EFFECT OF TILLAGE, LIMING AND CROPPING SYSTEMS ON MAIZE YIELDS IN DIFFERENT AGROECOLOGICAL ZONES IN KENYA

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ABSTRACT

Negative effects induced by climate change have contributed to reduced global yields of maize. There is therefore need to endow farmers with innovative and transformative climate smart agriculture technologies to urgently address food insecurity and the realities of climate change in cereal growing regions of Kenya. Technologies have been generated for improved maize and beans production and their impact has not been fully felt. In this study, technologies and innovations on tillage, liming and cropping systems that can improve maize and beans production were evaluated and demonstrated to farmers in different agro-ecological zones in Kenya with the aim of enhancing their adoption. Trials were established at KALRO-Njoro, KALRO-Kakamega, KALRO-Kitale, Baraton University, and Mabanga Agricultural Training Centre, in Nakuru, Kakamega, Trans-Nzoia, Nandi, and Bungoma Counties, respectively. The tillage treatments evaluated included conventional, tied ridges, minimum and zero tillage planted in plots applied with 2 t/ha of lime or without lime. The cropping systems evaluated were maize intercropped with beans or sole cropped maize. A split-split plot design with four replications was used. Results indicated that conventional, tied ridges, and minimum tillage produced higher ($P<0.05$) yields than the zero tillage with or without lime irrespective of the cropping system in Nakuru, Nandi and Trans-Nzoia Counties. In Nandi, Kakamega and Bungoma Counties, there were no differences ($P>0.05$) between the four tillage systems.

Keywords: Tillage, Liming, Cropping Systems, Agro-ecological Zones.

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INTRODUCTION

Climate change refers to changes in long-term weather patterns characterised by shifts in average weather conditions and in the frequency and severity of extremes that have occurred over a long period of time, generally 30 to 35 years (Cairns *et al*., 2013). In addition, vulnerability to climate change in sub-Saharan Africa further increases due to its large economic dependence on agriculture (IPCC5, 2014). There is frequent failure of rain-fed maize production in the region due to recurrent droughts, (Cairns *et al*., 2013). The frequency of dry spells is expected to increase, even though there is greater uncertainty around precipitation projections (Thornton *et al*., 2011). Lobell *et al*. (2008) showed that maize production in the region could decrease to 70% of current production levels by 2030. This calls for concerted efforts for breeding and cropping systems research (Cairns *et al*. 2013). It is therefore important to use systems that increase soil organic matter content and improve soil structure (Johansen *et al*. 2012). There is need to provide reliable and diversified crop yields from both cereals and legumes even under a changing climate to enable farmers to cope with the effects of climate change and maintain or increase food security and nutrition over time (Thierfelder and Wall, 2010; Thierfelder *et al*., 2017). Farmers have also to learn new management systems including land preparation, planting, residue, weed and crop management strategies, which all require knowledge and new skills (Giller *et al.,* 2009). Crop diversification, an essential component of conservation agriculture (Thierfelder *et al*., 2013), often includes legumes, which are central in improving yields in low input agriculture systems. Conservation agriculture is an important form of climate-smart agriculture (Richards *et al*., 2014) defined by three key principles; direct planting of crops with minimum soil disturbance, permanent soil cover by crop residues or cover crops and crop rotation or diversification. A range of key benefits and ecosystem services that are associated with climate adaptation include increased water infiltration, reduced soil moisture evaporation, reduced erosion and run-off , and the ability to plant early (Thierfelder *et al*., 2017). Despite the challenges encountered in maize and bean production, scientists have generated technologies for improved production whose impact is yet to be fully felt. Therefore, there is need to embrace and demonstrate these technologies, innovations and management practices (TIMPs) that improve maize and beans production with a view to allowing wider adoption by participating and non-participating Kenyan farmers. Considering the changing climatic conditions, the demonstration of these TIMPs is essential for the adoption of resilient farming systems. The specific objectives of the present work were to evaluate and demonstrate technologies and innovations on tillage, liming and cropping systems that can improve maize and beans production among farmers in different agro-ecological zones in Kenya with the aim of enhancing their adoption.

MATERIALS AND METHODS

The trials involving maize grown alone or intercropped with beans were established at KALRO-Njoro (Nakuru County), KALRO-Kakamega (Kakamega County), KALRO-Kitale (Trans-Nzoia County), Baraton University (Nandi County) and Mabanga Agricultural Training Centre (Bungoma County). The trial sites were selected deliberately with a view to represent the diversity of agro-climatic conditions varying in altitude, temperature, soil conditions and level as well as reliability of rainfall. They are mainly tropical humid climate characterized by day temperatures varying between 16 and 24ºC with mean annual rainfall varying from 1100-2700 mm. The trials were based on a split-split plot design. The tillage strategies tested included conventional, tied ridges, minimum and zero tillage. With zero tillage treatment, all the plots were minimally opened for planting seeds. Weed management involved some plots being subjected to hand removal of weeds and others through herbicides. Soil amendment by liming or no liming was assigned the main plot (at a rate of 2 t/ha) whereas tillage practices and cropping systems (maize intercropped with beans or sole cropped maize) were assigned sub-plot and sub-sub-plot, respectively. Plot sizes measured 5 x 6m in which maize and beans were sown as test crops at recommended spacing of 75 x 25cm either as sole crops or intercropped where beans were planted in between the maize rows. Inorganic fertilizers were applied at the rate of 60 kg/ha phosphate (P_2O_5) at planting and 60 kg/ha nitrogen (N) for top-dressing. All recommended agronomic practices were carried out and the crops harvested at physiological maturity. Grain samples were oven-dried at 65 ^{0}C to attain 12.5% moisture content. All data collected were analysed following analysis of variance procedure in SAS software (SAS, 2003). Treatment means were separated using least significant difference (LSD) at 5% level of significance.

