characterised by mid-season droughts and flash floods. There is need to rethink strategies to improve productivity (Tittonell & Giller, 2013), as approaches to curb food insecurity in the region have largely failed to capture the individual needs of farmers and therefore gains continue to be abortive. Blanket fertiliser recommendations on heterogenous soils are often promoted without consideration of farm specific needs. Farmers constantly use little to no fertiliser use, with resource constrained farmers failing to invest in organic fertilisers (Mtambanengwe & Mapfumo, 2005). Strategies to preserve moisture and maximise the little additional fertilisers continue to be relevant in soils with low soil organic carbon (SOC), areas experiencing rainfall variability and farmers who are resource constrained. Solutions that are often presented to work in the present environment have often worked elsewhere but with little empirical evidence on how they will perform in the local context. Governmental effort in Zimbabwe is concentrated on promoting CA but there is lack of knowledge on how the technology will perform in varied farming systems with little fertiliser use and dominated by maize monocropping. There is increased need to generate data on how the technology will perform in comparison to balanced CT systems. The study therefore aimed to: i) assess the influence of inherent soil fertility on the performance of CA and CT technologies under similar production environments in the smallholder farming systems, and ii) determine the interaction of soil fertility and tillage system on maize yield response to application of macronutrients. In this context, CA is used but is deficient in meeting all the necessary CA pillars. In its strictest sense they are tillage systems compared as a result.

MATERIALS AND METHODS

The study was established in Zimbabwe, Murewa district (17°49′S, 31°34′E; 1400 masl) spanning over three seasons till 2016. Murewa recorded daily cumulative rainfall of 1087 mm and a minimum cumulative daily rainfall of 587mm with varied distribution from November to March across the seasons. Characteristic sandy-lixisols with poor SOC content are dominant. Murewa has a strong crop-livestock interaction where livestock graze on crop residues and manure is used to fertilise fields. For this study, to help understand how CA best fits in the local farmer context, crop residues were retained in the field after each harvest and were partially grazed by livestock.

Farmers were tasked to identify the most fertile (rich) field and the least (poor) field in an exploratory survey involving 70 farms. Farmer's soil fertility rating was amongst other factors a function of preceding nutrient management and response to fertilizer amendments, historical crop productivity and indicator weed species. Composite soil samples consisting of five subsamples were collected along the field's diagonal line from the plough layer (0–20 cm depth) and bulked. The soil samples were air dried and prepared, pH and soil texture determined (Gee & Bauder, 1986) and tested for SOC (Okalebo, et al., 2002), total N determined, as well as available P (Anderson & Ingram, 1993) and extractable bases. Soils had clay content that ranged between 60 – 150 g kg^{-1} and SOC ranged between 0.18 – 0.89% C. Fields were later were grouped into three soil fertility classes (Field Types 1–3) as defined by Kurwakumire et al. (2014). The majority (48%) had SOC of less than 0.4% C – type 1. Experiments were set on these rich and poor fields as split-plot designs with tillage as the main plot (B-CA, F-CA and CT), 6 nutrient omission treatments as sub-plots in 6 x 5m plots and farmers used as replicates. Nutrient omission treatments were as follows: i) Control (no nutrients added), ii) PKS (single super phosphate, (18 P_2O_5 + 9% S) + muriate of potash (60% K). iii) NK (ammonium nitrate (34.5% N) + muriate of potash. iv) NPS (ammonium nitrate + single super phosphate). v) NPKS (ammonium nitrate + muriate of potash + single super phosphate). vi) NPKSM (ammonium nitrate + muriate of potash + single super phosphate, +cattle manure −M). Fertilizer treatments were designed to reflect amendments that are normally accessible and used by farmers which are usually constrained in availability as sole S fertilizers. Nitrogen was applied as a rainfall response strategy (targeting 0-140 kg N ha^{-1}), at 110 kg N ha^{-1} in years 1 and 2, and 90 kg N ha^{-1} in year 3. Other fertilizer rates were at 30 kg P ha^{-1}, 30 kg K ha^{-1}, and 5 Mg ha^{-1} manure. Manure used in the study contained an average of 1.1% N, 0.15% P, 0.18% Ca, 0.09% Mg, 0.7% K, 20 mg kg^{-1} Cu, 285 mg kg^{-1} Mn, 810 mg kg^{-1} Fe and 115 mg kg^{-1} Zn, which translate to annual nutrient investments of 55 kg N, 7.5 kg

P, 35 kg K, 4.5 kg Mg, 9 kg Ca, 0.1 kg Cu, 1.425 kg Mn, 4.05 kg Fe and 0.575 kg Zn ha^{-1}. Rain gauges were used to monitor rainfall in all study sites, and planting was done to achieve a plant population of 44400. Harvesting of maize plants was done at physiological maturity from central net plots of 3.6 m^2 (2 rows × 2 m long). Yields were computed and reported at 12.5% moisture content, in line with moisture level at which maize grain is reported and marketed in the region. Nutrient limitations/responses were determined by calculating the difference in the attainable yield and the nutrient-limited yield.

