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Influence of soil conservation practices on soil moisture and maize crop (*Zea mays* L.) productivity in Centre Benin

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Soil quality constitutes a major factor for crops growth. This study aimed at determining the sustainable soil conservation practices that would increase maize growth as well as production and improve the soil moisture. Two experimental sites were chosen: Dan localized on Acrisol and Za-zounmè localized on ferralsol. Two cropping seasons were investigated: the long rain seasons of 2018 and 2019. The experimental design was split-plot with four replications. The main factor was tillage with three modalities: no-tillage (NT); ridging parallel to the slope (PR); Isohypse ridging (IR) and the second factor was mulching with four amounts: 0, 3, 5 and 7 t.ha^{-1}. Tillage, mulch amount and their interaction significantly influenced the soil moisture, maize growth and yield over the two investigated cropping seasons at both sites whereby the highest values were obtained under IR for tillage, 7 t.ha^{-1} (for mulch amount) and IR7M (for the interaction tillage x mulch amount). Overall, IR significantly increased the maize growth speed by 8% at Dan and by 16% at Za-zounmè; the maize grain yield by 33% at Dan and by 30% at Za-zounmè and the soil water content by 24% at Dan and 20% at Za-zounmè, in comparison with No-Tillage. An increasing effect of mulch amount was also observed. As far as mulching is concerned, the highest values (in average of LR2018 and LR2019) of growth speed (3.77 cm.day^{-1} at Dan and 4.08 cm.day^{-1} at Za-zounmè); grain yield (3003.03 at Dan and 3471.09 kg.ha^{-1} at Za-zounmè) and soil water content (26.89 mm at Dan and 20.44 mm at Za-zounmè) were observed. This suggests that isohypse ridging associated with an appropriate amount of organic mulch could be an option to mitigate dry spells and drought and improve local farmers' income in the area of low rainfall in sub-Sahara Africa.

Key words: Crop residues, tillage practices, conservation agriculture, food security, watershed of Zou.

INTRODUCTION

Food security, soil and water conservation and climate change mitigation are the most important challenges that are facing developing countries including countries of sub-Saharan Africa (SSA) (Clover, 2003; Kiboi et al., 2019). Current cropping systems need therefore to be transformed for meeting these challenges. In Benin, agriculture is rainfed-based and small-scale farmers provide more than 80% of food production. In most of agro-ecological zones in Benin, continuous land use, burning of crop residues, and deep tillage have led to soil degradation (Saïdou et al., 2012). In addition, the erratic distribution of rainfall seriously compromises agricultural production. It is therefore necessary to adopt alternative practices to ensure food security for a growing population. For several decades, organic farming has been identified as an alternative form of farming to ensure food security and reduce the impact of agriculture on the environment (Badgley et al., 2007). Among all developed practices for tillage reducing and soil coverage improvement, retaining crop residue as soil mulch or soil cover is one of the highly beneficial practices of good soil management (Vincent-Caboud et al., 2019). Besides poor soil nutrient status, water is also a limiting factor of food production under rain fed conditions, and thus water and nutrients alternate within a particular season as key factors limiting crop production. According to its role on agricultural production in a tropical environment, the purpose of tillage is to ensure the well establishment of crops, improve water and air circulation of in the soil, promote warming, limit water runoff and weed infestations (Kurothe et al., 2014; Kiboi et al., 2019). Despite all the benefits mentioned above, many problems arise from continuous, yearly intensive tillage of agricultural soils (Idowu et al., 2019). Intensive disturbances of the soil may decrease soil quality (e.g., reducing organic matter, increasing soil erosion, etc.) (Idowu et al., 2017). Labreuche et al. (2007) consider that intensive tillage is generally considered to be an unfavorable factor for carbon storage and therefore unfavorable for soil organic matter. The main effect seems to be a lifting of the physical protection of organic matter by tillage. Under certain soil, climate and management conditions, No-tillage (NT) may have potential advantages over tillage. Reduction of runoff and erosion, increase in soil organic carbon (SOC), increase of root length density and soil water conservation are some of the main outcomes of NT practices (Lal, 2004; Martínez et al., 2008; Kolb et al., 2012; Soane et al., 2012; Fiorini et al., 2018). NT practices are considered as Conservation Agriculture practices (FAO, 2011) and reaching up to 70% of the total cultivated area in South America. However, various soil types react differently to the same tillage method with respect to some selected soil properties, and the effects of tillage method on crop yield vary with the crop species (Sharma and Abrol, 2005). In Africa and Europe, NT practices are not widespread and a decrease in crop yield and an increase in runoff and soil loss during its establishment has been reported (Akplo et al., 2019a; Basch et al., 2008; Pittelkow et al., 2015). However, there is lack of a clear understanding of their effects on soil conditions and crop yield for different soil, crop and climate condition (Singh and Malhi, 2006). In addition, in Benin as well as in several countries in Sub-Saharan Africa, tillage is made using manual hoe. Tillage systems that can enhance crop productivity under smallholder farming systems are therefore desirable. Contour ridges are regarded as water harvesting methods in semi-arid regions. It transforms the land into small pockets called tied ridges or soil bund called furrows and is very useful to stabilize yield (SUSTAINET, 2010; Uwizeyimana et al., 2018).The advantages of mulch are widely recognized (Araya et al., 2015; Toom et al., 2019). Crop residues as mulch at the soil surface acts as shade, protects the soil surface against raindrops and limit surface runoff (Bashagaluke et al., 2018), increased carbon sequestration (Balesdent et al., 2000), maintains soil moisture and maintains high soil biological activity (Douzet et al., 2010; Mazarei and Ahangar, 2013). Keeping this in view, this study aims at determining the effect of different tillage systems in combination with different crop residues amounts used as mulch on rain-fed maize growth and yield component and soil moisture.

METHODOLOGY

Site description

Field trials were carried out on an Acrisol at Dan (7°21’35” N; 002°05’09” E) and on a Ferralsol at Za-zounmè (7°12’50” N; 002°15’40” E) on the watershed of Zou (Figure 1). At Dan, the soil had Sandy-clay-loamy in texture and characterized by moderate organic matter content (1.37%); exchangeable Potassium (0.33 meq/100g of soil), available Phosphorus (12.6 ppm), pH (5.63) and high total nitrogen content (0.088%). The C: N ratio of 9.03 indicated a good decomposition of organic matter by microorganisms in the soil. Water infiltration was very slow (41 cm.day^{-1}) and the slope is 5%. At Za-zounmè, the soil is Sandy-loamy with moderate contents of organic matter (1.24%); exchangeable Potassium (0.36 meq/100 g of soil), high available Phosphorus (18.12 ppm), and total nitrogen content (0.069%) while the pH of the soil (6.40) was neutral. An average C: N ratio of 10.42 indicates good decomposition of organic matter. Water infiltration was very slow (120 cm.day^{-1}) and the slope is 4.6%. The rainfall pattern is bimodal in the two sites: Long Rain season (LR) from April to July and Short Rain season from September to November. For both sites, long time annual average rainfall ranged from 1100 to 1300 mm (Figure 1).

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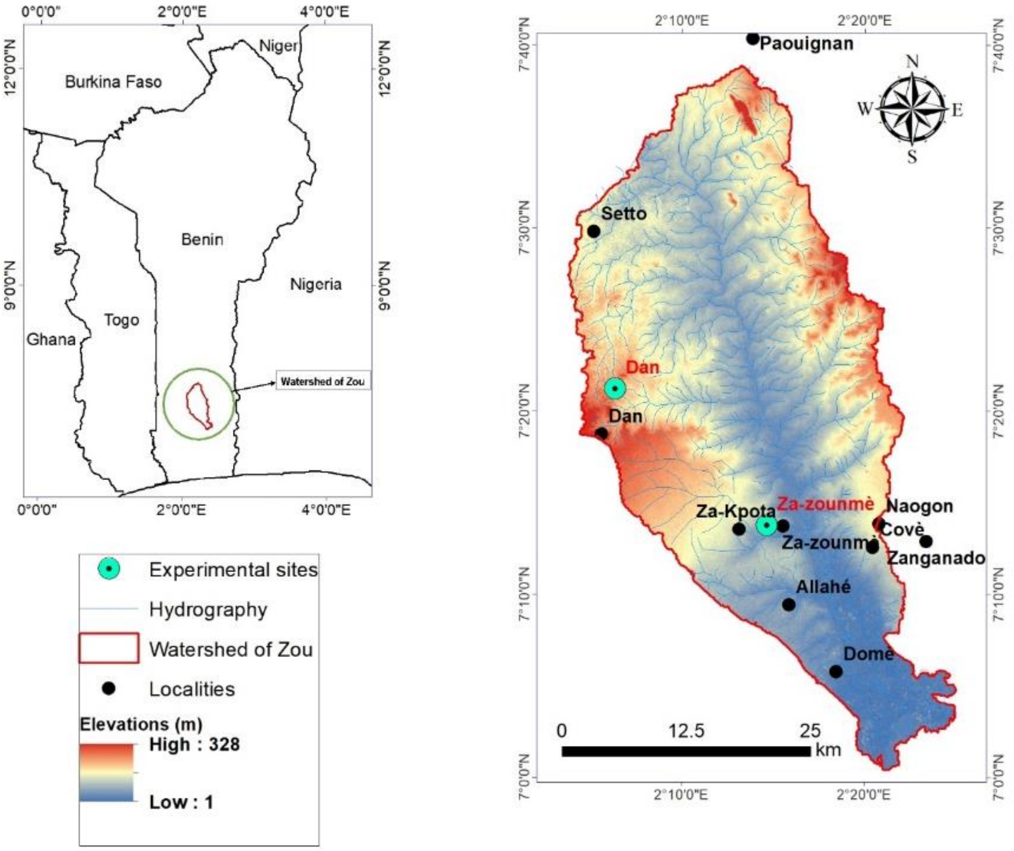


Figure 1. Map of the study area.

