

*Full Length Research Paper*

# **Effects of conservation tillage on maize (*Zea mays* L.) and beans (*Phaseolus vulgaris* L.) chlorophyll, sugars and yields in humic nitisols soils of Embu County, Kenya**

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**An experiment was conducted to determine the effects of conservation tillage (CT) practices on leaf chlorophyll content, sugars and yields of *Zea mays* L. and *Phaseolus vulgaris* L. for two consecutive cropping seasons at the Kenya Agricultural and Livestock Research Organization farm in Embu County, Kenya. The experimental design was a Randomized Complete Block Design with 9 treatments replicated 3 times. The treatments were, conventional tillage sole maize, zero tillage sole maize, Furrows/Ridges sole maize, conventional tillage sole bean, zero tillage sole bean, furrows and ridges sole bean, conventional tillage maize-bean intercrop, zero tillage maize-bean intercrop, furrows/ridges maize-bean intercrop. *Zea mays* L. and *Phaseolus vulgaris* L. plants grown under the CT plots had significantly more chlorophyll content, more sugar content and more grain weight than those under conventional tillage practices (CVT). The results provided a physiological basis for the observed increase in yields. They led to a conclusion that the CT method is suitable for improving crop productivity through enhancing physiological functions in the leaf.**

**Key words:** Conservation tillage, chlorophyll, grain weigh.

## **INTRODUCTION**

Approximately 65% of agricultural land in Sub-Saharan Africa (SSA) is degraded (Rockstrom et al., 2009). A major cause is intensive soil tilling and removal of crop residues (Rockstrom et al., 2009). Arable agriculture across sub-Saharan Africa is exposed to climate stress and climate change is predicted to further increase risks

of both extreme temperatures and drought (Niang et al., 2014). Negative impacts on crop yields are therefore expected (Schlenker and Lobell, 2010; Lobell et al., 2011).

According to Chivenge et al. (2007), tillage practice plays an important role in the manipulation of nutrient

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storage and release from soil organic matter (SOM). Conventional tillage (CVT) induces rapid mineralization of SOM and potential loss of soil carbon (C) and soil nitrogen (N). Several agricultural systems have been established to be climate-smart, and this includes conservation tillage (CT), (Rosenstock et al., 2016; Thierfelder et al., 2017). The benefits of CT include increased water infiltration, reduction in soil moisture evaporation and reduced soil erosion (Thierfelder et al., 2017).

Despite the yield benefits accruing from the CT practices in Sub-Saharan Africa (Twomlow and Bruneau, 2008), majority of smallholder farmers' fields are still under conventional tillage methods. Furthermore in SSA, the gaps in *Zea mays* L. yields are high with yields having trends of stagnation or decline (Ray et al., 2012; van Ittersum et al., 2013). This low productivity is associated with frequent dry spells and soil fertility depletion (Recha et al., 2012; Ngetich et al., 2012). According to Lobell et al., 2014, closing these yield gaps and reversing this yield decline is a priority. Improved soil and crop yields increase are reported elsewhere in the world as a result of CT practices (Kabirigi et al., 2015; Thierfelder et al., 2017). However, the physiological basis of the observed yield increases as a result of CT practices has not yet been reported. The objective of this study was therefore to determine the effects of CT practices on the chlorophyll content, sugar content and yields of *Z. mays* L. and *Phaseolus vulgaris* L.

## MATERIALS AND METHODS

### Study site description

The study was conducted at the Kenya Agricultural and Livestock Research Organization (KALRO) farm in Embu County, Eastern Kenya (latitude 00°33.18'S; longitude 037°53.27'E; altitude 1420 meters above sea level, in the upper midlands (UM) ecozone, 125 km North-East of Nairobi (Jaetzold et al., 2007). According to Nicholson (2000), annual rainfall is 1250 mm; the mean max. temperatures are 28°C and min. temperatures are 21°C (Jaetzold et al., 2007). Soils in the study site are Humic Nitisols.

The treatments included; three tillage methods, CVT, Furrows/Ridges (F/R), Zero Tillage (ZT) and three cropping patterns (sole *Zea mays* L. (SM), *P. vulgaris* L. (SB) and Maize-Bean intercropping (MB). The experiment was laid out on a Complete Randomized Block Design and replicated 3 times giving a total of 27 plots. The plot dimensions were 7.5 m wide × 10 m length each with 2.0 m path between the plots. For CT tillage practices, 75% of crop residues were applied on the plots by spreading them between the rows at the rate of 2.5 tons ha<sup>-1</sup> per season on the soil surface. *Z. mays* L. spacing was 75 cm between the rows and 50 cm within the rows. Two seeds were sown and this gave a plant population of 53333 plants ha<sup>-1</sup>. *P. vulgaris* L. spacing was 50 cm between the rows and 15 cm within the rows while maintaining one plant per hill. The spacing for intercropped bean was 50 cm between the rows and 20 cm within the rows while maintaining two plants per hill to give a plant population of 133333 plants ha<sup>-1</sup>. Weeds in the CT practices were controlled using the appropriate pre-emergence and post-emergence herbicides. Weeds in the conventional tillage were controlled by tilling the plots using hand hoes twice per season.

