OPTIMIZING MAIZE PRODUCTION THROUGH MINIMUM TILLAGE IN CONSERVATION AGRICULTURE (CA) SYSTEMS: EVIDENCE FROM MALAWI'S LOWLANDS

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ABSTRACT

Sustainable intensification in agricultural systems has been implemented and promoted across Sub-Saharan Africa (SSA) as a strategy for addressing low crop productivity often resulting in widespread food and nutritional insecurity. This study sought to assess the productivity potential of conservation agriculture (CA) cropping systems and associated crop establishment techniques. An on-station study was conducted at Chitala research station in Malawi. Maize grain productivity varied with crop establishment technique and cropping systems. Planting basins showed better performance during seasons with low to moderate wetness, and intervening less rainy months as observed in 2014/15 and 2015/16 cropping seasons. Conversely, direct seeding techniques with less soil surface disruption (dibble stick and Jab planter) performed better during seasons of high and persistent rainfall (2016/17 and 2017/18), with totals exceeding 800 mm. Rotation systems, particularly maize groundnut, outperformed other systems in maize grain yield, while intercropping systems incurred higher grain yield penalties among the tested systems. These results confirm previous findings on CA, indicating that rotating maize with legumes boosts maize grain yield, while maize-legume intercropping may reduce it.

INTRODUCTION

In SSA rainfall anomalies often lead to water stress, low crop yields accompanied by large yield gaps (Ligowe et al., 2017; Nyagumbo et al., 2020). This has resulted in widespread poverty, food insecurity and malnutrition (Makate et al., 2018). In effort to reduce the negative impacts of these challenges, conservation agriculture (CA) has gained significant attention across smallholder farmers, it has been promoted as a potential sustainable agricultural intensification technology in response to food insecurity and the adverse effects of climate (Omulo et al., 2024). Its principles hinge on reducing soil disturbance, crop diversification, and permanent soil cover (Mupangwa et al., 2021).

Minimum tillage as part of CA has been implemented across the region using varied crop establishment technologies such as manually prepared planting basins, jab planter and dibble sticks (Ngoma et al., 2015; Kidane et al., 2019). CA planting basins have been found useful in coping with rainfall variability and moisture deficits (Ngwira et al., 2013) as they improve conservation of soil moisture in the root zone thereby mitigating in-season dry spells (Ngwira et al., 2014). Alternative manual CA techniques, direct seeding using dibble stick or jab planter has also proved to be more profitable, less risky and also deliver labor reductions ranging between 45 to 55%

relative to the traditional farmer practice (Mupangwa et al., 2019). Crop diversification through legume inclusion into cereal based cropping systems has also been promoted as a solution to counter yield losses, enhance stability, and ensure nutritional security in a sustainable manner (Madembo et al., 2020).

The objective of this study was to evaluate the performance of maize cultivated as sole crop or integrated with grain legumes either as intercropping or rotation and to determine the maize grain yield performance of minimum tillage crop establishment techniques.

MATERIALS AND METHODS

The study was conducted, at Chitala research station in Malawi. The trial was laid out in a Randomized Complete Block Design with three replications of the 12 cropping systems. Cropping systems tested included conventional practice, CA sole maize, CA maize-legume intercrops and CA maize- legume rotations. Crop establishment techniques involved (1) the conventional semi-permanent hand hoed ridge and furrow system, (2) jab planter, (3) tapered wooden dibble sticks and (4) hand hoe prepared CA planting basins.

Using R (version 4.3.1), linear mixed models were fitted to test for significant differences in maize grain yield across treatments, seasons, cropping systems and to quantify the sources of residual variance in the data.

RESULTS AND DISCUSSION

Response of maize grain yield and total biomass to crop establishment techniques in different seasons

Crop establishment techniques significantly influenced maize grain and biomass yields across different seasons (Figure 1). During the 2014/15 and 2015/16 seasons, characterized by medium and low rainfall, planting basins and ridge-furrow systems yielded higher (4073 and 3907 kg ha^{-1} maize grain, respectively) compared to jab planter and dibble stick systems (3476 and 3213 kg ha^{-1}). Conversely, in the wetter 2016/17 and 2017/18 seasons, basin and ridge-furrow yields decreased (2807 and 2836 kg ha-1), while dibble stick and jab planter yields improved (3915 and 3256 kg ha-1). Biomass production showed a similar trend across these seasons. The CA basin system performance could potentially be attributed to its higher water harvesting capacity that promotes deeper water infiltration, better soil profile recharge and enhanced water retention capacity compared to dibble stick and jab planter (Nyagumbo et al., 2016). These results support the notion that CA basin systems can be an alternative and most preferred to drought prone regions of SSA (Mupangwa et al., 2017). These findings also agree well with regional findings in on-farm studies from southern Africa that put forward that CA basins can have negative impact on yields whenever incessant rainfall events leading to water logging, occurred (Mupangwa et al., 2012; Nyagumbo et al., 2020).