RESULTS

The ranges observed and means of selected soil chemical characteristics from the study sites areas shown in Table I .

TABLE I- SOIL CHARACTERISTICS OF SITES IN KENYA

Variable	Range	Mean
pH	4.26 - 7.74	5.37
Soil organic carbon (%)	0.1 - 5.12	1.99
Nitrogen (%)	0.02 - 0.5	0.2
Phosphorus (mg/kg)	0.0 - 80.0	28
Potassium ($cmol_c$/kg)	0.04 - 2.04	0.62
Zinc (mg/kg)	0.00 - 45.1	5.26
Bulk density (g/cm^3)	0.00 - 1.61	1.16
Soil carbon stock (tC/acre)	0.00 - 100.0	25.3

Tillage, liming and cropping systems

There were no significant interactions between the factors (tillage, liming and cropping systems) investigated. Therefore the results of the main effects are presented and discussed separately.

Effect of tillage practices on maize yields

Mean maize yields obtained under tested tillage practices across the Counties were as shown in Table II.

TABLE II- EFFECT OF TILLAGE ON MAIZE YIELDS (t/ha) ACROSS SITES

Tillage/County	Nakuru	Nandi	Trans Nzoia	Kakamega	Bungoma
Conventional tillage	6.41a	5.47a	5.15a	5.46a	1.79a
Tied Ridges	6.17ab	5.10a	4.96a	5.45a	1.79a
Minimum Tillage	5.35bc	5.45a	4.84a	6.08a	1.75a
Zero Tillage	5.12c	4.90a	4.09b	5.83a	1.99a
Mean	5.76	5.23	4.76	5.70	1.83
LSD ($p \leq 0.05$)	1.77	1.11	1.13	0.62	0.64
CV (%)	18.00	16.40	17.10	13.10	41.60

Means followed by the same letter within a column are not different ($p \leq 0.05$)

At KALRO-Njoro (Nakuru County), the conventional and tied ridges tillage methods produced the highest maize yields, while the minimum and zero tillage produced lower ($P \leq 0.05$) yields than the other tillage methods (Table II). At KALRO Kitale (Trans-Nzoia County) the zero tillage system produced lower ($P \leq 0.05$) yields than the conventional, tied ridges and minimum tillage methods while Nandi, Kakamega and Bungoma, there were no significant differences in maize yields between the tillage methods (Table II).

Combined effect of soil liming and tillage practice on maize yields

The liming effects on maize yields were not significant in Nakuru, Nandi, Kakamega and Bungoma Counties irrespective of the tillage method used (Table III). Even though in Nakuru County zero tillage produced lower ($P \leq 0.05$) maize yields than those planted under conventional and tied ridges tillage when planted without lime. However, the effect of liming on maize yields planted on station in Trans-Nzoia County showed that limed plots produced higher ($P < 0.05$) yields than those that had not been limed irrespective of the tillage method employed.

TABLE III- EFFECT OF LIMING ON MAIZE YIELDS UNDER DIFFERENT TILLAGE PRACTICES IN NAKURU, NANDI, TRANS-NZOIA, KAKAMEGA AND BUNGOMA COUNTIES DURING THE 2017 LONG RAINS SEASON

Tillage practice	Nakuru County		Nandi County		Trans-Nzoia County		Kakamega County		Bungoma County	
	With Lime	Without lime	With Lime	Without lime	With Lime	Without lime	With Lime	Without lime	With Lime	Without lime
Conventional Tillage	6.23a	6.59b	5.74a	5.21a	5.63b	4.68a	5.45a	5.49a	1.99a	1.59a
Tied Ridges	6.21a	6.14b	5.80a	4.40a	5.75b	4.17a	5.42a	5.47a	1.82a	1.75a
Minimum Tillage	5.65a	5.04ab	5.95a	4.95a	5.01a	4.68a	6.38a	5.77a	1.84a	1.66a
Zero Tillage	5.12a	5.13a	4.79a	5.00a	4.33a	3.85a	6.08a	5.58a	2.55a	1.43a
Mean	5.80	5.73	5.57	4.89	5.18	4.34	5.83	5.58	2.05	1.61
$LSD_{0.05}$	1.48	1.48	1.40	1.40	1.13	1.13	1.15	1.15	0.85	0.85
CV (%)	17.00	17.00	20.20	20.20	11.80	11.80	10.30	10.30	33.00	33.00

Means followed by the same letter within a column not different ($P < 0.05$).