Table 1. Treatment factorial combinations.

Tillage practices	Mulch amounts (t. ha^{-1})	Abbreviations
No tillage	0	NT0M
No tillage	3	NT3M
No tillage	5	NT5M
No tillage	7	NT7M
Ridging parallel to the slope	0	PR0M
Ridging parallel to the slope	3	PR3M
Ridging parallel to the slope	5	PR5M
Ridging parallel to the slope	7	PR7M
Isohypse ridging	0	IR0M
Isohypse ridging	3	IR3M
Isohypse ridging	5	IR5M
Isohypse ridging	7	IR7M

Experimental layout, treatments and management

The experiment was conducted for two long rains seasons, 2018 (LR2018) and 2019 (LR2019) at Dan and Za-zounmè. The both experimental sites were under fallow since 2000. The experiment was laid out in split-plot design. Three tillage practices (NT (no-tillage); PR (ridging parallel to the slope); IR (Isohypse ridging) were considered as main treatment while Four mulch amounts (0; 3; 5 and 7 t.ha^{-1}) were assigned in sub-plots. The treatments (Table 1) were replicated four times at each site. The plot sizes were 17 m x 6 m and 6 m by 3.5 m at Dan and Za-zounmè. The Ridging was done using a hand hoe to 30 cm depth. The Ridging parallel to the slope is a type of tillage whose seedling lines are oriented parallel to the slope direction. Isohypse ridging designates a type of ridging perpendicular to the slope. The no-tillage as made in this study consists in directly sowing without any actual soil work. The mulching was made at sowing with maize crop residue. The seedling poops were made with a machete or hoe on a depth proportional to the size of the seed. Being the dominant annual crop in the watershed of Zou, maize (*Zea mays* L.) variety DMR-AK94 was the test crop. The planting density was 62500 plants. ha^{-1}. Weeds management was done twice using a hand hoe on no-mulched plots while under mulched plots, it was by hand pulling. The harvest of maize was done 105 days after sowing.

Data collection

Rainfall measurement and soil moisture assessment

The rainfall amount was recorded daily over the two investigated cropping seasons. The device used was installed on each of the experimental site by the Direction of Agrometeorology of Benin. In each investigated season, gravimetric soil moisture was determined in the 20 top centimetres of soil two weekly. The soil samples were oven dried at 105°C for 48 h before determining gravimetric water content. For bulk density determination, soil samples were collected by stainless steel cores of 100 cm^3 in volume. Soil samples for bulk density determination were collected before planting from outside the plots but within the same field. Gravimetric water content for each soil layer were calculated using the procedure outlined by Anderson and Ingram (1993). Soil water content in percentage was converted in millimetres by multiplying volumetric water content by 20 cm and by the bulk density.

Growth parameters

Chlorophyll concentration of maize leaves and plant height were collected as maize growth index during the experiment. Height of adjacent plants on the middle row per plot were sampled (non-destructive sampling). Relative Chlorophyll content of maize leaves was taken at 30 Days After Sowing (6th leaf stage) and 60 Days After Sowing (10th leaf stage) using a Soil Plant Analysis Development SPAD-502Plus®meter. The measurements were made at middle of four leaves per plant and the mean values were recorded. Plant height was measured on the 15th, 30th, 45th and 60th Days after sowing using a ruler as the distance from the base of the plant to the uppermost extended leaf tip. Maize growth speed was estimated fitting linearly maize plant height in function of the time (15th, 30th, 45th and 60th). Growth speed rate was represented by the coefficient (“a”) of the regression equation.

Yield components

Maize was harvested at maturity from a net area of 15 m² in each plot at both sites. At the harvest, the cobs in each plot were separated from the stover and fresh weight of both grain and stover was determined. Also, the fresh weight of the straw was recorded. The cobs and straw were oven dried at 65°C until constant weight and weighed. The cobs were then hand shelled and the grains weighed. Grain yield (kg DM ha^{-1}) was estimated as follow (Saïdou et al., 2012):

$$\text{Grain yield} = \frac{10000 \times \text{P} \times \text{DM} \times \text{n}}{\text{NA}}$$

Where: DM denotes the Dry matter factor = dry weight of sample / wet weight of sample; n denote the Shelling factor = dry weight of grain / dry weight of cob; P denotes total wet weight and NA is the harvested net area.

The Straw yield (kg DM ha^{-1}) of maize were determined as follow:

$$\text{X} = \frac{10000 \times \text{P} \times \text{DM}}{\text{NA}}$$

Where: X denotes Straw; Husk and raffle yield.

The Harvest Index was calculated as follow:

$$\text{HI} = \frac{\text{Grain Yield}}{\text{Grain Yield} + \text{Straw Yield}}$$

Data analyses

Data were analyzed by year and by site due to variable weather of the LR2018 and LR2019 and growing conditions at Dan and Za-zounmè. The data collected from the experimental trials were submitted to a three-way analysis of variance (ANOVA) using PROC MIXED procedure. Tillage and mulching were assigned as fixed factor while block was considered as random factor. When F-test is significant for any fixed effects, a subsequent mean separation was performed using Post hoc Tukey’s Honestly Significant Difference at 5% significance level. Statistical analyses were carried out using SAS (Statistical Analysis System) software, (version 9.2).

RESULTS

Rainfall amount and distribution

The 2018 (LR2018) and 2019 (LR2019) long rain cropping seasons were characterized by different rainfall patterns at the both sites. At Dan, LR2019 was more rained than LR2018 (Figure 2a). Cumulatively, 443 and 355.88 mm were recorded in rainfall during respectively in LR2019 and LR2018 cropping seasons. Conversely, LR2018 was more rained than LR2019 at Za-zounmè where 620.6 and 541.1 mm were recorded over the LR2018 and LR2019 (Figure 2b). For the both sites, the most of the rain fell from 1 May to 30 June during the two year. This period closed with the vegetative stage of the maize variety grown at both sites. Total of 213.66 and 397.5 mm were recorded during the LR2018 whereas 250.3 and 388.6 mm were recorded during the LR2019 respectively at Dan and at Za-zounmè at the vegetative stage of the maize. During the LR2018, a meteorological drought (defined as the absence of rainfall for a period above twenty-eight days during the growing season) was observed from the 76th to 103th days after sowing at Za-zounmè while dry spells (absence of rainfall in periods ranging between 10–28 days during crop growing season) was observed at Dan from 89th to 110th days after sowing. Dry spells were observed at Dan from the 100th and 110th days after sowing in LR2019. At Za-zounmè, two dry spells were observed. They appeared during the vegetative stage (from 33th to 44th days after

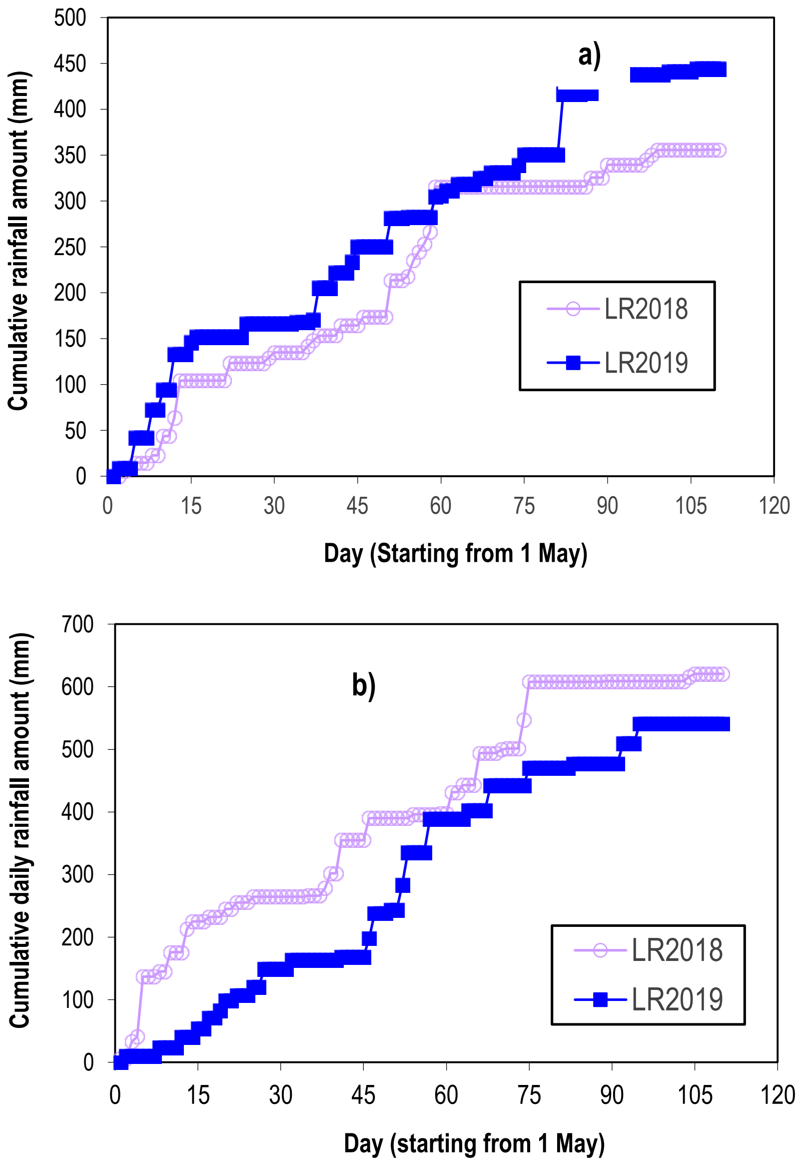


Figure 2. Rainfall at Za-zounmè between 1 May and 31 August during 2018 and 2019 Long Rain seasons at a) Dan and b) Za-zounmè.

sowing) and during the ripening stage (from 93th to 110th days after sowing).

