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Effects of Climate Smart Agricultural practices and Planting Dates on Maize Growth and Nutrient Uptake in Semi-Arid Tanzania

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Abstract

The shift of growing season's onset due to rainfall and seasonal variability are among the climate change impacts affecting agricultural productivity in semi-arid. Previous studies have also noted the seasonal variations in planting windows in semi-arid Tanzania. Because of such rainfall variability due to uncertainties of climate change, farmers face difficulties in determining the appropriate planting dates. Though, climate-smart agriculture (CSA) practices are reinforced to mitigate such climatic extremes and sustain crop production, there is limited information on the performance of CSA practices under the uncertainty of planting windows due to unpredictable rainfall on-set and patterns. This study assessed the effects of CSA practices at different planting windows on maize growth and nutrient uptakes at Mlali village of Dodoma, Tanzania. A split-plot experimental design was adopted, treatments involved CSA practices (*Chololo* pits, tied ridges, intercropping and Ox-cultivation – as a control) and/at planting windows (Early, Normal and Late planting). The planting windows were determined based on previous studies and Tanzania national weather forecasts. The results showed that, CSA practices had a significant ($p < 0.05$) effect on maize height and N nutrient uptake. Similar biomass and Mg nutrient uptake were significantly affected ($p < 0.05$) by both CSA practices and planting dates though Leaf Area Index (LAI) were significantly affected ($p < 0.05$) by planting windows. *Chololo* pits and tied ridges and late planting dates had the highest soil moisture, plant heights, and biomass. Ox-cultivation had a slight high N, K and Mg nutrient uptake followed with *Chololo* pits and tied ridges.

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Introduction

Globally, climate change and variability are the most climatic extremes which threatens food production and food security (Wheeler and von Braun, 2013; Porter *et al.*, 2014). In Sub Saharan Africa (SSA) shifts in the timing of rains due to increases in climate variability and extreme events has been a reason for low production and sometimes crop failures (Cairns *et al.*, 2013; Morton *et al.*, 2014). Early signs of climate change such as increase in temperature and drought spells hindered germination, plant development and yield in Southern and Eastern Africa (Cairns *et al.*, 2012, 2013).In Southern Africa, limited soil moisture was found to be the most climate extreme threatened and stressed crop growth and yield due to prolonged droughts (Thierfelder *et al.*, 2017).

Traditionally, number of practices has been done by farmers to address climatic change and variability (Majule *et al.*, 2012; Scherr, 2012). These practices include shifting cultivation, use of drought-tolerant varieties, use of ox-plows in land preparation and use of farmyard manure (Kimaro, 2016; Thierfelder *et al.*, 2017). Recently, climate Smart Agriculture (CSA) practices has been proposed as a climate resilient to mitigate concerns of food security and climate change challenges (FAO, 2013; Neufeldtetal.2013; Thierfelder *et al.*, 2017). CSA needs a holistic and integrative approaches to achieve its three main pillars: a). sustainably increasing agricultural productivity and incomes; b). Adapting and building resilience to climate change, andc). Reducing and/or eliminating greenhouse gas emissions (FAO, 2013).

Climate-smart agriculture (CSA) suggests appropriate land management practices that are resilient and adaptive among farmers to climate variability to mitigate climate change (Thornton, 2018; Kimaro *et al.*, 2019).

The greater resilience of the system qualifies the management practices that are able to overcome abiotic stressesas climate-smart. Notably, seasonal variations areamong the climate extremes due to unpredictable rainfall on-set, in-seasonal draught spells and cessation of rains (Mashingaidze *et al.*, 2012; Thierfelder *et al.*, 2017). These shift and unpredictable rainfall patterns, expose farmers in semiarid of Tanzania to uncertainty of practices and planting dates (Kimaro *et al.*, 2016; Nyagumbo *et al.*, 2013, 2017). Rainfall variability and inappropriate planting times, caused poor germination, wilting, poor grain filling, increased pest and disease incidences are among the risks farmers in central Tanzania encounter (Scherr, 2012).

Although, optimum planting date is a precursor for higher crop production due to its important role in plant physiology and yield of maize (Chisanga *et al.*, 2014;Kimaro *et al.*, 2016), but this needs a well understanding of its resilient systems which integrates both locally adaptive management practices and planting dates (Thornton *et al.*, 2014, 2018: Shrestha *et al.*, 2018).