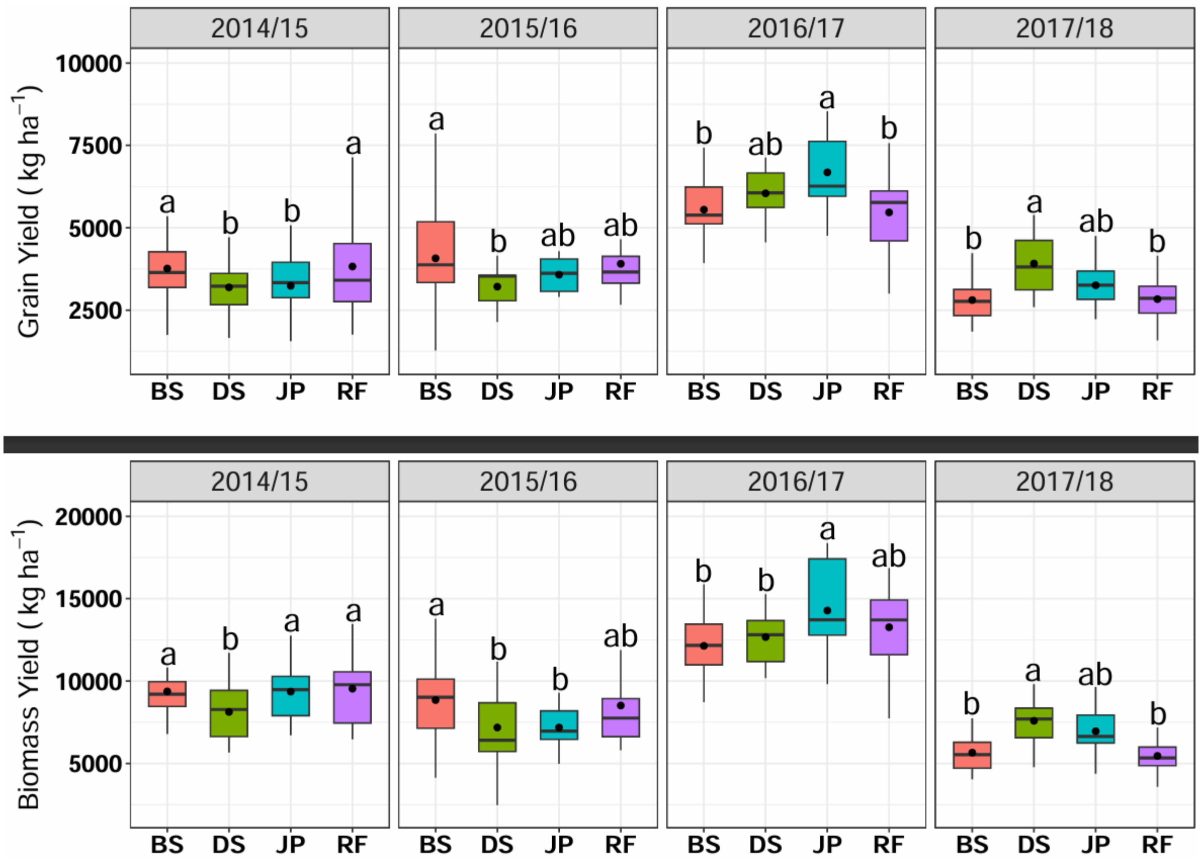

Figure 11. Interaction effects of season and crop establishment techniques on maize grain yield and total biomass during experimentation in Malawi Chitala (2014-2017). Circles inside boxes represent means, horizontal bar in the middle of each box represents the median, while lower and upper box plot boundaries represent the 25th and 75th percentiles respectively. Lower and upper whiskers represent the minimum and maximum values respectively. For each rainfall regime different letters above boxes indicate significant differences at 5% significance level between respective crop establishment techniques. Crop establishment techniques: BS = basin system, DS= dibble stick, JP= jab planter and RF= Ridge-furrow.