Average soil water content at 0-20cm during the maize growing season

Average soil water content at 0-20 cm depth was significantly affected by tillage, mulching and the interaction (Tillage*mulching) in the both sites during the two investigated seasons (LR18 and LR19) (Table 2). IR yielded the highest soil water content at 0-20cm on the both sites. PR was not significantly different from NT in LR2018 at Dan and in LR2019 at Za-zounmè. The soil water content significantly increased ($p<0.05$) with an increase in mulch amount whereby the highest soil water content was obtained with 7 t ha^{-1} mulch. However, during LR2018, significant difference was not obtained between 3 and 5 t ha^{-1} mulch at Dan while the difference was not significant between 0, 3 and 5 t ha^{-1} mulch at Za-zounmè. During LR2019, no significant difference was not found between 0 and 3 t ha^{-1} mulch at Dan whereas 7; 5 and 3 t ha^{-1} significantly increased respectively by 39, 31 and 21% compared with 0 t ha^{-1}. As far as the interaction (Tillage*Mulching) is concerned, the highest water content was found with the treatment IR7M while the treatment NT0M led to the lowest water content at 0-20 cm (Figure 3a and b). Overall, for each tillage

Table 2. Simple effects of tillage and mulching on the average soil water content (mm) at Dan and Za-zounmè during LR2018 and LR2019 seasons.

Treatments	LR2018		LR2019	
	Dan	Za-zounmè	Dan	Za-zounmè
Tillage[1]				
NT	20.58^{b}	17.71^{c}	21.08^{c}	15.36^{b}
PR	23.79^{b}	18.99^{b}	24.16^{b}	15.80^{a}
IR	25.51^{a}	20.87^{a}	26.20^{a}	18.78^{b}
Mulching[2]				
0M	19.85^{c}	18.69^{b}	20.32^{c}	12.44^{d}
3M	22.41^{b}	18.93^{b}	22.87^{c}	15.83^{c}
5M	24.21^{b}	18.65^{b}	24.99^{ab}	17.92^{b}
7M	26.71^{a}	20.48^{a}	27.08^{a}	20.39^{a}

[1] Tillage: NT= No-tillage; PR= Ridging in the slope direction; IR= Isohypse Ridging

[2] Mulching: 0M= 0 t ha^{-1} of mulch; 3M= 3 t ha^{-1} of mulch; 5M= 5 t ha^{-1} of mulch; 7M= 7 t ha^{-1} of mulch

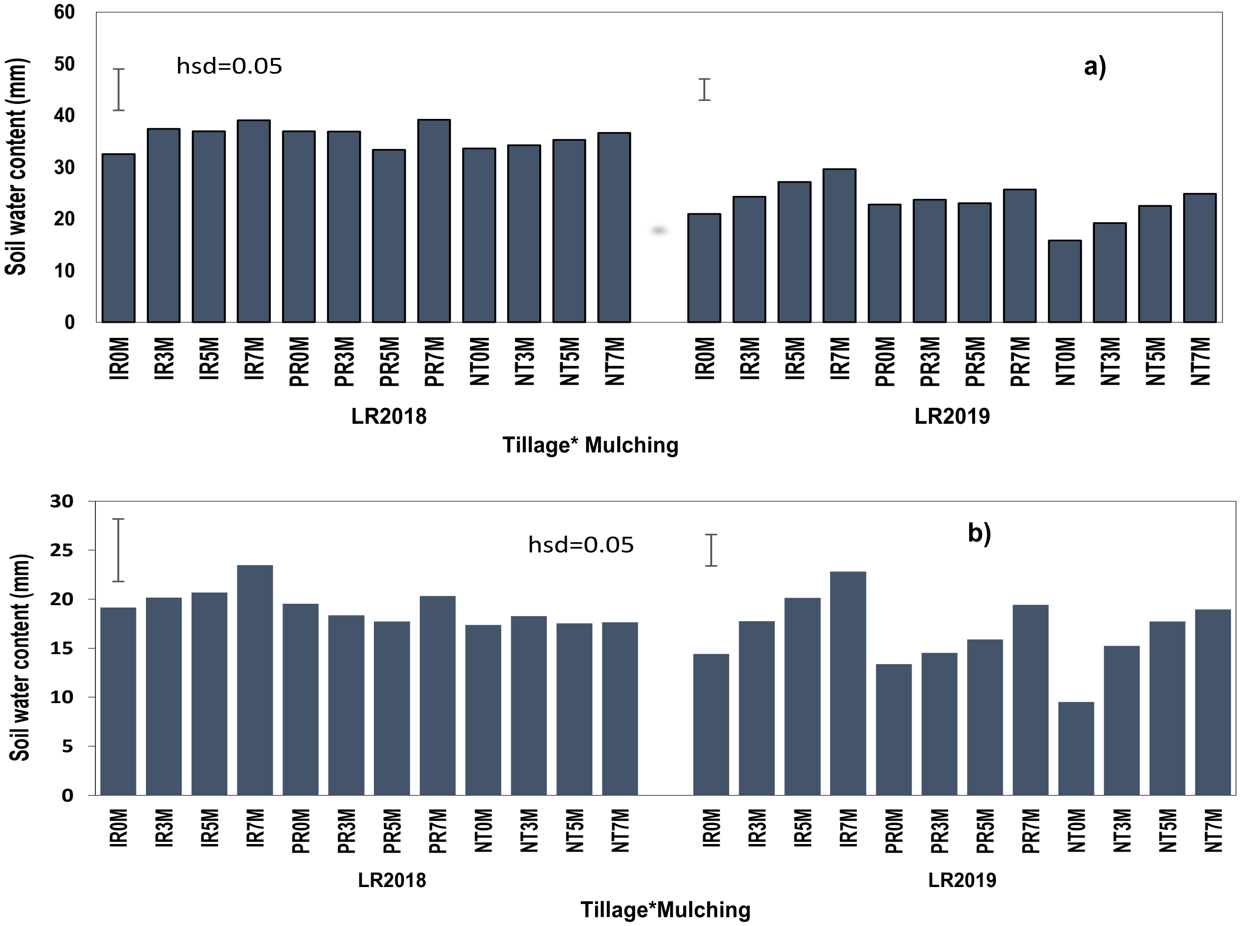


Figure 3. Interactive effect of tillage and mulching on soil water content during LR2018 and LR2019 seasons at a) Dan and b) Za-zounmè. Significant differences of the post hoc Tukey's HSD test performed in case of effects if the model were significant (p≤0.05). Error bars indicate the Honestly Significant Difference value.

IR0M= Isohypse ridging+0 t ha^{-1} of mulch; IR3M= Isohypse ridging+3 t ha^{-1} of mulch; IR5M= Isohypse ridging+5 t ha^{-1} of mulch; IR7M= Isohypse ridging+7 t ha^{-1} of mulch; PR0M= Ridging in the slope direction +0 t ha^{-1} of mulch; PR3M Ridging in the slope direction +3 t ha^{-1} of mulch; PR5M= Ridging in the slope direction+5 t ha^{-1} of mulch; PR7M= Ridging in the slope direction +7 t ha^{-1} of mulch; NT0M= No-tillage+0 t ha^{-1} of mulch; NT3M= No-tillage+3 t ha^{-1} of mulch; NT5M= No-tillage+5 t ha^{-1} of mulch; NT7M= No-tillage+7 t ha^{-1} of mulch.

practice, the water content increased with the mulch amount. At Dan, no significant difference was obtained between the treatments IR3M; PR0M; PR3M; PR5M; PR7M and NT5M in LR2018 whereby an average soil water content of 23 mm was obtained. During LR2019, the water content was lower than LR2018 and no significant difference was found between NT0M; NT3M; NT5M and NT7M. At Za-zounmè, the water content obtained with the treatments IR0M; PR0M (13.38 mm); PR3M (14.52 mm); PR5M (15.89 mm) and NT3M (15.23 mm) was statistically equal during LR2018. In opposite to Dan, the water content was high in LR2019 than LR2018 at Za-zounmè. During LR2019, IR3M (24.29 mm); PR3M (23.72 mm); PR5M (23.00 mm); NT5M (22.49 mm); NT7M (22.82 mm) were statistically equal (Figure 3).