Adoption of*in-situ* rain water harvesting management (IRWH) options in combination with planting windows may also be a resilient system which aligns with CSA practices (Kimaro *et al.*, 2018; Shrestha *et al.*, 2018).Integration of IRWH (in this study referred as CSA practices)with optimum planting dates can sustain increased food productivity in semi-arid areas (Mudatenguha *et al.*, 2014). Though, climate smart agriculture (CSA) practices are has been promoted to mitigate climate change effects for sustainable crop production, little information on the performance of CSA practices under the uncertainty of planting windows due to rainfall on-set of growing seasons.

This article summarizes various effects of CSA practices and planting dates on maize growth, development and plant nutrient uptake. This information may be useful for maize growers and researchers in semi-arid conditions.

Materials and methods

Study site

The study was carried out at Mlali village in one of farmer's farm at latitude 6°16'384"S and longitude

36°44'787"E at an elevation of 1220 m above sea level in Kongwa District in Dodoma region, Tanzania under semi-arid conditions. Kongwa District is one among the seven Districts of the Dodoma Region of Tanzania. The District is bordered to the north by Manyara Region, to the south by Mpwapwa District, to the east by Morogoro Region, and to the west by Chamwino District (Fig. 1).

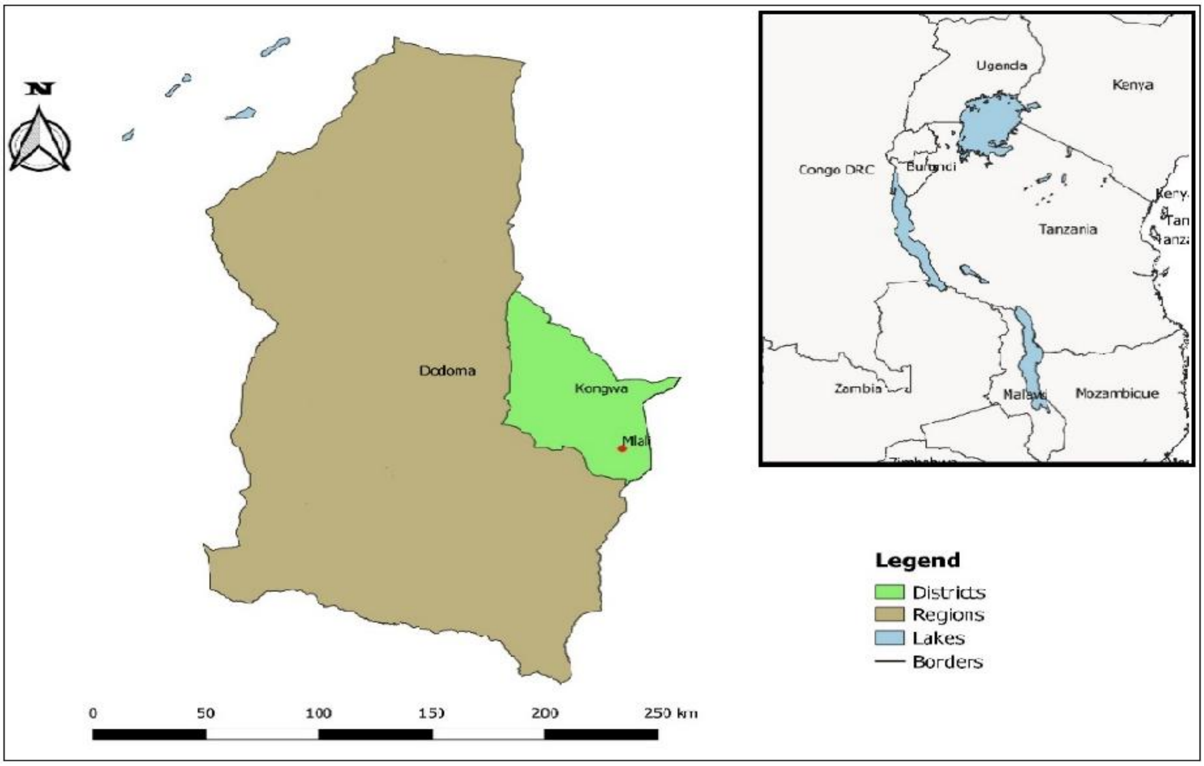

Fig. 1. Map of Tanzania, Dodoma Region and Kongwa District indicating the study site Mlali village.

