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SEASONAL VARIATIONS, NITROGEN/ WATER USE EFFICIENCY AND DRY MATTER YIELD OF MAIZE AND MAIZE/ COWPEA INTERCROP UNDER DIFFERENT TILLAGE AND CROPPING SYSTEMS

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Abstract
The use of proper cropping and tillage practices is essential to maintain high yields, plant nitrogen use efficiency (NUE), plant water use efficiency (WUE), and dry matter yield (DMY). This study evaluated the effect of tillage systems (conventional tillage (CT) Minimum Tillage (MT) and No-tillage (NT)) and cropping systems (maize monoculture and maize/cowpea intercropping) on seasonal variations in NUE, WUE, and DMY of maize in the rainforest agro-ecologies of Nigeria. The experiment was laid out in a split-plot design with four replicates. The results showed that plant nitrogen use efficiency (PNUE) and plant water use efficiency (PWUE) had higher values in a mixed cropping system compared to the sole maize indicating efficient nitrogen and water use in a mixed cropping system. Similarly, MT system under mixed cropping system had higher PNUE and PWUE over the disc plough and NT system. The late season plant out yielded the early season plant for growth and yield parameters. Significantly higher values were recorded for the late season crop for plant height (121.61cm), leaf area (0.73cm^2), days to first tarselling (44.87 days), shoot fresh weigh (162.94g), shoot dry weight (86.34g), grain weight on cob (258g), 1000 grain weigh (342.78g), number of seeds/cob (265) and grain yield (0.63t/ha) over the early season crop which had lower values. The interaction effect shows that there is a significant difference in all the measured growth parameters except for leaf area, grain yield and harvest index. MT significantly increased NUE and had significant effect on WUE and DMY. Conversely, NT had no significant effect on WUE and dry matter yield of maize. Maize/cowpea intercropping had a significant positive effect on NUE and DMY, but no effect on WUE. The study also found that NUE, WUE, and DMY were significantly higher in the late rainy season than in the early rainy season. CT had no significant effect on NUE, WUE, and DMY, but significantly reduced soil moisture content in the topsoil. In conclusion, MT and maize/cowpea intercropping are recommended to improve NUE and DMY, while CT should be avoided due to its negative impact on soil moisture content. Further research is needed to determine the feasibility of using these strategies in other agro ecological zones and under different management practices.

Keywords: *Cropping systems, Tillage systems, Seasons, Maize/Cowpea intercrop, Nitrogen/ Water Use Efficiency, Dry matter yield*

Introduction

Maize (Zea mays L.) is one of the most important cereal crops grown worldwide. It is the staple food for many people in Sub-Saharan Africa and is also a major source of animal feed and industrial raw material. Cowpea (Vigna unguiculata *L. Walp*) is a legume crop that is gaining popularity in the region due to its nutritional and environmental benefits. Maize-cowpea intercrop has been shown to improve soil fertility, reduce pests and diseases, and maximize land use (Mason *et al* 2016, Omoigui et al, 2019). However, the productivity of maize and cowpea is influenced by several factors, including soil fertility, water availability, temperature, and cropping system. In this study, seasonal variations in plant nitrogen/water use efficiency and dry matter yield of maize and maize/cowpea intercrop under different tillage and cropping systems will be examined.

(Feng et *al*, 2018). Many developing countries face major challenges to achieve food security in a sustainable manner, considering the increasing population, limited availability of land and water resources (Tsoho and Salau, 2012). Most common farming system is mixed farming, mixed cropping or mono cropping due largely to consideration for risk minimization, stable income and adaptability to a particular season (Sani and Haruna, 2010). Crop production in Nigeria is dominated by small-scale farmers who cultivate between 0.1-5.99 hectares and produce about 85-90% of the total food consumed in the country (Maurice *et al.*, 2013). These farmers are constrained by inadequate finance to expand production, hence rely on personal savings for their agricultural operations. They are also influenced by farm specific factors, which delineate their production frontiers resulting in low outputs. Studies have shown that socioeconomic characteristics affect farmers' efficiency in production as it influences production decisions, availability and level of use of modern inputs and technology. When scarce resources are not efficiently utilized by resource poor farmers, it could have a multiplier effect on their livelihood and incomes (Dereje, *et al*, 2013). These farmers would not be able to generate sufficient incomes to mitigate the rising cost of living, increasing population and the normal long dry spell in some parts of the country (Prost *et al* 2015). This situation creates supply shortages in terms of food availability and accessibility and indirectly creates demand shortage by denying households access to sufficient income. Maize and cowpea in the South Western part of Nigeria is produced under rain fed conditions where the rainfall is usually inadequate, short in duration, poorly distributed and highly variable between and within seasons (Wamari *et al.*, 2012). Yield and water use efficiency in an idea cropping system is dependent of standard irrigation system. (Ahmed, *et al*, 2012). Although there has been an increase in their production due to expansion of cultivated land into marginal areas, productivity per unit area of land has continued to decline. These low yields have been attributed to low soil fertility, periodic water stress, diseases and pests (Katungi *et al.*, 2010). Therefore, intercropping may help improve productivity of low external input farming, a characteristic of smallholder farmers, who depend largely on natural resources such as rainfall and soil fertility (Muhammed *et al*, 2014) Thus, the choice of crop cultivars and hence agronomic manipulations to certify the most effective use of limiting resources is critical for high crop yields. Conservation of soil moisture through tillage practices is an important management objective for crop production in semi-arid areas. Identification of the best tillage methods that not only improve rainwater infiltration but also conserve adequate soil moisture for plant growth is imperative (Cornelis *et al.*, 2013). Conservation tillage also conserves available rainwater which is otherwise lost in the magnitude of 70 to 85 % of rainfall in Sub Saharan Africa, through soil evaporation and through deep percolation and surface run-off hence makes it beneficial to the crops (Cornelis *et al.*, 2013). Although conservation tillage is highly encouraged, there is strong evidence that this kind of tillage may not be good for soils prone to surface crusting and sealing, a characteristic for most of the soils in the semi-arid areas of Kenya (Gitau *et al.*, 2006; Mujdeci *et al.*, 2010; Giller *et al.*, 2011). Tillage – based conventional agriculture is assumed to have led to soil organic matter decline, water runoff, soil erosion and other manifestations of physical, chemical and biological soil degradation (Thierfelder and Wall, 2009, Manyatsi *et al.*, 2011). Studies in the temperate and tropical rainforest regions have shown that continuous no-till improved soil structure and reduced erosion, which led to an increase in maize yields than on conventionally tilled soils (Abel *et al*, 2016)