Variation of the soil water content during the growing season of maize

There was some fluctuation in the soil water content during the maize growing season at the both studied sites. In general, the significant effect of tillage, mulch amounts and tillage x mulch amounts were associated with the low soil water content level. The effect of tillage was significant on the 15th day during the LR2018 and from 15th to the 90th days after sowing during the LR2019 at Dan (Figure 4a). At Za-zounmè, the tillage effect was significant from the 15th to 45th while it was from 75th to 105th days after sowing (DAS) in LR2018 season and from 15th to the 60th and on the 105th DAS in the LR2019 season (Figure 4b). The soil water content was slightly higher on the IR and PR compared with the No-Tillage on the vegetative stage (from 0th the 45th days after sowing) and on the grain formation and ripening phase of the maize (from the 45th to the 105th DAS). As far as mulching effect is concerned, it was found out that a significant effect on the 15th, 30th and 45th DAS in the LR2018 season and on the 15th, 30th, 45th, 75th and 90th DAS in the LR2019 season at Dan (Figure 5a). Comparatively higher soil water contents were obtained on the mulch applied plot than the 0 t ha^{-1} mulch. However, on the days with significant effect of the mulch amounts, the water content recorded on the plot with 5 and 7 t ha^{-1} were not significantly different. On the site of Za-zounmè, the mulch amounts significantly influenced the soil water content on the 15th, 30th, 45th, 75th and 90th days after sowing in the LR2018 and on the 15th, 15th, 30th, 45th, 60th, 75th 90th and 105th days after sowing in the LR2019 season (Figure 5b). In contrast with of the trend observed at Dan, the soil water content significantly increased with the mulch amounts and significant difference was observed between the water content recorded on the plot with 3, 5 and 7 t ha^{-1}. The interactive effect of tillage and mulching (Tillage x mulching) was significant of the soil water content on the 15th, 45th, 60th and the 90th days after sowing in the LR2018 and on the 15th, 30th, 45th, 75th, 90th and 105th days after in the LR2019 season at Dan (Figure 6a). However, at Za-zounmè, the effect was significant on the 30th, 45th, 75th, and 90th in the LR2018 season and on the 15th, 30th, 45th, 60th, 75th, 90th and 105th days after sowing in the LR2019 (Figure 6b). During the both studied growing seasons of maize, the highest soil water contents were recorded with IR7M and IR5M at Dan and with IR7M at Za-zounmè.

Influence of soil tillage mulching on maize growth

Growth speed

Tillage and mulching have significantly influenced the growth speed of maize during the both Long rain seasons (LR2018 and LR2019). The highest maize growth speed was observed with Isohypse Ridging (IR) during the two trial seasons in the both sites (Table 3). At Dan, the growth speed was significantly increased by 7% under IR and PR compared with the NT during both LR2018 and LR2019 seasons. At Za-zounmè, IR significantly increased growth speed by 8% during LR2018 season and by 29% during LR2019 season compared with NT. The influence of the mulching was significant on the growth speed of maize at the both sites during the two trial seasons. At Dan and Za-zounmè, it was observed an increasing effect of the mulch amount on the growth speed of the maize. The highest maize growth speed was obtained when 7 t.ha^{-1} mulch were applied and the lowest growth speed was obtained on the plot with 0 t.ha^{-1} mulch. The interactions' (Tillage x Mulching) had no significant effect on the maize growth speed in LR2019 season (Table 4). Conversely, its influence was significant on maize growth speed on the both sites in LR2018 season. During the both trial seasons, the highest growth speed was obtained with the IR7M treatment. In LR2018 season, it was found out that at Dan there is no-statistical difference between the treatments IR0M (2.72 cm.day^{-1}); NT0M (2.46 cm.day^{-1}) and PR0M (2.62 cm.day^{-1}) which led to the lowest growth speed. Also, the difference between the treatments IR3M (3.17 cm.day^{-1}); IR5M (3.31 cm.day^{-1}); NT3M (3.17 cm.day^{-1}); NT5M (3.24 cm.day^{-1}) and PR3M (3.06 cm.day^{-1}) was no-significant. However, treatment IR7M lead to the highest growth speed (4.05 cm.day^{-1}) at Dan. Similarly, at Za-zounmè, the lowest maize speed growth was observed with the treatment NT0M (3.43 cm.day^{-1}) and the highest maize speed growth was observed with the treatment IR7M (4.85 cm.day^{-1}). The treatments IR0M; IR3M; NT3M; NT5M and PR3M were found to be statistically equal and led to 3.60 cm.day^{-1} in average.

Relative chlorophyll content

Tillage and mulching have significantly influenced maize

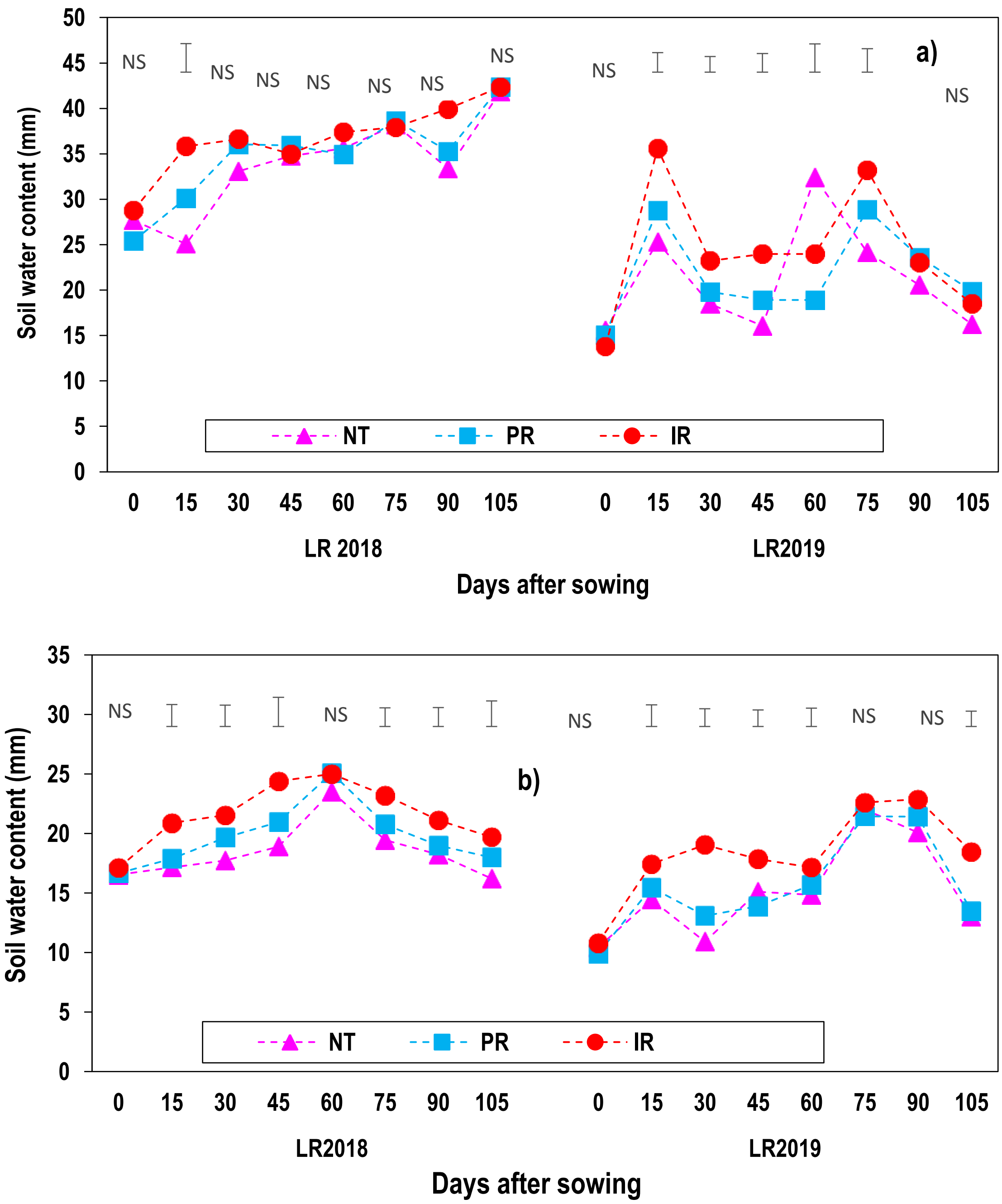


Figure 4. Effect of tillage on soil water content distribution during LR2018 and LR2019 seasons at a) Dan and b) Za-zounmè. NT= No-tillage; PR= Ridging in the slope direction; IR= Isohypse Ridging. Significant differences of the post hoc Tukey's HSD test performed in case of effect if the model was significant ($p < 0.05$). Error bars indicate the Minimum Significant Difference value. NS= not significant.