Experimental design, treatments and management

The experimental design was laid in a split - plot design with four selected CSA practices as treatments (consisting of tied ridges, *Chololo* pits, intercropping and ox-cultivation – as a control) assigned as main plots and three planting dates (early, normal and late) assigned as sub-plot replicated three times.

In both seasons, maize variety (STAHA) and pigeon pea variety (ICEAP 0040, *Mali*) were planted. The experimental treatment plot size was the 7 × 5-m and the unplanted buffer strips between plots and blocks were 1-m and 2-m respectively. For intercropping treatments (maize and pigeon peas) planted across the three different planting dates. Three (3) seeds were sown per hole at a spacing of 0.6 m within rows and 0.9-m for maize and in alternate rows for pigeon peas in intercropping treatments. One week after emergence, one plant per hole was thinned leaving out 2 plants per hole.

Weeding was done by hand hoe two times specifically in the 4th and 8th week after emergence to avoid competition of resources such as light, water, nutrients between weeds and crops and also to improve soil physical conditions. DAP fertilizer (18P:46N:0K) was used as a source of P at a rate of 15kg P/ha. Nitrogen was applied as Urea (46%N) at two splits (at planting and 4th week after planting) of 30 kg N ha^{-1} for a total of 60 Kg N ha^{-1} for all treatments.

Pest and diseases control was done by use of pesticides and insecticides effective against detected pests and diseases in the plots. Common pests detected were Crickets (*Gryllus assimilis*), Fall Armyworm (FAW) (*Spodoptera frugiperda*) which mostly affected maize and pigeon peas during germination and vegetative phase respectively. Pesticides and insecticides like Cutter (Acetamiprid 64g/l + Emmamectin Benzoate 48g/l) at a rate of

40mls/20litres, Duduba and Karate (Lambda Cyhalothrin) insecticides were applied after every two weeks until tussling in maize and flowering in pigeon peas was set as recommended by Pipoly and Granson (2012).

Data Collection

Assessment of Soil Moisture, Maize plant growth and nutrient uptake parameters

Soil moisture content in percent was measured using the gravimetric method, this was done at 3rd, 6th, 9th, 11thand 14th weeks after planting (Karuma *et al.*, 2014). Soil samples were collected at a depth of 0-20 cm by using a soil auger, from four randomly points within each treatment then packed in a zipped plastic bags shipped to laboratory for analysis.

The soil samples were weighed using a digital weighing balance, then oven dried at 105°C for 48 hours and re-weighed. Its differences in mass between the wet and the dry soil sample were expressed in percent soil moisture content. The mean percent of soil moisture content from four soil samples for each treatment were recorded following weeks after planting in which soil samples were collected.

Five plants per row within a net area (4 m x 3.6 m) were randomly-selected and measured for growth parameters at their 3rd, 6th, 9th, 11th and 14th weeks after planting treatment (Tewodros *et al.*, 2009).The mean from five plants for each treatment were computed for their growth parameters to obtain mean data for plant growth stages. Maize plant stem girth (mm) was measured at the base of maize plant root collar diameter (RCD) 5 cm from the soil surface by using a digital veneer caliper. Plant height (cm) was measured from the soil surface to the base of the tassel by using a wood meter rulerfor each plot/treatment.

Leaf Area Index (LAI) was measured by using AccuPAR LP-80 Ceptometer (Decagon Divices 2015) for the same sampled five maize plants in each treatment as described by Chen (1997). Determination of dry biomass weight of maize plants was done at flowering stage for each treatment within plot net area (4 m x 3.6 m). The same five plants were sampled from the maize rows and its fresh weights were recorded, packed in a brown paper bag after optimal air dry then shipped to laboratory for oven dry analysis (Ghosh *et al.*, 2017). These samples were oven dried at 70 °C until constant weight (no further changes) was obtained for determination of whole dry matter yield per each treatment.

Five maize plants at roasting growth stage in each treatment combination, were sampled from the maize rows and their fresh weights were recorded. Oven dried biomass samples of maize were ground and wet digested for analysis of N Kjedahl method, P by stannous chlorine method while K, Mg, Ca using atomic absorption spectrophotometer. Nutrient content in this were calculated as a product of biomass (Mgha^{-1}) and the corresponding concentration of each element and the values were expressed in Kgha^{-1} all the procedures were as per Anderson and Ingram (1993).

Statistical analysis

Data collected were subjected to analysis of variance (ANOVA) using the GenStat software (15th Edition) in a Split Plot Design. Treatment means separation test were done by using Turkey's-Test at 5% level of significance. The basic assumption in the ANOVA was that each observation (Yij) is independent and residuals are normally distributed. In addition, correlation analysis of soil moisture and growth and yield variables were conducted to understand their relationships.