Materials and methods

Experimental site and ambient conditions

The experiment was conducted in the Research Farm of the Department of Crop, Soil and Pest Management, Federal University of Technology Akure, located in the rain forest area of South Western Nigeria between April, and October, 2018. Temperature and relative humidity fluctuated between 25-31^{o}C and 28-35^{0}C respectively, during the period of the experiment. The experiment was carried out to examine seasonal variations, NUE/WUE and **d**ry matter yields of maize, maize /cowpea intercrop under different tillage and cropping systems

Planting materials

Seeds of improved (Oba super), a dry land maize and cowpea (IT98K-572-2-1) varieties were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and planted at two rainy seasons. The first planting was carried out between April and June for the early rainy crop while the late season planting was carried out between August and October, 2018

Treatments and experimental design

Treatment consisted of three tillage practices namely, Conventional tillage system (CT) involving Disc Ploughing (DP), Minimum tillage (MT) system involving Hand hoeing with Ridges (HHR), and No tillage system (NT) where the land was not disturbed before planting was initiated. Two cropping systems and two planting seasons were used namely: Monocropping/Sole system (MS/SC) where only one crop was planted for the growing season and mixed cropping system, (MCS) where maize as the major crop was planted along with cowpea. In addition, these planting were carried out in the early and late rainy seasons. The cropping systems treatments were Sole Maize (SM), Sole Cowpea (SC) and Maize - Cowpea intercrop (M + C). The experiment was a 2x2x3 factorial scheme arranged in a Split-Plot Design at two planting seasons with tillage practices as the main plots and the cropping system as the sub plots, with four replications. The 12 treatments were replicated 4 times to make a total of 48 plots in all.

The following were the treatments combinations

Maize planted as a sole crop (SM) in Disc Ploughed land (DPS) in a conventional tillage system

Maize planted as a sole crop (SM) in a Miminum tillage system involving Hand hoeing with Ridges (HHR)

Maize planted as a sole crop (SM) in a No tillage system (NTS) where the land was left undisturbed.

Maize + Cowpea intercrop (M+C) in Disc ploughed land in a Conventional tillage system

Maize + Cowpea intercrop (M+C) in a Minimum tillage system involving Hand hoeing with Ridges (HHR)

Maize + Cowpea intercrop (M+C) in a No tillage system (NTS) where the land was left undisturbed.
These crops were planted in rows in 25 m^2 plots. Maize was planted at a spacing of 90 × 30 cm in pure stands with the sole cowpea crop planted at a spacing of 45 × 15 cm. In the intercropping plots, the cowpea was at a spacing of 90 × 15 cm, grown between the maize rows. The fertilized plots received basal compound fertilizer (NPK) application at planting at a rate of 20 kg N/ha for all the treatment combination for the early and the late rainy season crop.

Measurement of crop growth and yield analysis
In order to assess crop growth, the following maize growth parameters were collected: maize plant height, leaf area, shoot fresh and dry weight, days to first tarselling, 1000 grain weight, grain weight on cob, number of grains/cob and maize grain yield. Maize plant height was measured periodically (different weeks after planting) throughout the growing season from the ground level to the uppermost full extended leaf and to the tip of the tassel after tarselling, using measuring tape. Maize leaf area was estimated by length multiplied by maximum width and multiplied by 0.75, which is the maize calibration factor (Elings, 2000). Final crop biomass and grain yields were determined from plants harvested in a sample area of 2 × 2 m at the centre of the plot. Harvesting of maize was done after the crops were dried in the field and fresh biomass was measured on site. The harvex index which is the ratio of harvested grain yield was estimated as:
Harvest Index (HI0 = Harvest Index (HI) = Grain yield (kg/ha/ Biological yield (kg/ha) x 100 while the biological yield is the total dry matter per plant or per unit area.