leaves chlorophyll content (Chl) on the 30th Days After Sowing (6th leaf stage) and 60th Days After Sowing (10th leaf stage) at both sites during the LR2018 season. During the LR2019 season, tillage significantly influenced chlorophyll levels in maize leaves at the 6th leaf stage at Dan and at the 10th leaf stage at Za-zounmè (Table 3). The effect of mulching was significant at the 6th leaf stage at Za-zounmè at the 10th leaf stage at Dan and Za-zounmè. At the 6th leaf stage, Chl content was significantly higher under IR and PR of 26% compared to NT at Dan and 17 and 7% compared with NT at Za-zounmè during the LR2018 season. During the LR2019 season, Chl content was also significantly higher under IR and PR of 18 and 13% compared to NT at Dan and 19 and 11%

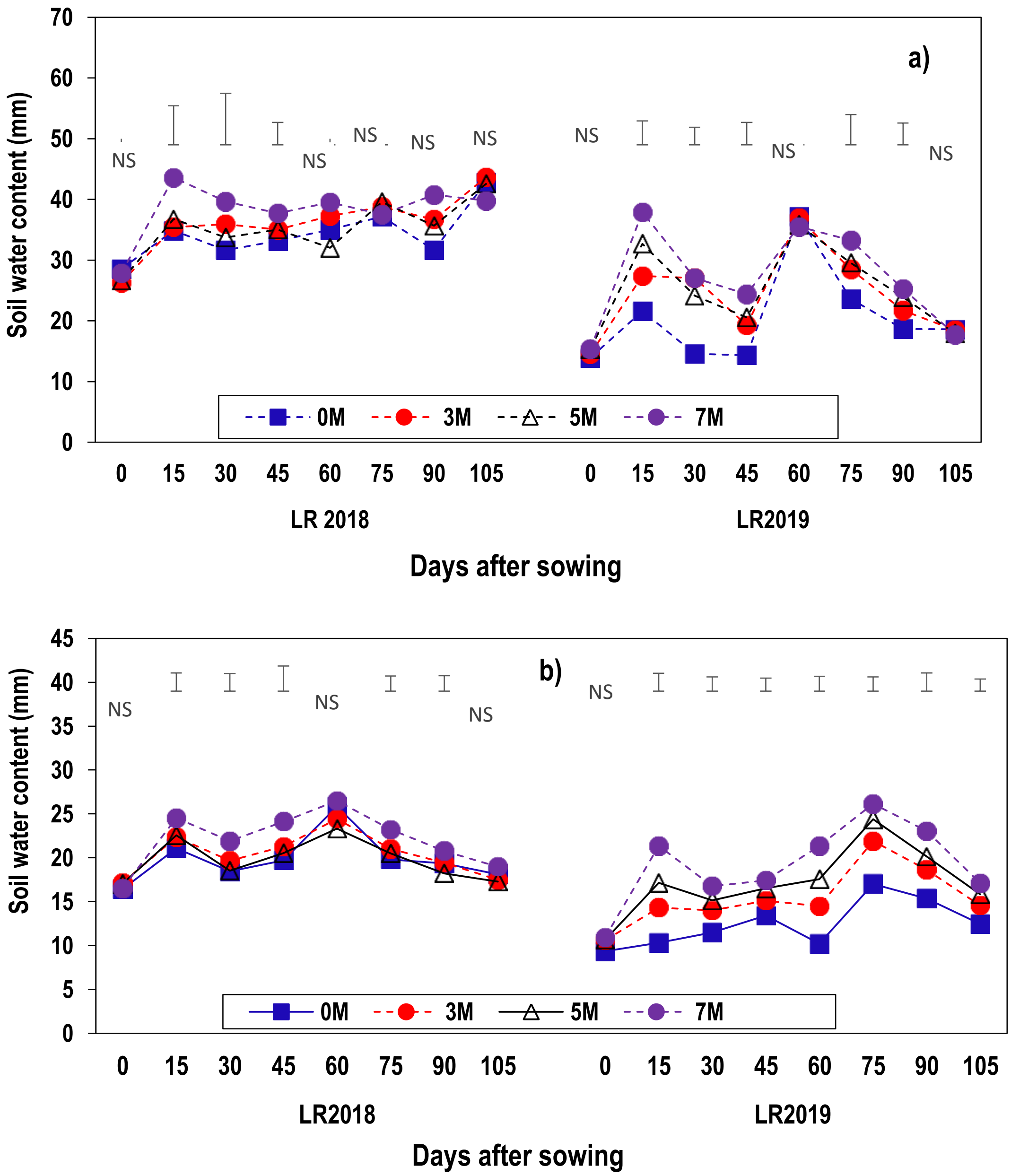
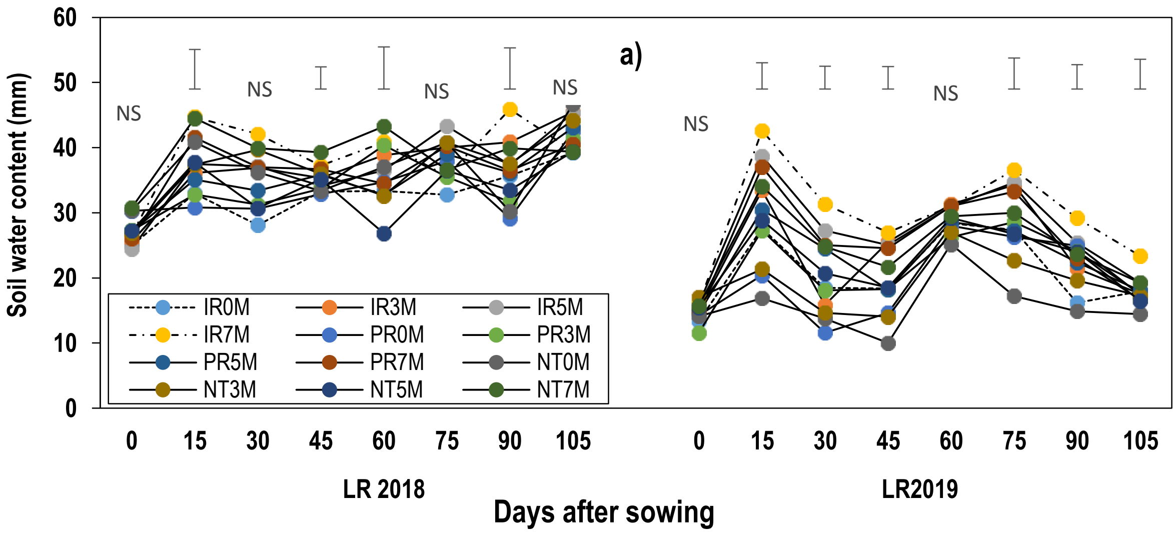


Figure 5. Effect of Mulching on soil water content distribution during LR2018 and LR2019 seasons at a) Dan and b) Za-zounmè. 0M= 0 t ha^{-1} of mulch; 3M= 3 t ha^{-1} of mulch; 5M= 5 t ha^{-1} of mulch; 7M= 7 t ha^{-1} of mulch. Significant differences of the post hoc Tukey's HSD test performed in case of effect if the model was significant ($p < 0.05$). Error bars indicate the Minimum Significant Difference value. NS= not significant.

compared to NT at Za-zounmè. For mulching, the strongest Chl content was observed with 7 $t.ha^{-1}$ mulch except at Za-zounmè where the strongest Chl content was obtained with 5M during the LR2018 season. Compared with the plot without mulch (0 $t.ha^{-1}$ mulch), 7, 5, and 3 $t.ha^{-1}$ mulch significantly increased content Chl by 23%, 17% and 8% at Dan and by 3, 15 and 3% at Za-zounmè during the LR2018 season. During the LR2019 season, Chl content grew significantly by 22, 16, and 13% under 7; 5 and 3 $t.ha^{-1}$ mulch compared with 0 $t.ha^{-1}$ mulch at Dan and 24, 20 and 8% under 7; 5 and 3 $t.ha^{-1}$ mulch compared with 0 $t.ha^{-1}$ mulch at Za-zounmè. The interactive effect (Tillage x Mulching) was significant only at Za-zounmè during the LR2018 season (Table 4). Isohypse ridging associated with 7 $t.ha^{-1}$ mulch (IR7M) yielded the highest Chl content in the 6th leaf stage of maize leaves. As for the 10th leaf stage, the content was significantly higher under IR and PR compared to NT at