Results

Soil characteristics of the experiment site

The soil texture is sandy loam with a pH 6.2, rated according to (FAO, 2010; Landon, 1991). Organic carbon of the soil was 0.39%, rated as very low, total N of the soil was 0.031%, rated as very low and extractable P was 15.85 mg/kg, rated as medium, exchangeable Ca and K were 3.54 cmol/kg and 0.35 cmol(+)/kg, rated as medium (NSS, 1990) (Table 1).

Table 1. Main and interaction effects of CSA practices and planting dates on Maize plant growth components for the 2018/2019 growing season at Mlali Dodoma, Tanzania.

	2018 Cropping season			2019 Cropping season		
	Plant height (cm)	Leaf Area Index (%)	Biomass (t ha^{-1})	Plant height (cm)	Leaf Area Index (%)	Biomass (t ha^{-1})
CSA practices						
Intercropping	89.41b	1.01a	1.264a	85.13b	1.252a	0.93a
Ox-cultivation	70.0a	1.06a	1.36ab	65.66a	1.315a	1.026ab
Tied ridges	96.86b	0.89a	1.452b	92.56b	1.499a	1.119b
Chololo pits	101.61b	0.7a	1.489b	96.83b	1.398a	1.156b
LSD	14.308	0.381	0.131	6.867	0.28	0.131
CV (%)	16.4	42.3	9.7	17.1	20.9	14.3
P-Value	<0.001	0.229	0.008	<0.001	0.311	0.002
Planting dates (PD)						
Normal	84.58a	1.007ab	1.514b	80.20a	1.358ab	1.181b
Early	87.81a	1.086b	1.294a	83.5a	1.194a	0.960a
Late	95.99a	0.664a	1.366a	91.35a	1.546b	1.032ab
LSD	12.391	0.33	0.114	5.947	0.242	0.114
CV (%)	16.4	42.3	9.7	17.1	20.9	14.3
P-Value	0.168	0.034	0.002	0.184	0.022	0.008

Means followed by same letter (s) in the same column are not significantly different according to Tukey's Test at $p \le 0.05$.CV is the coefficient of variation. LSD is Least Significance Difference. CSA is Climate Smart Agriculture practice. PD is planting date.

The soil fertility status of the experimental site (Table 1) would be of medium status, supporting maize and pigeon peas production. However, optimization of some nutrients would be required. Soil moisture significantly increased ($p = 0.049$) across CSA practices in the 6th week after emergence (Fig. 2). *Chololo* pits had the highest percent soil moisture of 7.2%, followed by tied ridges and intercropping both at 6.4% as compared with ox-cultivation which had the lowest percent soil moisture content of 6.0%. Despite, there were no significant differences ($P>0.05$) in soil moisture across CSA practices, planting dates and their interactions in the 3rd, 6th, 9th, 11th and 14th weeks after emergency, the variations were noted. For example, *Chololo* pits and tied ridges CSA practices had the highest percent soil moisture, similar there was high soil moisture at early and late planting windows (Fig. 3).

Maize growth parameters

Maize plant height: Maize plant heightwere significantly affected ($p < 0.001$) byClimate smart agriculture (CSA) practices in both cropping seasons (Table 1). There were no significant differences ($p > 0.05$) between planting date, and their interaction between CSA practices and planting dates with respect to Maize plant height. *Chololo* pits and tied ridges CSA practices had the highest maize plant heights (at 101.6 cm and 96.83 cm) in 2018 and (at 96.8 cm and 92.6 cm) in 2019 cropping seasons respectively.

Although planting dates had no significant differences, maize plant height varied differently in both cropping seasons. Late planting dates resulted into the highest maize plant height (at 95.99 cm) in 2018 and (91.35cm) in 2019. Early and normal planting date for both cropping seasons had the lowest (at 87.8 cm and 84.6 cm) in 2018 and (83.5 cm and 80.2 cm) in 2019.

Their interaction showed variations in maize plant heights, whereby the highest maize plant height was in *Chololo* pits at late planting date increased plant height at 76% followed by tied ridges at late planting date (56%) and *Chololo* pits at early (53.3%) while the lowest height was in ox-cultivation at late planting date (4%) and ox-cultivation early planting date (13%).