Maize grain yield under different cropping systems

Significant differences in maize grain yields were observed among cropping systems over four seasons (Figure 2, A-D). Maize-legume rotations consistently yielded the highest, while maize-legume intercropping systems had the lowest yields. Maize-groundnut rotation outperformed maize-cowpea intercropping by 1173, 878, 2700, and 987 kg ha^{-1} across the seasons. Within intercropping systems, maize-pigeon pea consistently yielded 9%, 4%, 45%, and 7% more than maize-cowpea. Similarly, maize-cowpea rotation surpassed maize-cowpea intercropping, with yield increases ranging from 725 to 2700 kg ha-1 across seasons. Maize grain yield advantage of the rotation system can be attributed to the high legume densities in rotation systems (i.e. the legume phase of the rotation) which may result in biological nitrogen fixation (BNF) that can supplement the applied mineral nitrogen thereby leading to high yield performance of rotation systems (Mutsamba et al., 2020; Mupangwa et al., 2021). Also, high plant density in intercropping systems combining maize and the associated legumes is usually 1.5–2 times the density of plants in sole crops, thus, resulting in inter and intraspecific competition for essential growth resources such as nutrients, water and light between maize and the companion legume and this can lead to suppression of component crop yields compared to rotations and sole systems (Madembo et al., 2020; Njira et al., 2021). In intercropping systems, maize-pigeon pea significantly outperformed maize-cowpea. Pigeon pea develops much slower initially, and its greatest demand for water and nutrients occurs after maize has been harvested and as such, there will be little competition with the primary maize crop (Kimaro et al., 2009; Madembo et al., 2020).

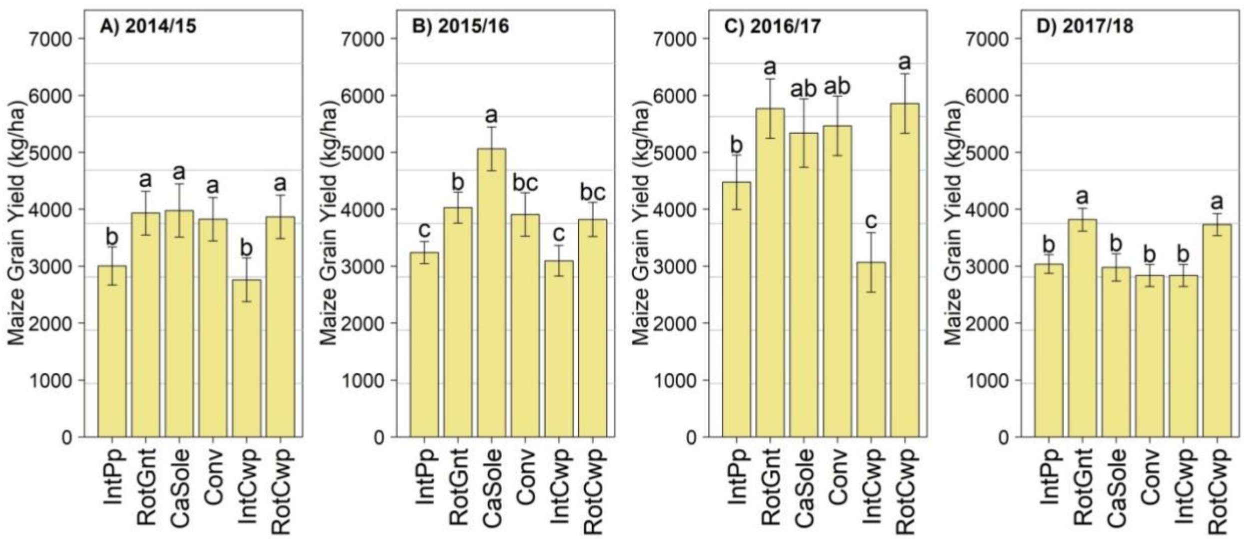

Figure 12. Mean maize grain yield of the tested cropping systems over four consecutive growing seasons (2014-15 to 2017-18) in Chitala, Malawi. For each season, different letters above bars indicate significant differences between respective cropping systems at $P < 0.05$. Cropping systems RotCwp = Maize-cowpea rotation, IntCwp = Maize-cowpea intercrop, RotGnt = Maize-groundnut rotation, IntPp = Maize-pigeon pea intercrop, MzSole = Maize sole and Conv = Conventional.

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