Soil & Tillage Research 170 (2017) 157–166

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

Minimum tillage, tied ridging and mulching for better maize yield and yield stability in the Central Highlands of Kenya

M.N. Kiboi[a,c,*], K.F. Ngetich[a], J. Diels[b], M. Mucheru-Muna[c], J. Mugwe[c], D.N. Mugendi[a]

[a] University of Embu, P. O. Box 6, 60100, Embu, Kenya
[b] KU Leuven, Celestijnenlaan 200E, B-3001 Leuven, Belgium
[c] Kenyatta University, P. O. Box 43844-00100, Nairobi, Kenya

ARTICLE INFO

Keywords:
Conservation-effective management techniques
Conservation agriculture
Smallholder farmers

ABSTRACT

Most smallholder farmers in Sub-Saharan Africa and in Kenya have been experiencing a decrease in crop yields in the recent decades. Droughts and prolonged dry spells are common and water is becoming the main limiting factor during crop growing seasons threatening smallholder farmers' livelihood. Hence, availability and adoption of conservation-effective management practices (CEM) that foster soil conservation, water retention, improved crop yield and yield stability under the small-holder rainfed farming system is desirable. Based on this, we evaluated effects of selected CEM techniques on maize (*Zea mays* L.) yields, yield stability and farmers' willingness to take up the techniques. We hypothesized that, the CEM techniques will not only increase maize yield but also the yield stability. The selected CEM were minimum tillage (MT), mulching (MC) and tied ridging (TR) tested alongside a control (conventional tillage) (CT) in two sites, a semi-arid (with predominant soil type being Cambisols with cambic B horizons) and sub-humid agro-ecologies (with predominant soil type being Humic Nitisols), in the Central Highlands of Kenya. We implemented field trials on-farm for four seasons: short rains 2011 (SR11), long rains 2012 (LR12), short rains 2012 (SR12) and long rains 2013 (LR13). The test crop was Maize (*Zea Mays L.*). A key informant's interview with the farmers who implemented the field trial was conducted to assess their willingness to take up CEM techniques. Rainfall distribution and amount varied widely between the two sites. Maize grain yields were significantly higher in TR and MC treatments during the LR12, SR12 and LR13 seasons in the semi-arid site compared to CT. Tied ridging doubled grain yields during SR12 season in the semi-arid site. In the sub-humid site, grain yields significantly increased under all the tested CEM techniques during SR11, LR12 and SR12 seasons. Maize grain yields were more stable under TR and MC with residual variances of 0.107 and 0.183 $Mg\ ha^{-2}$, respectively in the semi-arid site. Mulching, MT and TR techniques indicated yield stability with residual variances of 0.017, 0.039 and 0.155 $Mg\ ha^{-2}$, respectively, in the sub-humid site. We concluded that, under semi-arid conditions, tied ridging is a better CEM technique that not only positively affect maize yields but it also enhances yield stability. Under sub-humid agro-ecological conditions, mulching technique performed comparatively well in terms of increasing maize grain yields and yield stability. The n were further affirmed by the farmers' willingness to continue practicing TR and MC practice in Mbeere South and Meru South, respectively.

1. Introduction

In Sub-Saharan Africa (SSA), rain-fed agriculture is the dominant source of food production practice by most smallholder farmers (Rockström, 2000; Cooper et al., 2008). Droughts and dry spells are common in the tropics and water is becoming the main limiting factor during crop growing seasons threatening smallholder farmers' food security (Wadzanayi and Stroosnijder, 2015; Mafongoya et al., 2016). The reliance on erratic rainfall and exposure to climate risk illustrate the livelihoods of smallholder farmers in the SSA region (Patt et al., 2010). These constraints exacerbate efforts to sustainably increase agricultural production, reduce poverty and enhance food security (Hansen et al., 2011). Additionally, farmers practice rigorous soil preparation by hoe or plough together with removal or burning of crop residues which exposes the land to climatic hazards such as torrential rain and wind leading to land degradation and low crop yield (Benites et al., 1998). Hence, adoption of conservation-effective management practices (CEM) that foster soil conservation, water retention, improved crop yield and yield stability under the small-holder rainfed farming system is desirable.