Maize Leaf Area Index: In both cropping seasons, Leaf Area Index (LAI) were significantly affected (p = 0.034 in 2018 and at p = 0.022 in 2019) by Planting dates (Table 1). But in both cropping seasons CSA practices and their interactions (between CSA practices and planting dates) were not significant (p > 0.05).Leaf Area Index (LAI) under planting dates ranged from 0.6% to 1.1% in 2018 season and from 1.2% to 1.6% in 2019 seasons. In 2018 season early planting date had the highest percent LAI (at 1.08) whereby in 2019 the highest percent LAI was in normal planting date (1.36).

Table 2. Biomass yield (t ha^{-1}) and nutrient content (Kg ha^{-1}) of maize for the 2019 cropping season under different CSA practices and planting date treatments at Mlali Dodoma, Tanzania.

Treatment	Maize					
	Biom.	N	P	K	Mg	Ca
CSA practices						
Intercropping	0.93a	5.46a	4.17a	1.963a	1.90a	0.297a
Ox-cultivation	1.026ab	9.15b	4.47a	2.653a	2.44b	0.263a
Tied ridges	1.119b	8.95b	4.55a	2.557a	2.36b	0.362a
Chololo pits	1.156b	9.82b	5.40a	2.337a	2.35b	0.344a
LSD	0.131	1.980	0.938	0.973	0.500	0.103a
CV (%)	14.3	42.2	25.9	28.4	25.6	38.5
P-Value	0.002	0.006	0.094	0.315	0.005	0.177
Planting date (PD)						
Normal	1.181b	9.04a	5.309a	2.493a	2.42a	2.423a
Early	0.960a	7.11a	4.217a	2.127a	1.89a	1.892a
Late	1.032ab	8.88a	4.409a	2.513a	2.47ab	2.470a
LSD	0.114	3.046	1.040	0.584	0.500	0.106
CV (%)	14.3	42.2	25.9	28.4	25.6	38.5
P-Value	0.008	0.355	0.089	0.315	0.048	0.945

Means followed by same letter (s) in the same column are not significantly different according to Tukey's Test at P ≤ 0.05.CV is the coefficient of variation. LSD is Least Significance Difference. CSA is Climate Smart Agriculture practice. PD is planting date.

However, LAI were not significant difference (p> 0.05) on CSA practices and their interaction (between CSA practices and planting dates). In CSA practices, percent LAI were ranged from 0.7% to 1.1 in 2018 and 1.25 to 1.5 in 2019 cropping seasons. The highest value of LAI was in intercropping (1.01) in 2018 and tied ridges (1.5%) in 2019. Also percent LAI based on their interactions ranged from 0.53 to 1.6 in 2018 and from 1.07 to 1.76 in 2019 cropping season. Tied ridges CSA practice increased LAI by 43% as compared by intercropping. Unlike, early planting had less leaf area index by 51% between 2018 and 2019. Maize biomass: In both cropping seasons, Climate Smart Agriculture (CSA) practices and planting dates had significant differences (atp = 0.008 and at p= 0.002) in 2018 and (at p = 0.002 and at p= 0.008) in 2019on biomass respectively (Table 1). Above ground maize biomass across selected CSA practices increased from 1.3 t ha^{-1} to 1.5 t ha^{-1} in 2018 and from 0.93 t^{-1} to 1.16 t ha^{-1} in 2019 cropping seasons. Similarly, to planting dates, above ground biomass increased at a range of 1.3 t ha^{-1} to 1.51 t ha^{-1} in 2018 and from 0.96 t ha^{-1} to 1.18 t ha^{-1} in 2019 cropping seasons respectively (Table 1).

The lowest dry biomass weight under CSA practices was (1.2 t ha-¹) obtained under intercropping while normal planting dates had a lowest dry biomass (1.3 t ha¹) for planting dates and intercropping CSA practices in combination with normal planting dates resulted into the lowest dry biomass weight of 0.93 t ha-¹ for the two cropping seasons. Maize Nutrient Uptake: CSA practices had a significant ($p = 0.006$) effect on Nitrogen (N) nutrient uptake. Alike, Magnesium (Mg) nutrient uptake were significantly affected by both CSA practices (at $p < 0.005$) and Planting dates (at $p = 0.048$). Also, there were significant differences ($p = 0.038$) forthe interaction between CSA practices and planting dates on Phosphorus (P) nutrient uptake by maize plant, although the interaction between CSA practices and planting date were not significant on N, K, Mg and Ca nutrient uptake (Table 2).