Effect of tillage practice and cropping systems on maize yields

Cropping systems did not affect ($P > 0.05$) maize yields in Nakuru, Nandi, Trans-Nzoia, Kakamega, and Bungoma Counties irrespective of the tillage method used (Table IV). Similarly, tillage effects on maize yields were not significant in Nandi, Kakamega, and Bungoma Counties irrespective of the cropping system used (Table IV). However, the effect of tillage technique on maize yields in Nakuru County showed that plots under conventional tillage produced higher ($P < 0.05$) yields (Table IV) than those under zero tillage in the sole maize cropping system. Similarly, in the sole maize cropping system the effect of tillage technique on maize yields in Trans-Nzoia County showed that plots under tied ridges produced significantly ($P< 0.05$) higher yields (Table IV) than those under other tillage methods. Finally, the effect of tillage technique on maize yields in Trans-Nzoia County showed that plots under conventional tillage grown in the in the sole maize/ beans intercropping system produced significantly ($P\leq 0.05$) higher yields (Table IV) than those under other tillage methods.

that not all agricultural enterprises and soil conditions are suited to conservation tillage, the current results concur with Thierfelder *et al*. (2012), Manyatsi *et al*. (2011) and FAO (2002) that advocate for conservation agriculture practices such as reduced or zero tillage, tied ridging and mulch that reduce soil water evaporation.

In all the plots inorganic fertilizers were applied at the recommended rates at planting and top-dressing and as such fertilizer application was not a factor. The findings suggest that soils in Nandi County are acidic and therefore farmers should lime the soils. The study also revealed that the soil fertility and organic matter in the study areas in Nandi, Kakamega, and Bungoma Counties were homogeneous and hence producing similar tillage effects. However, in Nakuru and Trans-Nzoia Counties it is probable that the conventional, tied ridges, and minimum tillage methods had better soil tilth than zero tillage hence higher produced yields than those under zero tillage with or without lime. These results tend to concur with Opala *et al*. (2018) who suggested that more attention should be focused on N and P replenishment at these sites rather than liming.

TABLE IV -EFFECT OF CROPPING SYSTEM ON MAIZE YIELDS UNDER DIFFERENT TILLAGE METHODS

	Nakuru County		Nandi County		Trans-Nzoia County		Kakamega County		Bungoma County	
Tillage	Maize	Maize /Beans	Maize	Maize/ Beans	Maize	Maize /Beans	Maize	Maize/ Beans	Maize	Maize/ Beans
Conventional Tillage	6.53b	6.29a	5.23a	5.72a	5.04ab	5.27b	5.34a	5.59a	2.07a	1.52a
Tied Ridges	6.15ab	6.20a	5.42a	4.78a	5.71b	4.21a	5.45a	5.44a	1.58a	1.99a
Minimum Tillage	5.41ab	5.28a	5.67a	5.24a	4.76a	4.93ab	6.48b	5.68a	1.52a	1.98a
Zero Tillage	5.12a	5.12a	5.19a	4.61a	4.49a	3.69a	5.64a	6.03a	1.81a	2.18a
Mean	5.81	5.72	5.38	5.09	5.00	4.52	5.73	5.68	1.74	1.92
LSD ($p \leq 0.05$)	1.24	1.24	1.25	1.25	0.81	0.81	0.80	0.80	0.82	0.82
CV (%)	18.00	18.00	16.30	16.30	17.10	17.10	13.10	13.10	41.60	41.60

Means followed by the same letter within a column are not different ($P \leq 0.05$)

DISCUSSION

Farmers in Nakuru County could adopt either the conventional or tied ridges tillage methods while in Nandi and Trans-Nzoia Counties, farmers could also adopt minimum tillage, whereas results obtained in Kakamega and Bungoma Counties, suggest that farmers could use any of the four methods. Although Mati (2012) inferred

The current findings suggest that with or without beans intercropping, maize yields were not affected in the five Counties and as such farmers could adopt either of the two cropping systems. A mixture of maize and beans forms a significant part of food consumed in these Counties and as such this could form an important basis in selecting the intercrop system. It should be noted that the benefits of the N-fixed by the beans in soil and its interactions with maize crop, if any, will be felt during subsequent cropping seasons. The current results contrast the findings of Karuma *et al*. (2018) who observed that sole maize crop performed better than the intercropped maize. They also noted that yield reduction in intercropped maize compared to the sole maize are associated with interspecies competition in the intercrop.

CONCLUSIONS

Liming is not necessary in Nakuru, Trans-Nzoia, Kakamega and Bungoma Counties as the soils were not acidic while it is necessary in Nandi County. Farmers in the five Counties could adopt either the sole maize or maize/beans cropping system without compromising maize yield.

RECOMMENDATIONS

Farmers in Nakuru County could adopt either the conventional or tied ridges tillage methods while in Nandi and Trans-Nzoia Counties, farmers could also adopt minimum tillage. In Kakamega and Bungoma Counties, farmers could adopt any of the four tillage methods. Farmers in the five Counties could adopt either the sole maize or maize/beans intercrop system.

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