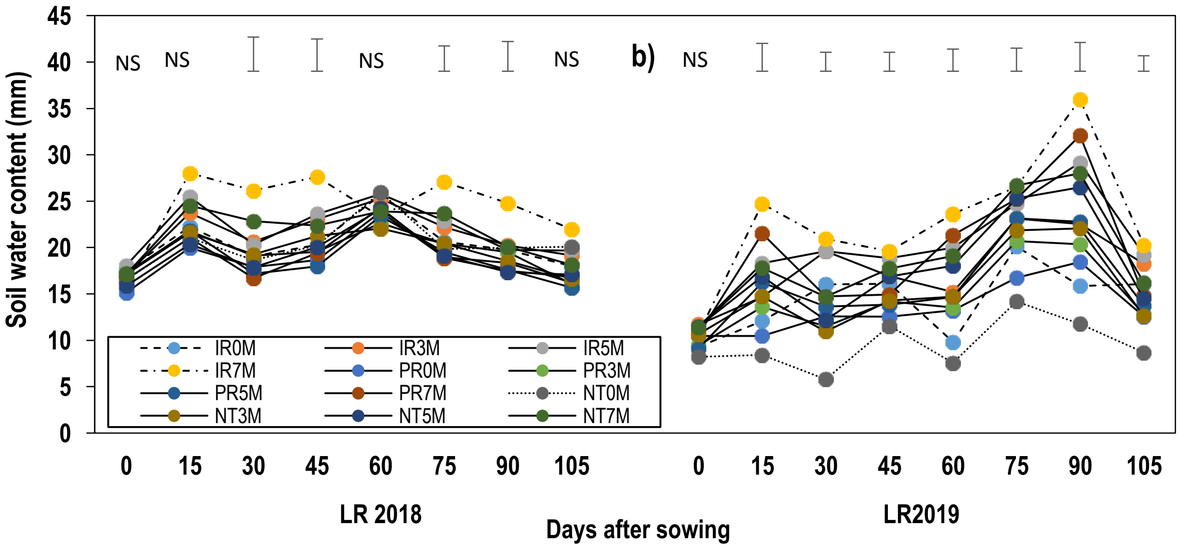


Figure 6. Interactive effect of tillage and mulching on soil water content distribution during LR2018 and LR2019 seasons at a) Dan and b) Za-zounmè. IR0M= Isohypse ridging+0 t ha^{-1} of mulch; IR3M= Isohypse ridging+3 t ha^{-1} of mulch; IR5M= Isohypse ridging+5 t ha^{-1} of mulch; IR7M= Isohypse ridging +7 t ha^{-1} of mulch; PR0M= Ridging in the slope direction +0 t ha^{-1} of mulch; PR3M Ridging in the slope direction + 3 t ha^{-1} of mulch; PR5M= Ridging in the slope direction+5 t ha^{-1} of mulch; PR7M= Ridging in the slope direction +7 t ha^{-1} of mulch; NT0M= No-tillage+0 t ha^{-1} of mulch; NT3M= No-tillage+3 t ha^{-1} of mulch; NT5M= No-tillage + 5 t ha^{-1} of mulch; NT7M= No-tillage+7 t ha^{-1} of mulch . Significant differences of the post hoc Tukey's HSD test performed in case of effect if the model was significant ($p < 0.05$). Error bars indicate the Minimum Significant Difference value. NS= not significant.

both sites for both seasons. The highest Chl content was obtained with isohypse ridging (31.52 and 34.79 respectively at Dan and Za-zounmè). Regarding mulching, the highest value was obtained under 7 t.ha^{-1} mulch at Dan during the two seasons and at Za-zounmè during the LR2019 season. During the LR2018 season, the highest value of Chl content at the 10th leaf stage was observed under 5M. The interactive effect (Tillage x Mulching) was not significant on the Chl content at the 10th leaf stage at both Dan and Za-zounmè sites and during both seasons.

Influence of soil tillage and mulching on maize yield

Grain yield

Tillage, mulch amount and their interaction (Tillage x mulching) significantly influenced the grains yield of maize at the both investigated sites. During the both LR2018 and LR2019 seasons, Isohypse Ridging recorded the highest grain yield (Table 3). PR increased in average the grain yield by 4% in LR2018 and by 22% in LR2019, compared with NT. However, the difference between the

Table 3. Simple effects of tillage and mulching on maize growth and yield at Dan and Za-zounmè during LR2018 and LR2019 seasons.

Modalities	LR2018						LR2019					
	Growth speed (cm. day^{-1})	Relative chlorophyll content at 30 after sowing	Relative chlorophyll content at 60 after sowing	Grains Yield (kg.ha^{-1} Dry matter)	Straw Yield (kg .ha^{-1} Dry matter)	Harvest index	Growth speed (cm. day^{-1})	Relative chlorophyll content at 30 after sowing	Relative chlorophyll content at 60 after sowing	Grains Yield (kg. ha^{-1} Dry matter)	Straw Yield (kg.ha^{-1} Dry matter)	Harvest index
						Dan						
Tillage[1]												
NT	3.05^{b}	26.26^{b}	34.50^{b}	2040.25^{b}	2219.47^{b}	0.48^{a}	3.11^{b}	27.26^{b}	32.53^{c}	2289.42^{c}	2594.67^{b}	0.45^{b}
PR	3.29^{a}	30.67^{a}	36.73^{a}	2145.71^{b}	2797.85^{a}	0.43^{b}	3.35^{ab}	30.81^{a}	35.97^{b}	2781.43^{b}	2805.54^{b}	0.52^{a}
IR	3.31^{a}	31.96^{a}	37.04^{a}	2569.27^{a}	2771.62^{a}	0.47^{a}	3.52^{a}	32.28^{a}	38.65^{a}	3185.50^{a}	3304.42^{a}	0.48^{ab}
Mulching[2]												
0M	2.59^{d}	26.48^{b}	34.23^{b}	1880.50^{c}	2047.28^{d}	0.49^{a}	2.94^{b}	26.67^{c}	31.55^{c}	2055.72^{b}	2403.81^{c}	0.46^{b}
3M	3.13^{c}	28.63^{ab}	35.34^{b}	2178.65^{b}	2334.26^{c}	0.47^{ab}	3.01^{b}	30.20^{b}	34.16^{b}	2394.12^{b}	2563.14^{bc}	0.48^{ab}
5M	3.51^{b}	30.88^{a}	39.25^{a}	2343.17^{b}	2686.07^{b}	0.47^{ab}	3.62^{a}	31.05^{ab}	37.98^{a}	3157.43^{a}	2942.83^{b}	0.52^{a}
7M	3.81^{a}	32.52^{a}	35.34^{b}	2604.84^{a}	3317.65^{a}	0.44^{b}	3.73^{a}	32.55^{a}	39.18^{a}	3401.21^{a}	3695.02^{a}	0.48^{ab}
						Za-zounmè						
Tillage[1]												
NT	3.72^{b}	34.50^{b}	30.87^{b}	2791.30^{b}	3086.1^{c}	0.48^{a}	3.02^{c}	32.53^{c}	27.98^{c}	2121.27^{b}	2392.75^{b}	0.45^{a}
PR	3.80^{b}	36.73^{a}	32.06^{b}	2891.95^{b}	3482.04^{b}	0.46^{ab}	3.53^{b}	35.97^{b}	30.62^{b}	2472.38^{b}	2939.43^{ab}	0.47^{a}
IR	4.02^{a}	37.04^{a}	34.79^{a}	3174.12^{a}	4331.54^{a}	0.42^{b}	3.89^{a}	38.65^{a}	35.08^{a}	3108.51^{a}	3644.13^{a}	0.46^{a}
Mulching[2]												
0M	3.53^{c}	34.23^{b}	30.20^{a}	2514.52^{d}	2926.1^{c}	0.46^{a}	3.19^{b}	31.55^{c}	28.62^{b}	1808.06^{c}	2611.70^{c}	0.42^{a}
3M	3.67^{bc}	35.34^{b}	33.02^{ab}	2775.34^{c}	3687.07^{b}	0.43^{b}	3.37^{b}	34.16^{b}	31.24^{ab}	2230.81^{bc}	2569.55^{c}	0.52^{a}
5M	3.88^{b}	39.25^{a}	34.28^{a}	2953.39^{b}	4100.50^{a}	0.43^{b}	3.50^{ab}	37.98^{a}	32.03^{a}	2788.12^{ab}	3029.65^{b}	0.48^{a}
7M	4.33^{a}	35.34^{b}	32.79^{ab}	3566.57^{a}	4003.28^{a}	0.47^{a}	3.83^{a}	39.18^{a}	33.00^{a}	3375.62^{a}	4217.11^{a}	0.44^{a}

[1] **Tillage: NT**: no-tillage; **PR**: ridging parallel to the slope; **IR**: Isohypse ridging; [2] **Mulching: 0M**: 0 t ha^{-1} of Mulch; **3M:** 3 t ha^{-1} of Mulch; **5M**: 5 t ha^{-1} of Mulch; **7M**: 7 t ha^{-1} of Mulch. For each factor, same superscript letters denote no significant difference between the means at a given site. Different letters indicate significant differences of the post hoc Tukey's HSD test performed in case effects if the model were significant ($p \leq 0.05$).

grain yield obtained with ridging parallel to the slope (PR) and those obtained on No-Tillage (NT) were not statistically significant in LR2018. Conversely, the difference was significant in LR2019. Mulch amount significantly increased the maize grains yield. For both studied sites, the highest grains yield was obtained when 7 t.ha^{-1} mulch was applied while the least mean values was obtained with 0 t.ha^{-1} mulch. But it is statistically remarkable that the difference between 3, 5 and 7 t.ha^{-1} mulch was not significant at Dan contrarily to Za-zounmè where the difference between the mulch amounts was significant. The means of grain yield obtained under the interactive effect of tillage and mulching (treatments) are presented in Table 4. As it can be seen, the treatments IR7M gave the highest grains yield at Dan (2991.15 and 4475.31 kg.ha^{-1} DM respectively in LR2018 and LR2019 seasons) and Za-zounmè (3648.74 and 4722.62 kg.ha^{-1} DM respectively in LR2018 and LR2019 seasons) whereas, the smallest maize grains yield were obtained with the treatments PR0M and NT0M at the both site throughout the study period. In general,

Table 4. Interactive effect of tillage and mulch amounts on maize growth and yield at Dan and Za-zounmè during LR2018 and LR2019 seasons.