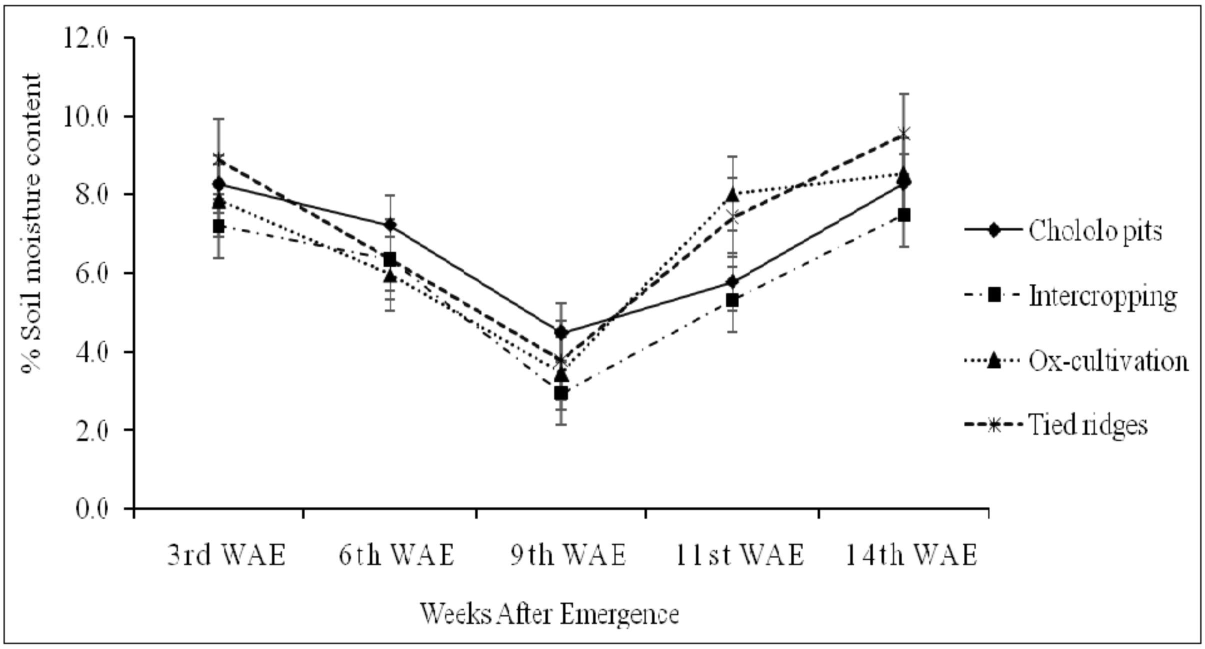

Fig. 2. Effects of Climate Smart Agricultural (CSA) practices on Gravimetric Soil Moisture at Mlali village determined in both cropping seasons (n = 4).

Nitrogen (N), Potassium (K) and Magnesium (Mg) were high in ox-cultivation CSA practices followed by *Chololo* pits practices, whereby *Chololo* pits and Tied ridges had the higher amount of Phosphorus (P) and Calcium (Ca) nutrient uptake by maize plant. Nutrient uptake by maize plant ranged from 5.5 Kg ha-¹ to 10 Kg ha-¹across CSA practices, whereby *Chololo* pits and ox-cultivation had the highest N uptake at 9.8 Kg N ha-¹and 9.2 Kg N ha-¹respectively.

Planting date had the nutrient uptake ranged from 0.9 Kg ha-¹ to 9 Kg ha-¹ whereby normal planting date resulted into the highest nutrient uptake as compared with early and late planting dates. Magnesium (Mg) nutrient uptake was significantly affected by planting date with the highest 2.47 Kg Mg ha-¹at late planting window absorbed by maize plant. Early planted maize resulted into higher amount of P uptake by the plant (at 2.5 Kg P/ha) which is 0.58% increase when compared with nutrient uptake under early planting date (1.89 Kg ha-¹).