* Corresponding author at: University of Embu, P. O. Box 6, 60100 Embu, Kenya.
E-mail address: milka.kiboi@gmail.com (M.N. Kiboi).

http://dx.doi.org/10.1016/j.still.2017.04.001
Received 11 November 2016; Received in revised form 10 March 2017; Accepted 1 April 2017
0167-1987/

Maize yields from smallholder farms in semi-arid and sub-humid areas of Kenya are usually below 1.0 Mg ha^{-1} against a potential of 6 to 8 Mg ha^{-1}. These areas experience frequent crop failures as a result of drought (Rockström et al., 2009). The impact of drought stress on crop productivity is severe since farmers have limited management alternatives (FAO, 2002) for soil water content. In the study region, there has been a decline in maize crop yield in the recent past (Mucheru-Muna et al., 2007, 2014; Mugwe et al., 2009). This is attributed to erratic rainfall, poor agricultural water management practices and degraded soil quality (Ngetich et al., 2014a,b; Okeyo et al., 2014; Kisaka et al., 2015). Practices that increase maize yields are therefore required.

Mbeere South and Meru South sub-counties in Kenya are experiencing low and erratic rainfall as well as high evapotranspiration rates (Jaetzold et al., 2007). The majority of the smallholder farmers in these areas depend on rain-fed agricultural production systems (Mugwe et al., 2009). Implementing a conservation-effective management system that can have a direct bearing on crop production and soil quality (Kuotsu et al., 2014) are key adaptation practices that can mitigate growing water shortages, deteriorating soil conditions (Kurukulasuriya and Rosenthal, 2003) and crop production risks (Bennie and Hensley, 2001). Mulching, tied ridging, and minimum tillage are examples of CEM techniques that have the potential to enhance soil water storage and availability for crop use. Besides soil water content conservation, mulching using crop residues, increases soil organic matter concentration and recycle plant nutrients upon decomposition. This, in turn, affects crop growth and yield directly by supplying crop nutrients and indirectly by improving soil physical properties (e.g., stability of aggregates and porosity) which enhance soil quality and stimulate plant growth (Celik et al., 2004). Tied ridging can reduce runoff, increase profile water content and hence root growth and development. Increased soil water content enhances crop response to rainfall, fertilizer, and nitrogen availability to plants (Jensen et al., 2003). Management of soil through minimum tillage affects the storage of water and evaporation and thus has a beneficial effect on the conservation of rain water and crop production (Lenssen et al., 2007). Additionally, crop yield stability or the ability of a crop to perform consistently, whether at high or low yield, across a range of environments (De Vita et al., 2010), is also influenced by agricultural management and environmental factors (Berzsenyi and Dang, 2008).

In response to the rain-fed related challenges and growing pressures on Africa's soil fertility and water retention capacity (Grabowski et al., 2014) interest in conservation agriculture (CA) uptake by smallholder farmers has increased. Conservation agriculture is practiced on about 125 M ha worldwide (Kassam and Brammer, 2013). Minimum tillage is one of the three core elements of conservation tillage (the other two being crop residue retention and legume rotations). Reduced energy requirements under minimum tillage as well as significant yield gains attributed to early planting, improved water retention and consequently increased fertilizer responsiveness (Grabowski et al., 2014) are some of the major benefits attributed to conservation agriculture. Of the three core elements of CA, adoption of minimum tillage by smallholder farmers in the tropics remains low leading to limited empirical evidence on lauded benefits of CA under smallholder farming systems of the tropics.