All the data violated the ANOVA assumptions, hence were transformed before ANOVA analysis. Soils were grouped into three classes based on SOC content according to Kurwakumire et al. (2014). Data was clustered into three field Types based on SOC content. Data was subjected to ANOVA analysis using a generalized linear model to test tillage effects (main plot factor), fertilization (sub-plot factor), and their interactions on grain yields across the three years. [Field Type 1, SOC < 0.4; Type 2, 0.4% < SOC < 0.6%; and Type 3, SOC > 0.6%]. Separation of means was done using the Fischer's protected least significance test (LSD) at 5% significance level. All statistical analyses were done using GENSTAT version 14 statistical package.

RESULTS

The season (year), field type and fertilization showed significant maize yield effects ($P<0.005$). Maize productivity constantly increased as we moved from type 1 (SOC< 0.4%) to type 3 (SOC > 0.6%) fields across all seasons and treatments. Full NPKS + manure treatment showed consistently larger grain yields across all field types, whilst the control (0.27–0.38 Mg ha^{-1}) and PKS (0.36–0.48 Mg ha^{-1}) treatments were consistently lower for all field types.

Whilst no tillage effects were observed in the first year, significant tillage effects were only observed from the second season ($P = 0.005$). The B-CA outperformed both F-CA and CT (by up to 1 Mg ha^{-1}), even in poor soils (with SOC < 0.4%), which could be as a result of increased soil water availability and precise fertilizer application. Grain yield differences (deviation from the NPKS treatments) showed largest negative differences under B-CA and the largest positive differences (0.8 Mg ha^{-1}) for NPKSM treatment under B-CA as well, suggesting additional benefits of using manure. Nutrient omission experiments showed a constant grain yield penalty following N omission across all sites. Nutrient N and P response was highest in soils with > 0.6% SOC at 37 kg grain kg^{-1} N and 63 kg grain kg^{-1} P applied.

DISCUSSION

In year 2, B-CA showed significantly higher yields than both F-CA and CT. Improved nutrient targeting, cumulative fertilizer effects and increased efficiency of rainwater are highlighted as the major reasons surrounding successes in CA systems, especially in seasons with limited seasonal rainfall. Thierfelder and Wall (2012)' s studies have proved the benefits of CA over CT after at least one cropping season, while Kihara et al. (2011), sited gains after 3 cropping seasons. Concerns have been raised over the increased costs on labor with CA, but Twomlow et al. (2008a, 2008b) established that CA gave returns that are twice those of CT. Whilst residue retention helps improve soil quality (Govaerts, et al., 2009), and retain P in soils, it is proving to be extremely difficult to retain all crop residues as livestock are left to graze openly (Zingore, et al., 2011). Using both organic and inorganic fertlizers resulted in increased crop productivity which was synonymous with results from Mtambanengwe et al., (2006) and Kurwakumire et al., (2014). Mtambanengwe and Mapfumo, (2005); Zingore et al., (2008) attributed these increases partly to pH amelioration, increased water infiltration, reduced runoff and increased SOC and improved micronutrient uptake. Strategic fertilizer targeting was identified as one of the strategies for viable fertilizer use (Giller, et al., 2006).

Inherent soil fertility affects maize response to applied fertilizers (Vanlauwe et al., 2006) and integrating N_2- fixing is suggested as the most viable option in many cases (Chikowo et al., 2004; Rusinamhodzi et al., 2012). Farmers' ability to rate fields as poor and rich could be exploited to allow them to focus limited nutrient amendments on fields that give better returns to nutrient amendment. These results were in line with results by Zingore et al. (2007) where home fields that had higher SOC content, available P and exchangeable bases, had higher yields than the outfields with poor SOC content. Rehabilitating depleted soils therefore proves to be necessary to get meaningful returns to input investments.

CONCLUSIONS

The study investigated the effect of tillage practices on productivity as affected by nutrient management on predominantly poor fertility soils. The positive effect of B-CA was observed from the second year, and was probably a function of both season type and accumulation of nutrients. Basins-based CA concentrates nutrients as nutrient application is physically localized near plant roots hence superior yields observed. The highest yields were achieved with the application of NPKSM irrespective of tillage system. As expected on soils with such low SOC, N was the most limiting nutrient for maize crop productivity. Prioritization is therefore essential due to poor residual effects of N fertilizer, particularly on sandy soils. Co-application of N and P was the ideal fertilizer investment strategy in Year 1. This fertilization strategy is beneficial irrespective of tillage system, when acutely poor soils that are non-responsive to fertilizers are avoided. This highlights the challenges to sustainable crop production intensification faced by smallholder farmers in SSA. Maize grain yields were consistently larger for SOC rich fields. Response to N increased with increase in soil fertility, suggesting higher N use efficiency for soils with higher SOC. Combining both organic and inorganic nutrient sources therefore proves to be a viable approach to nutrient management to ensure maize productivity on poor soils, which were the most widespread soils in agro-ecologies receiving unreliable rainfall.

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