### Data collection

The chlorophyll concentration was measured three times per season (before flowering, at flowering and after flowering for bean and maize using a SPAD-502 chlorophyll meter (Konica Minolta Sensing Inc., Tokyo, Japan) five randomly selected plants per plot were sampled.

### Leaf sugar content

This was measured three times per crop growing season (before flowering, at flowering and after flowering) on bean and maize leaves using the anthrone method (Li, 2000).

### Bean and maize grain yields

The bean plants in the net plots were uprooted. The bean pods were manually separated from the stover, sun-dried and packaged into sacks before threshing the grain from the residues. The grains were then dried in the sun to approximately 12.5% moisture content which was determined using a moisture meter before taking the final weight. The total bean grain yield per hectare was then calculated.

All the maize plants on the net plots were harvested by cutting at the ground level after 50% physiological maturity. The maize ears were manually separated from the husks and were dried in the sun. Maize grain was then separated from cobs by hand shelling. After shelling the grains were then dried in the oven for 48 h to adjust the grain moisture content to 12.5% which was determined by the use of a moisture meter. The total grain yield per hectare was then calculated. All data obtained were subjected to analysis of variance (ANOVA) according to the general linear model (GLM) procedure of the Statistical Analysis System (SAS Institute Inc., 2003). The differences between treatment means were considered significant when ( $p \leq 0.05$ ).

## RESULTS AND DISCUSSION

### Chlorophyll concentration

Bean plant's chlorophyll content varied significantly ( $p \leq 0.05$ ) in all the cropping seasons due to tillage practices (Table 1). Maize chlorophyll content was not affected significantly ( $p \leq 0.05$ ) before and at anthesis (Table 2). However, there was a significant difference ( $p \leq 0.05$ ) on the chlorophyll content after anthesis in the SR 2015 (Table 2). The maize chlorophyll content differed significantly only at anthesis for LR 2016 due to tillage practices ( $p = 0.0003$ ). The highest chlorophyll concentration in all the seasons was recorded at the flowering stage. This is due to increased development of chloroplasts which increases the rate of photosynthesis as the plants manufacture more photosynthetic assimilates to be translocated to the grains for grain filling. The lowest chlorophyll content concentrations were observed at the crop physiological maturity stage (Tables 1 and 2). This could be attributed to the fact that the plants had reached senescence and the loosening of the chloroplasts in the plant leaves.

The CT practices recorded higher chlorophyll content in

**Table 1.** Effects of tillage practices on bean sugar content (%) at different stages of crop development during short rains SR 2015 and LR 2016.

Tillage practice	Leaf sugar content SR 2015			Leaf sugar content LR 2016		
	Before anthesis	At anthesis	After anthesis	Before anthesis	At anthesis	After anthesis
Conventional tillage	1.9	3.2	1.5	2.0	3.3	1.6
Zero tillage	2.3	2.9	1.5	2.2	3.1	1.3
Furrows/ridges	2.2	3.2	1.7	2.2	3.3	1.7
LSD (0.05)	0.6	0.5	0.5	0.5	0.5	0.6
p-value	0.3	0.4	0.16	0.5	0.5	0.4

Values followed by the same letter along the column are not significantly different  $p \leq 0.05$ . LSD = Least significant difference; SR = short rains; LR = long rains.

**Table 2.** Effects of tillage practices on maize sugar content (%) at different stages of crop development during SR 2015 and LR 2016.