	LR2018						LR2019					
Treatments	**Growth speed (cm.day^{-1})**	**Chlorophyll content at 30 after sowing**	**Chlorophyll content at 60 after sowing**	**Grains yield (kg.ha^{-1} Dry matter)**	**Straw Yield (kg.ha^{-1} Dry matter)**	**Harvest index**	**Growth speed (cm.day^{-1})**	**Chlorophyll content at 30 after sowing**	**Chlorophyll content at 60 after sowing**	**Grains Yield (kg.ha^{-1} Dry matter)**	**Straw yield (kg.ha^{-1} dry matter)**	**Harvest index**
						Dan						
IR0M	2.72^{e}	26.78^{bc}	24.29^{d}	2102.36^{def}	2258.58^{gh}	0.48^{b}	2.91^{a}	26.76^{a}	26.66^{a}	2052.34^{de}	2696.16^{bcd}	0.43^{b}
IR3M	3.17^{d}	30.66^{abc}	29.58^{abc}	2540.04^{bc}	2373.43^{fg}	0.51^{ab}	3.52^{a}	27.83^{a}	28.41^{a}	2526.61^{cd}	2790.51^{bcd}	0.48^{ab}
IR5M	3.31^{d}	33.31^{ab}	34.94^{ab}	2643.53^{ac}	2828.27^{cd}	0.48^{b}	3.70^{a}	27.02^{a}	28.85^{a}	3687.92^{b}	3167.68^{bc}	0.54^{ab}
IR7M	4.06^{a}	37.09^{a}	37.28^{a}	2991.15^{a}	3626.21^{a}	0.45^{c}	3.83^{a}	33.30^{a}	33.69^{a}	4475.31^{a}	4563.15^{a}	0.50^{ab}
PR0M	2.62^{e}	30.16^{abc}	27.96^{abc}	1780.96^{f}	2505.18^{efg}	0.41^{e}	3.03^{a}	31.22^{a}	28.60^{a}	2493.62^{cde}	2729.93^{bcd}	0.48^{ab}
PR3M	3.06^{d}	28.97^{abc}	29.63^{abc}	2078.02^{def}	2580.57^{de}	0.45^{c}	3.25^{a}	33.58^{a}	31.85^{a}	$2602.^{cd}$	2413.6^{cd}	0.52^{ab}
PR5M	3.67^{bc}	29.53^{abc}	30.33^{abc}	2278.57^{cde}	2817.99^{cd}	0.46^{c}	3.33^{a}	30.41^{a}	31.75^{a}	3165.62^{bc}	2379.08^{cd}	0.59^{a}
PR7M	4.00^{ab}	34.00^{ab}	37.42^{a}	2445.31^{bcd}	3287.66^{b}	0.43^{d}	3.73^{a}	33.14^{a}	34.43^{a}	2863.8^{bcd}	2856.29^{bcd}	0.50^{ab}
NT0M	2.46^{e}	22.5^{ac}	21.40^{d}	1758.11^{f}	1378.07^{i}	0.56^{a}	2.90^{a}	28.88^{a}	27.84^{a}	1621.2^{e}	1785.32^{d}	0.47^{ab}
NT3M	3.17^{d}	26.27^{cd}	25.97^{abc}	1917.9^{ef}	2048.78^{h}	0.48^{b}	2.99	28.10^{a}	28.7^{a}	2053.17^{de}	2485.32^{bcd}	0.45^{b}
NT5M	3.24^{d}	29.81^{abc}	33.61^{ab}	2107.16^{efd}	2411.94^{fg}	0.47^{b}	3.36^{a}	31.68^{a}	31.48^{a}	2618.75^{cd}	3281.73^{bc}	0.44^{b}
NT7M	3.36^{cd}	26.45^{bc}	32.03^{abc}	2377.81^{bcd}	3039.08^{bc}	0.44^{d}	3.31^{a}	30.25^{a}	33.6^{a}	2864.57^{bcd}	3665.63^{ab}	0.44^{b}
						Za-zounmè						
IR0M	3.65^{bcd}	35.23^{abc}	30.81^{ab}	2674.2^{e}	3421.13^{cd}	0.44^{cdef}	2.86^{a}	33.61^{a}	31.22^{a}	1926.33^{c}	2520.78^{bc}	0.45^{a}
IR3M	3.67^{bcd}	34.67^{abc}	34.54^{ab}	3101.18^{cd}	4514.22^{a}	0.41^{f}	3.45^{a}	34.97^{a}	32.69^{a}	2397.10^{bc}	2776.81^{bc}	0.46^{a}
IR5M	3.94^{bc}	37.90^{abc}	37.75^{a}	3272.36^{bc}	4520.62^{a}	0.40^{f}	3.71^{a}	34.19^{a}	31.16^{a}	3087.07^{b}	3433.65^{bc}	0.47^{a}
IR7M	4.85^{a}	40.37^{ab}	36.09^{ab}	3648.74^{a}	4870.19^{a}	0.45^{bcde}	4.02^{a}	37.93^{a}	34.51^{a}	4722.62^{a}	5511.84^{a}	0.46^{a}
PR0M	3.52^{cd}	34.58^{abc}	28.59^{b}	2765.05^{e}	3067^{de}	0.47^{abcd}	2.79	31.59^{a}	29.85^{a}	1800.31^{c}	3076.55^{bc}	0.49^{a}
PR3M	3.67^{bcd}	36.37^{abc}	33.16^{ab}	2484.7^{e}	3248.35^{cd}	0.40^{f}	3.38^{a}	35.02^{a}	33.87^{a}	2442.44^{bc}	2869.21^{bc}	0.47^{a}
PR5M	3.95^{bc}	41.68^{a}	32.76^{ab}	2803.2^{de}	3800.30^{b}	0.46^{abcd}	3.48^{a}	34.63^{a}	32.94^{a}	2313.11^{bc}	3082.39^{bc}	0.46^{a}
PR7M	4.08^{b}	34.28^{abc}	33.74^{ab}	3514.83^{ab}	3812.52^{b}	0.48^{abc}	3.77^{a}	36.16^{a}	33.79^{a}	3083.72^{b}	3729.58^{b}	0.47^{a}
NT0M	3.43^{d}	32.87^{bc}	31.23^{ab}	2104.31^{f}	2290.15^{f}	0.48^{abcd}	2.63^{a}	29.44^{a}	24.84^{b}	1700.22^{c}	2082.80^{bc}	0.46^{a}
NT3M	3.66^{bcd}	34.97^{abc}	31.36^{ab}	2740.15^{e}	2746.67^{e}	0.50^{a}	3.39^{a}	34.68^{a}	30.08^{a}	1727.02^{c}	1893.71^{c}	0.47^{a}
NT5M	3.77^{bcd}	38.18^{abc}	32.34^{ab}	2784.61^{e}	3630.86^{b}	0.43^{efd}	3.67^{a}	36.82^{a}	29.4^{a}	3122.32^{b}	2553.73^{bc}	0.45^{a}
NT7M	4.04^{b}	31.97^{c}	28.55^{b}	3536.12^{ab}	3676.71^{b}	0.49^{ab}	3.66^{a}	37.56^{a}	33.02^{a}	1968.92^{c}	3140.77^{bc}	0.46^{a}

NT0M: No tillage + 0 t ha^{-1} of mulch; **NT3M**: No tillage + 3 t ha^{-1} of mulch; **NT5M:** No tillage + 5 t ha^{-1} of mulch; **NT7M:** No tillage + 7 t ha^{-1} of mulch; **PR0M:** Ridging parallel to the slope + 0 t ha^{-1}; **PR3M :** Ridging parallel to the slope + 3 t ha^{-1} of mulch; **PR5M** : Ridging parallel to the slope + 5 t ha^{-1} of mulch; **PR7M** : Ridging parallel to the slope + 7 t ha^{-1} of mulch; **IR0M :** Isohypse ridging + 0 t ha^{-1} of mulch; **IR3M :** Isohypse ridging + 3 t ha^{-1} of mulch; **IR5M:** Isohypse ridging + 5 t ha^{-1} of mulch; **IR7M**: Isohypse ridging + 7 t ha^{-1} of mulch.

the grain yield was greater in LR2019 season than in LR2018 season at Dan while LR2018 yielded to great grains compared with LR2019 at Za-zounmè.