Discussion

Effects of CSA practices on maize plant growth

Maize grown under *Chololo* pits and tied ridges CSA practices resulted into the highest and fastest growth in both cropping seasons. Unlike to maize grown under intercropping and ox-cultivation.*Chololo* pits outperformed tied ridge on maize plant height, which is expected in drought areas as described by (Howell *et al.*, 2002; Janvier *et al.*, 2014). Maize plants at 50% flowering stage showed that late planting dates recorded the tallest plant height almost twice of maize plants from early and normal planting date treatments. In this study, we found that the shorter maize plant height treatments resulted into low grain yield as compared with taller maize treatments. Our results agree with the study by Boomsma *et al.* (2010) that shorter plants are an indicator of low grain yield. This may perhaps have attributed by increase in soil water content in these *Chololo* pits and tied ridges CSA practices. Thus soil moisture retained under *Chololo* pits and tied ridges CSA practices might have been a principal to better root development leading to increased maize growth. Our results agree with results by Kouyaté *et al.*, (2012) who reported that sorghum grown under planting pits increased sorghum growth due to high soil water retained.

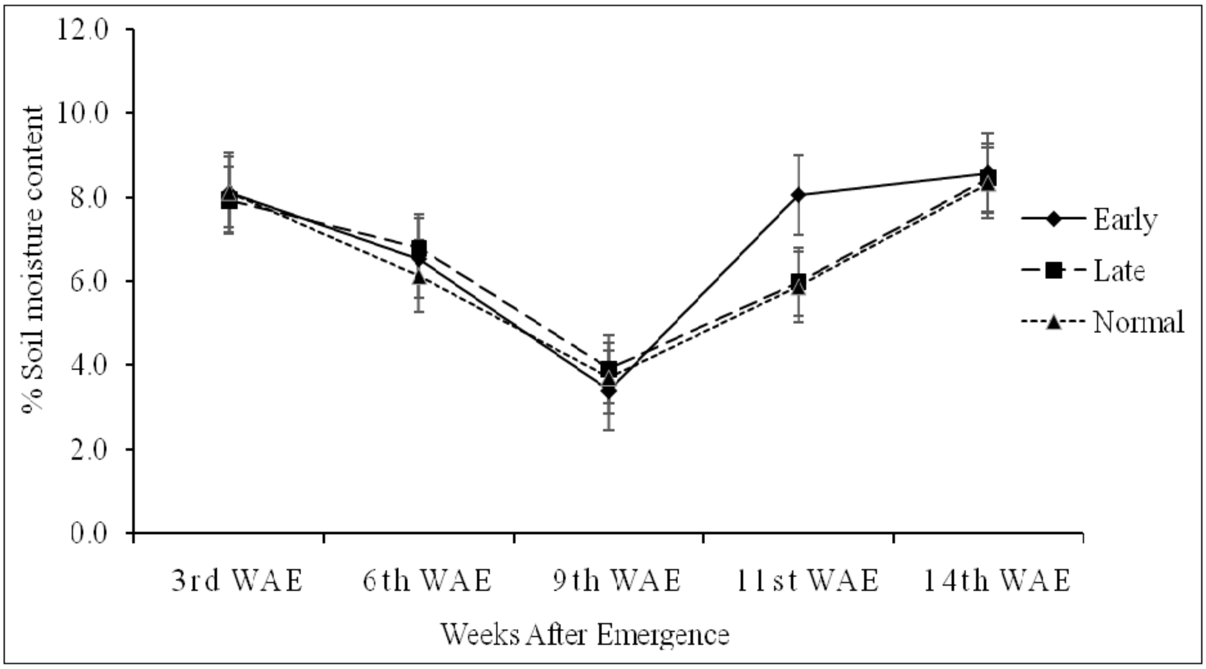

Fig. 3. Effects of Planting dates (PD) on Gravimetric Soil Moisture at Mlali village determined in both cropping seasons (n = 3).

The poor performance of normal planting dates on maize plant height be associated with poor rainfall distribution and a drought spell in late February to mid-April 2019. Our result aligns with findings by Parthasarathi *et al.* (2013) that water deficit might have stopped maize growth due to early flowering compared to early and late planting dates. Also the study byHatfield *et al.*, (2015) revealed that limited water availability to plant at flowering growth stage affected its physiological status as it caused decline in photosynthetic rates and plant growth. Reduction of leaf number under water deficits is a result of reduced leaf appearance rate and reduced plant height as well as accelerated leaf senescence (Gupta *et al.*, 2001). Early planting resulted in the shortest plants since it coincided with the driest period. Our finding, aligns with Biazin, (2012) plant height and plant biomass decreased slightly in the late planting in response to decreasing soil water content and temperature. Aldrich *et al.* (1986) associated late planting with a shortened season; this may have limited plant growth. In our study, we found that Leaf Area Index (LAI) significantly affected by Planting dates in both cropping seasons. Our result agrees with Shrestha, (2018); Mongi *et al.* (2010), Mertz *et al.* (2009) that temperatures encountered with early planting tend to reduce plant height by decreasing internode length and leaf numbers which lower Leaf area.Non-significant differences of CSA practices and their interaction (between CSA practices and planting dates) onLeaf Area Index were affected by drought spells occurred prior to flowering maize growth stage. Previous studies by Morrison *et al.* (1992) crops suffered from droughts resulted into poor LAI because of their poor leaves arrangement of and poor canopy impede sunlight interception which promote other metabolic processes such as photosynthesis. *Chololo* pits and tied ridges CSA practices had shown resilience on leaf area due to its high capacity of soil moisture conservation. Few plant leaves at 50% flowering were affected by drought spell that had influenced light interception and fresh biomass but were promising state in *Chololo* pits and tied ridges as compared with ox-cultivation and intercropping CSA practices.