Tillage practice	Leaf sugar content SR 2015			Leaf sugar content LR 2016		
	Before anthesis	At anthesis	After anthesis	Before anthesis	At anthesis	After anthesis
Conventional tillage	1.7 <sup>b</sup>	2.6 <sup>b</sup>	1.3 <sup>b</sup>	2.1 <sup>b</sup>	2.7 <sup>b</sup>	1.4 <sup>b</sup>
Zero tillage	2.4 <sup>a</sup>	2.9 <sup>a</sup>	1.6 <sup>b</sup>	2.4 <sup>a</sup>	3.3 <sup>a</sup>	1.3 <sup>b</sup>
Furrows/ridges	2.4 <sup>a</sup>	3.4 <sup>a</sup>	1.9 <sup>a</sup>	2.6 <sup>a</sup>	3.6 <sup>a</sup>	2.0 <sup>a</sup>
LSD (0.05)	0.4	0.4	0.3	0.3	0.5	0.2
p-value	0.005	0.004	0.0005	0.02	0.01	0.0001

Values followed by the same letter along the column are not significantly different  $p \leq 0.05$ . LSD = Least significant difference; SR = short rains; LR = long rains.

comparison with the CVT practice after flowering in the two crop growing seasons (Tables 1 and 2). Higher chlorophyll concentration shows how better a crop is performing and this is an indication of the potential yield (Namuco et al., 2009). The chlorophyll concentration determines the level of photosynthesis and primary productivity according to Egli and Rucker (2012). Studies that were done by Agamy et al. (2012) reported that improved plant nutrients have a positive impact on the growth of a plant and yield factors including chloroplasts in leaf cells. The results of this study are in agreement with their observations (Figures 1 to 4).

### Leaf sugar content

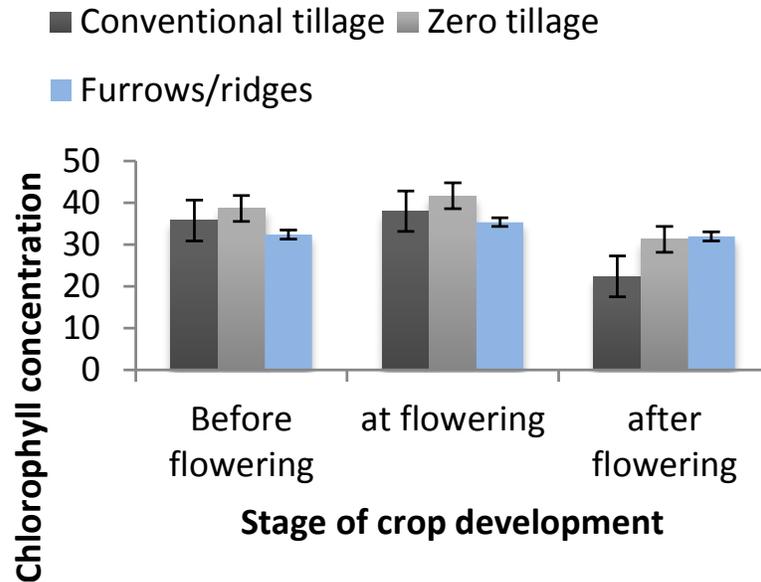
Sugar content in beans was highest at the flowering stage for both seasons (Table 1). Maize leaf sugars differed significantly ( $p \leq 0.05$ ) at all stages of growth due to tillage practices (Table 2). In comparison, crops grown under CT practices had more sugar content as compared to those grown under CVT (Tables 1 and 2). The sugars were highest at the point of maximum chlorophyll content in both maize and beans (Tables 1 and 2). This could be due to the fact that at maximum chlorophyll content, the

plants were actively involved in the manufacture of photosynthetic assimilates in preparation for grain filling. The amount of chlorophyll in the leaves is an indicator of the rate of  $\text{CO}_2$  assimilation per unit time and this governs the sugar content in the leaves (Nitasha et al., 2018).

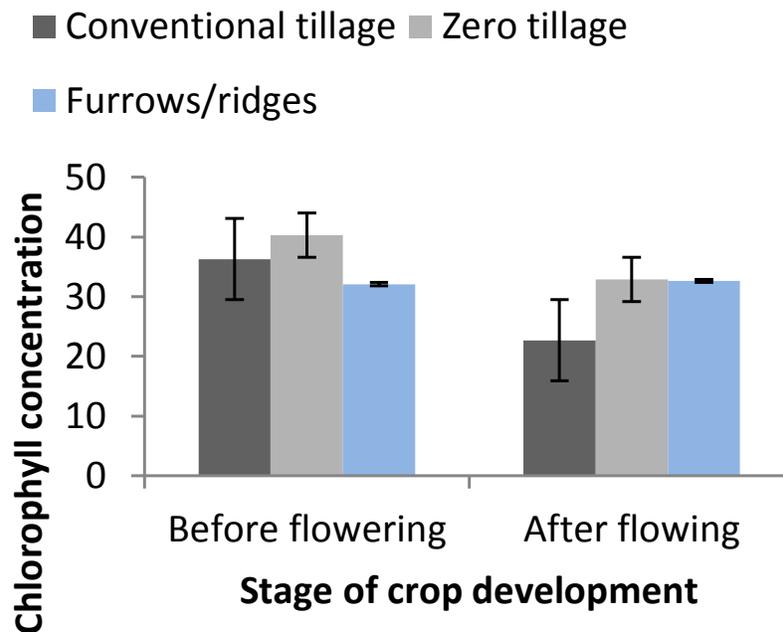
Sugar content was lowest after flowering (Tables 1 and 2). This decrease in sugar content in the leaves could have been as a result of translocation of the photosynthetic assimilates from the leaves to the grains during grain filling. This could also be attributed to the fact that the plant leaves had reached senescence hence the chloroplasts had started aging.