Soil water, whose major input is rainfall in the study area, is a basic requirement for crop growth and development from sowing to maturity (Khuram and Rasul, 2011; Ngetich et al., 2014a). Conservation-effective management techniques have the potential of improving rainfall use efficiency, increase and stabilize maize yields (African Conservation Tillage Network, 2008; Giller et al., 2009). A meta-analysis by Bouma et al. (2016) outlined that water harvesting technologies increases crop yields significantly although smallholder farmers are still reluctant to invest in the technologies. They recommended that more work is needed to build up the scientific knowledge base. According to Gicheru et al. (2004) efficient use of any rainfall requires appropriate soil management and tillage that enhance rainfall penetration and conserve adequate soil water for plant growth.

Increasing yields at farm level is usually a major objective in most crop production systems; however, improving yield stability is also an important objective of agricultural progress (Slafer and Kernich, 1996). In the study area, maize performance under the selected CEM techniques have been tested successfully under researcher designed and managed field trials by Ngetich et al. (2014b) and Okeyo et al. (2014) but their performance under smallholder farmers' conditions has not been established. Most studies overlook stability of yields over time, which is one of the important factors for food security (Piepho, 1998). Crop yield stability with less risk of crop failure is of great importance as it may provide an incentive to invest in crop management practices that improve yields (Barron, 2004), implying more predictable returns. Therefore, in order to evaluate the performance of potential yield enhancing CEM techniques effectively, there is a need to assess them at the smallholder farmers' level and incorporate yield stability evaluation. Such evaluation can facilitate derivation of accurate best-fit recommendations for ailing agro-ecology conditions. Moreover, on-farm trials ensure that research results accurately incorporate the effects of farmer management, which could otherwise be different when technologies are implemented onto farms. Also, technologies that perform well during on-farm trials are most likely to be taken up by farmers. We, therefore, set to evaluate the effects of the selected CEM techniques on maize yields and yield stability in on-farm conditions and determine the willingness of farmers to uptake them. We hypothesized that, the CEM techniques will not only increase maize yield but also the yield stability.

2. Materials and methods

2.1. Study area

The study was carried out in Mbeere South sub-county, Embu County and Meru South sub-county, Tharaka-Nithi County. Maize (*Zea Mays L.*) is the predominant annual crop in the two regions. The rainfall pattern is bimodal in the two sub-counties with a long rain season (LR) lasting from March to June and a short rain season (SR) from late October to December, hence two cropping seasons per year (Jaetzold et al., 2007).

Mbeere South sub-county is located in the lower midland zone four (LM4) and lower midland zone five (LM5) agro-ecological zone (Fig. 1), on the eastern slopes of Mount Kenya (Jaetzold et al., 2007). The majority of the farmers in the two zones use very little or no farm inputs. Mbeere South lies at an altitude of 700 to 1200 m above the sea level (a.s.l.) and has a mean annual temperature ranging from 21.6 °C with high evapotranspiration rates. The average annual rainfall ranges from 700 mm to 900 mm. The predominant soil type is Cambisols with cambic B horizons (FAO, 1988). These soils are less weathered than most of the other soils of the humid tropics. The soil texture is predominantly sandy clay loam (Ngetich et al., 2014b). Selected soil characteristics are presented in Table 1. Cropping systems is mainly maize-based, with beans (*Phaseolus vulgaris* L.) as the preferred legume for intercrop, although cowpea (*Vigna unguiculata* L.), groundnut (*Arachis hypogaea L.)* and green grams (*Vigna radiate* L.) are gaining importance.

Fig. 1 Meru South sub-county is located in the upper midland zone two (UM2) and upper midland zone three (UM3) agro-ecological zone, on the eastern slopes of Mount. Kenya (Fig. 1). Meru South sub-county lies at an altitude of 1500 m above sea level (a.s.l) with an annual mean temperature of 20 °C. The sub-county receives total annual rainfall of 1200 mm to 1400 mm (Jaetzold et al., 2007). It is a predominantly maize growing zone with smallholdings ranging from 0.1 to 2 ha with an average of 1.2 ha per household (Shisanya et al., 2009). The soil type is predominantly Humic Nitisols, a typically deep and weathered soil with moderate to high inherent fertility (Jaetzold et al., 2007). These