The higher the ground biomass across both CSA practices and planting dates, this signifies the resilience of water stress tolerant and high yield. According to Kimaro *et al.* (2009) grain and biomass yield were associated with N and P nutrient uptake. We found high biomass yield influenced N and Mg uptake by maize plant. In this study we found that among CSA practices assessed, Intercropping had the lowest biomass dry weight whereby Kimaro *et al.* (2009) suggested that this might be due to shading effects and nutrient competition between maize and pigeon peas.

Effects of CSA practices, planting date and their interaction on Maize Nutrient Uptake

Climate Smart Agriculture (CSA) practices improved uptake of nitrogen nutrient by plant which is a critical nutrient for increased crop yield. In this study, we found that there was a positive correlation between soil moisture and nutrient uptake by maize plant. For example, the higher percent soil moisture content in *Chololo* pits and Tied ridges CSA practices is highly associated with higher N, P, K, Mg and Ca nutrient uptake. Our results agree with Lipper *et al.*, (2014) who found that nutrient uptake of any crops were influenced by soil moisture due to its direct involvement in microbial activities, transportation to the root and solution equilibrium. Also in our results we agree with studies by Fatondji *et al.*, (2006) and Patel *et al.*, (2013) that sufficient available water and amendments around the root zone had positive significant effect on soil fertility. Apart from *Chololo* pits and Tied ridges CSA practices which performed better on nutrient uptake by maize plant, ox-cultivation CSA practice also had the highest Mg and K nutrient uptake by plant as compared to intercropping practice. This supports the findings that *Chololo* pits CSA practices makes available soil water potential at the soil root surface to regulate nutrient concentration for enhanced nutrient uptake (Kimaro *et al.*, 2008; Kurwakumire *et al.*, 2014). Our results show that, soil moisture in *Chololo* and tied at normal and late planting dates made nutrient uptake possible through diffusion process were dissolved Mg^{+2} in soil solution. Similarly, to our findings, Nyoki and Ndakidemi (2016) found that the uptake of water and ions by a plant around root zone seems to concentration gradient in response to which water and ion flow from the root surface thus made it easier for Mg uptake by plant. The site was found to be P limit as there was no significant differences across tested CSA practices and planting date. Similar study by Kimaro *et al.*, (2016) it suggests that such P limit influenced photosynthesis and biomass production however P was not statistically significant.

This is highly linked to a concept by Comerfod, (2005) that nutrients uptake is through mineralization and immobilization, thus among other factors soil water during mineralization plays in regulating the soil solution concentration of nitrogen (N), phosphorus (P) and sulphur (S). The increase in P nutrient uptake by the plant for early planting date reflects 5.8% as compared to early planting date.

Conclusion

Our results revealed that Climate Smart Agricultural (CSA) practices had a significant ($p < 0.05$) effect on maize plant height and N nutrient uptake. Also Biomass and Magnesium (Mg) nutrient uptake were significantly affected ($p < 0.05$) by both CSA practices and Planting dates though Leaf Area Index (LAI) were significantly affected ($p < 0.05$) only by Planting dates. *Chololo* pits and tied ridges CSA practices and late planting dates had the highest soil moisture content, maize plant heights, and biomass. Ox-cultivation had a slight high N, K and Mg nutrient uptake followed with *Chololo* pits and tied ridges CSA practices.This study shows that *Chololo* pits and tied ridges CSA practices and late planting windoware recommended as climate change adaptation and mitigation strategies among smallholder farmers to improve sustainable crop production under changing climate in semi-arid areas like Kongwa district.

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