### Bean and maize grain weight

The CT practices produced more grain weight in both seasons than in the CVT (Figures 5 and 6). The high bean and maize grain yields under the CT practices could be attributed to increased photosynthetic rates as denoted by the high leaf chlorophyll and sugar content than CVT. Miriti (2010) while working in Makueni sub County in Kenya also found out that there were higher maize yields by 55% in the tied ridged plots than in the CVT plots.



**Figure 1.** Effects of tillage practices on bean chlorophyll concentration (units of SPAD) taken before, at and after flowering during SR 2015.

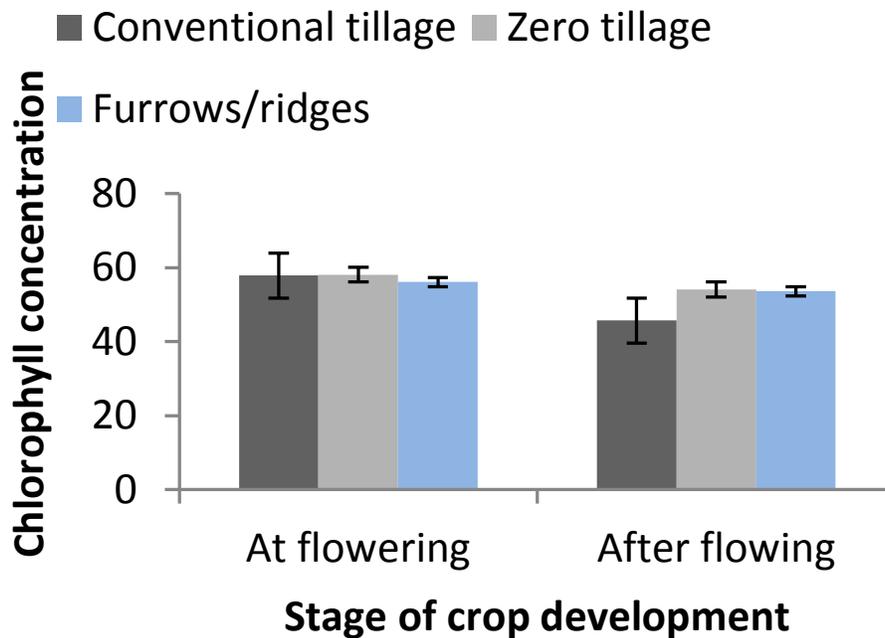


**Figure 2.** Effects of tillage practices on bean chlorophyll Concentration (units of SPAD) taken before, at and after flowering During LR 2016.