Straw yield

Mean straw yield of maize under the different tillage practice, mulch amount and their interactions are shown in Tables 3 and 4. Tillage showed significant ($p < 0.05$) difference in straw yield of maize at Dan and Za-zounmè with the lowest values of 2407.07 and 2739.43 kg. ha^{-1}, respectively, being observed under No-Tillage (NT) whereas the largest values of 2978.56 and 3987.84 $kg.ha^{-1}$, respectively, were obtained Isohypse ridging (IR) in average over the two investigated season. There were significant variations ($p < 0.05$) among the different mulch amount. The greatest maize straw yield was observed under the plot with 7 $t.ha^{-1}$ mulch. On the other hand, smallest yield of maize straw was observed under 0 $t.ha^{-1}$ mulch throughout the LR2018 and LR2019 seasons. Tillage and mulch amount interacted to influence significantly the maize straw yield over the both investigated cropping seasons. The largest value was obtained under isohypse ridging with 7 $t.ha^{-1}$ mulch (4094.68 $kg.ha^{-1}$ in average at Dan and 5191.02 $kg.ha^{-1}$ in average at Za-zounmè over LR2018 and LR2019). Similar to the grain yield, the straw yield was greater in LR2019 season than in LR2018 season at Dan while LR2018 yielded to great straw compared with LR2019 at Za-zounmè.

Harvest index

According to the ANOVA results, the maize harvest index was significantly ($p < 0.05$) affected by tillage, mulch amount and their interaction at Dan throughout the both investigated seasons. The harvest index was higher under No-tillage (NT) and Isohypse Ridging (IR) in LR2018 (0.48 and 0.47 respectively) whereas the highest values were observed under ridging parallel to the slope (PR) and Isohypse Ridging (IR) in LR2019 (0.52 and 0.48 respectively) (Table 3). As far as the effect of mulch amount is concerned, the smallest harvest index was obtained under 7 $t.ha^{-1}$ mulch in LR2018 season and under 0 $t.ha^{-1}$ mulch in LR2019 season. Tillage and mulch amount interacted to influence significantly the maize straw yield at Dan over the investigated cropping seasons.

No-tillage associated with 0 $t.ha^{-1}$ (0.56) in LR2018 season and ridging parallel to the slope associated with 5 $t.ha^{-1}$ (0.59) in LR2019 season yielded the highest harvest index. At Za-zounmè, the effects of the different factors under study were significant on the maize harvest index only in LR2018 season. The harvest index was highest under No-tillage (0.48) and lowest under Isohypse Ridging (0.42) in LR2018 at Za-zounmè. For the mulching treatments, 0 $t.ha^{-1}$ and 7 $t.ha^{-1}$ mulch yielded the great harvest index. Similarly to the site of Dan, the interactive effect of tillage and mulching was significant in the LR2018 season (Table 4). Isohypse Ridging associated with 5 $t.ha^{-1}$ mulch (IR5M); Isohypse Ridging associated with 3 $t.ha^{-1}$ mulch (IR3M) and ridging parallel to the slope associated with 3 $t.ha^{-1}$ (PR3M) yielded the lowest harvest index.

DISCUSSION

Water constitutes a key factor for crops growth and yield (Mansouri et al., 2010). Over the two investigated cropping seasons, the rainfall patterns were quite different at both sites. At Dan, total seasonal rainfall for both LR2018 and LR2019 was below the long-term average of 572.34 mm. Also, total seasonal rainfall recorded was low than the long-term average of 670.12 mm at Za-zounmè. From the sowing date to the vegetative stage of the maize, 213.66 and 397.5 mm were recorded during the LR2018 whereas 250.3 and 388.6 mm were recorded during the LR2019 respectively at Dan and at Za-zounmè. These rainfall values are below the 450 mm needed for optimal maize growth. This implies that maize mays need supplementary water input as water control plant phenological, physiological and morphological (Pandey et al., 2000).

The results of this study show that tillage and mulching significantly influence water content of soil, maize growth as well as its yield components. The highest soil moisture values were obtained under Isohypse ridging whereas the lowest were obtained under No-tillage at both sites during the two investigated cropping seasons. Consequently, IR allowed the highest maize growth, grain and straw yield compared with Ridging parallel (PR) to the slope and No-Tillage (NT). This may be due to the fact that in Isohypse Ridging system, ridges are made following the contour lines and acts as obstacle for runoff by reducing the velocity of water and maintain it onsite. Contour ridges constitute water conservation and erosion control practice used to increase surface run-off storage near the cropped area, in contrast to the flat tillage and ridging parallel to the slope over some area in Africa (Uwizeyimana et al., 2018; Akplo et al., 2019b). It may also due to the fact that NT practices are used at first time on the experimental sites. These findings are similar to those of Basch et al. (2008) and Pittelkow et al. (2015) which notified a decrease in crop yield and an increase in runoff and soil loss during the establishment of NT. Mekhlouf et al. (2011) found that there is no significant difference between different tillage practices on grain and straw yields in wheat. Hountongninou (2016) reported that tillage does not significantly affect maize grain yield and justified this by the sandy-clayey texture of its study site, which provides a similar environment under plowing. Although NT is recognized as one of the Conservation Agriculture practices (Lal, 2004; Reicosky and Saxton, 2007; Martínez et al., 2008; Tabaglio et al., 2009; Kolb et al., 2012; Soane et al., 2012; Fiorini et al., 2018), its adoption requires a transition phase (on average 7-8 years), characterized by higher annual weed and disease pressures, slow rebuilding aggregates in soil, and lower and variable yields (Knowler and Bradshaw, 2007; Pagnani et al., 2019). However, as outlined in Sharma and Abrol (2005), soil types react differently to the same tillage method. That certainly why the grain yield had significantly decreased by 708.8 kg.ha^{-1} under no-tillage at Za-zounmè, whilst it increased by 262.8 kg.ha^{-1} at Dan under no-tillage between 2018 and 2019. In addition, Results of this study revealed that significant effect of tillage on the soil moisture is associated with the low rainfall period where low soil contents were recorded. On other hand in case of high rainfall period, tillage effect was not significant. This demonstrates that IR can be used for drought and dry spells.

The mulching treatments resulted in a significant improvement in soil water content, maize growth and yield over the investigated cropping seasons at both experimental sites. Soil water content consistently increased with increase in surface cover across the three tillage practices. On other hand, the lowest values of soil moisture, growth speed, relative chlorophyll content, grain yield, straw yield and harvest index were obtained with 0 t.ha^{-1} mulch whereas the highest values were recorded with 5 and 7 t.ha^{-1} of mulch. One of the major roles played by mulch cover was probably reducing soil evaporation (Mupangwa et al., 2007). Hatfield et al. (2001) reported a reduction of 34-50% in soil water evaporation under residue mulching. Under the high rainfall of LR2018, the soil water contents under 0, 3 and 5 t.ha^{-1} mulch were not significantly different at Za-zounmè while significant difference was found in LR2019 where low rainfall were recorded. Our results are consistent with those of many researchers (Mupangwa et al., 2007; Barthès et al., 2010; Badou et al., 2013, Uwizeyimana et al., 2018; Akplo et al., 2019a). Over the two targeted cropping seasons, the highest water contents of soil are associated with a great maize growth and yield. Researchers agree on the advantages of the mulching practice. Mulch increases soil moisture and nutrients availability to plant roots in turn, leading to higher plant growth and yield (Muhammad et al., 2015; Qi et al., 2016). Also, the vegetation cover itself constitutes a source of organic matter which, after decomposition, increases the cation exchange capacity and the water retention capacity of the soil, which improves the nutrient supply of the soil (Pervaiz et al., 2009). Tillage and mulching significantly interacted on soil moisture, maize growth and yield. The interactive effect of tillage and mulch was significant on the 15th, 45th, 60th and the 90th days after sowing in the LR2018 and on the 15th, 30th, 45th, 75th, 90th and 105th days after in the LR2019 season at Dan while at Za-zounmè, significant effect was observed on the 30th, 45th, 75th and 90th during the LR2018 season and on the 15th, 30th, 45th, 60th, 75th, 90th and 105th days after sowing during the LR2019. In general, the periods with significant effect were associated with prolonged period of short precipitation resulting water deficiencies and lack of soil moisture. Overall, for each tillage practice, the water content increased with the mulch amount. Similar trends were observed with maize growth and yield. Mulch enhanced the effect of tillage whereby the highest values were found with the treatments Isohypse Ridging with at least 3 t.ha^{-1} mulch (IR3M, IR5M; IR7M), Ridging Parallel to the slope + 7 t.ha^{-1} mulch (PR7M) and No-tillage + 7 t.ha^{-1} mulch (NT7M) and while the treatment No-tillage + 0 t.ha^{-1} mulch NT0M load to the lowest values.

Conclusion

Water conservation constitutes a key challenge in crop productivity stabilization in rain-fed cropping systems in Sub-Saharan Africa. This study explored the effect of different tillage practices in combination with different crop residues amounts used as mulch on rain-fed maize growth and yield component and soil moisture. Findings from this study revealed that Isohypse Ridging saved water and improved maize growth and yield in the drought conditions comparatively to Ridging Parallel to the slope and No-Tillage over the investigated cropping seasons. Also a significant increase of water content of soil, maize growth and yield with an increased in mulch cover was observed whereby the highest values were obtained under 5 and 7 t.ha^{-1} mulch. Tillage and mulch amounts interacted significantly on water content of soil, maize growth and yield. Findings of this study showed the high values under isohypse ridging + 7 t.ha^{-1} mulch. This suggests that isohypse ridging associated with organic mulching could be at short time, an option to mitigate dry spells and drought and to improve local farmers' income in the area of low rainfall.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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