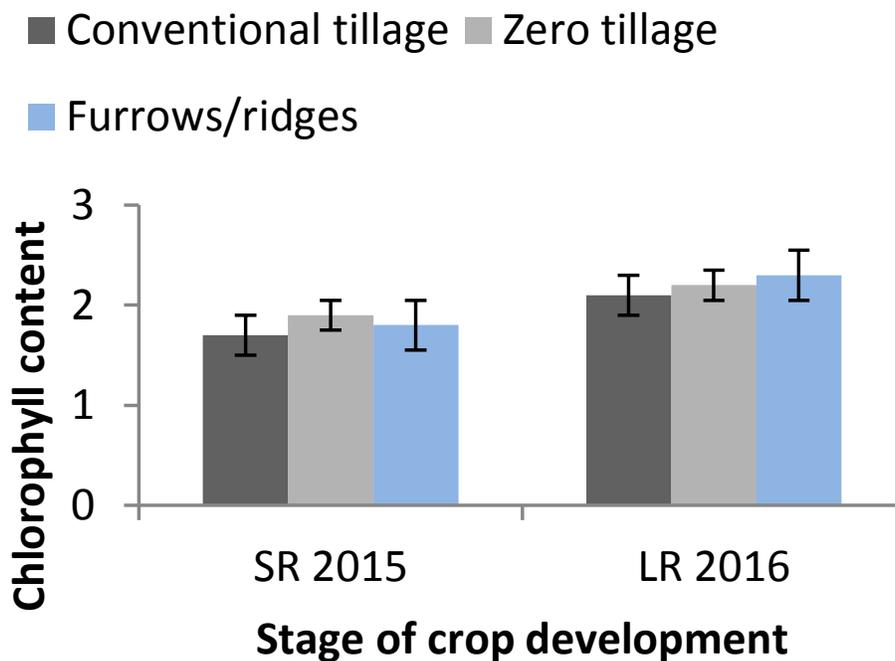
## CONCLUSION AND RECOMMENDATIONS

Conservation tillage practices increased the crop's chlorophyll content than the conventional tillage practices. This is an indicator of increased rate of photosynthesis in the *Z. mays* L. and the *P. vulgaris* L. crops grown under

the conservation tillage practices than those under the conventional tillage practices. Conservation tillage practices had more *Z. mays* L. and *P. vulgaris* L. leaf sugar content than conventional tillage practices. This led to the observed crop yield increases under the conservation tillage practices than those under



**Figure 3.** Effects of tillage practices on maize chlorophyll concentration (units of SPAD) at different stages of crop development during short rains SR 2015.

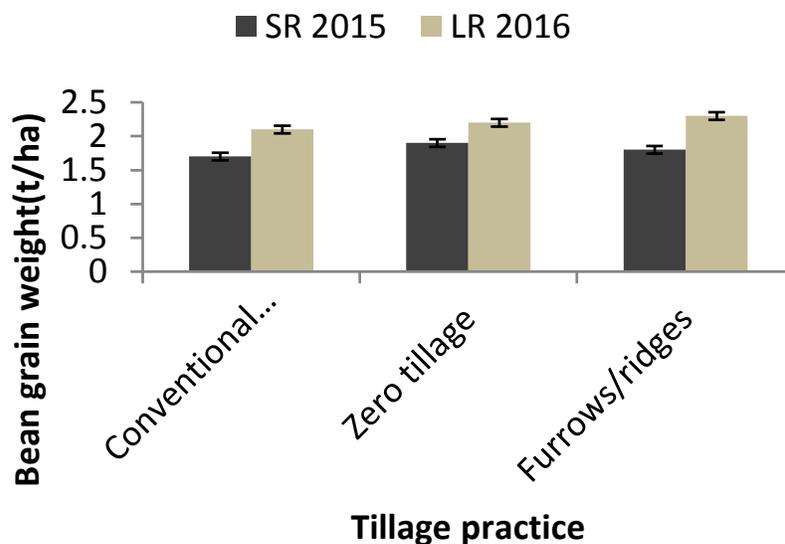


**Figure 4.** Effects of tillage practices on maize chlorophyll concentration (units of SPAD) at different stages of crop development during short rains LR 2016.

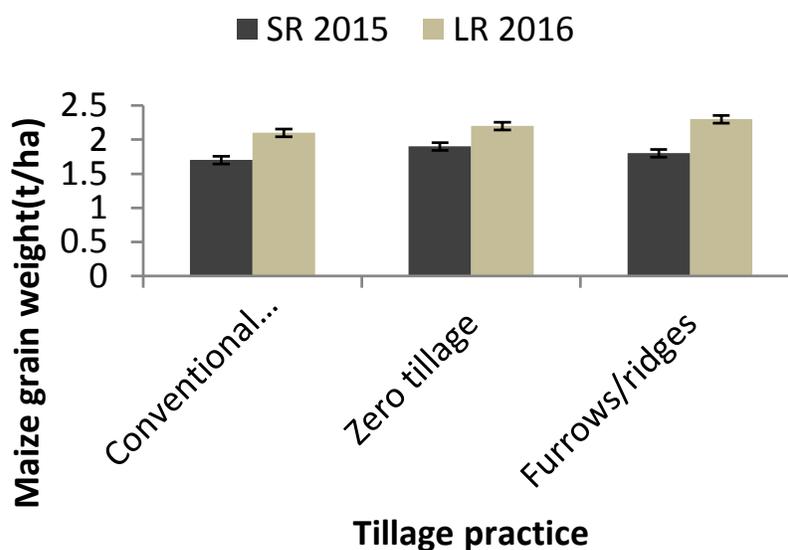
conventional tillage practices. As a result, it will be a good practice to promote conservation tillage practices among farmers for increased crop yields.

#### CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.



**Figure 5.** Effects of tillage practices on bean grain weight during short rains 2015 and long rains 2016 seasons.



**Figure 6.** Effects of tillage practices on maize grain yields during short rains 2015 and long rains 2016 seasons.

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