The yields were calculated based on the mean experimental plot area and later adjusted to metric kg per hectare (kg/ha).

Soil sample analysis and field management practices
Topsoil samples were gotten from 0–15 cm over the entire plot using grid method and put together to obtain a composite sample before establishing the experiment. Samples were also collected after each harvest from individual treatment plots. The soil sample was dried under shade, passed through 2 mm sieve for subsequent chemical analyses [pH, organic carbon (OC), total N, exchangeable Ca, Mg, K, available P, CE and particle size distribution for the first soil sample collected at onset of the experiment. During the study, rainfall data for the study area were obtained from Federal University of Technology, (FUTA) Meteorological Station. Maize stubbles were harvested at maturity, oven-dried and weighed to obtain dry matter yield. The grains were removed from the cobs and weighed to obtain yield of the grain, which was converted to hectare with the following calculation;

$$\text{Yield/ha} = \frac{\text{Plot yield} * 10000}{\text{Plot area}} \quad (1)$$

Basagram herbicide with Active ingredient Bentazon) was applied as a post emergence herbicide at 4litres per/ha using hand knapsack sprayer fitted with a green deflector nozzle to deliver the liquid. Application was done three weeks after planting. Both crops were protected against insect pests by regular spraying with DD Force, an organophosphate to destroy all sucking and chewing insects such as aphids, spider mites and trips. This was applied at two weeks interval before

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tillering and flowering for maize and cowpea respectively at the rate of 4litres per ha and weekly till maturity.

Determination of the Leaf Relative Water Content of Maize

This was determined at harvest for the early and late season crop by cutting the top-most of fully expanded leaves; the leaves were immediately weighed to obtain fresh weight and kept in small sealed plastic bags of ice box. The leaves were then soaked in water for 4hrs and blotted with tissue paper to remove moisture on the leaves. They were then weighed to obtain the turgid weight and the turgid leaves were oven-dried at 800c for 24hrs in a ventilated oven. The dried leaves were weighed and reported in gram per leaves, Painawadee *et al.*, (2009). The leaf relative water content of maize is estimated as the amount of water in the leaf at the time of sampling relative to the maximal water a leaf can hold as was calculated according to the following formula proposed by Slavick, (1979)

RWC (%) = [(FW-DW) / (TW-DW)] ×100

Where, FW is the sample fresh weight. TW is the sample turgid weight.
DW is the sample dry weight.
Leaf areas were estimated as suggested by O'Neal *et al.*, (2002).

Determination of Percentage soil moisture content and Water Use Efficiency (WUE)

The percentage moisture content of each soil sample was determined using the following method;
Weight of plastic pot ----------------------- x
Weight of top soil --------------------------- x
Weight of top soil plus plastic pot ----- x
Weight of the three water levels (ml) --x

$$Moisture\ content\ (\%) = \frac{W2 - W3}{W2 - W1} \times 100$$

Each pot was weighed and the weight differences (kg) were converted to volume (ml). The values obtained for each pot represented the volume of water applied to that particular pot at that period. The average volume of water used rate was determined for each cowpea variety. The water use efficiency based on biomass was calculated according to Abidoye, (2004) as follows:

$$WUE\ (g/kg) = \frac{\text{Biomass (g/plant)}}{\text{Water used rate (kg/plant)}}$$

The water use/consumptive rate was estimated from the total rainfall amount collected in mm from the meteorological station for the period of the experiment for maize crop in the early and late rainy season. The crop water use (CWU) in this study f0r maize ranges from 310mm-483mm.
Crop water use varies depending on soil, climate, management practices, and the maize cultivar used.

Determination of plant nitrogen use efficiency (PNUE)

Nitrogen Use Efficiency: Nitrogen use efficiency (NUE) was determined as described by Moll et al. Haegele *et al*, (2012) as follows: weight of the grains divided by the amount of N applied to soil, that is, kg grain/kg N-fertilizer. Nitrogen use efficiency is made up of two primary components known as N uptake efficiency (NUpE) and N utilization efficiency (NUtE).
Nitrogen use efficiency (NUE) = YN/FN (kg grain/kg N-fertilizer)
Where:
FN: amount of N fertilizer applied (kg/haN).
YN: crop yield with applied N fertilizer (kg/haN) Fertilizer

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Statistical analysis

The design of the experiment was a 2x3 factorial scheme arranged in a Split-Plot Design with tillage practices as the main plots and the cropping system as the sub plots, with four replications. Data gotten from this research were analyzed for differences in variance (ANOVA) using software of statistical analysis system (SAS) 22 to determine the main plot and the sub plot. Mean separation was done using the DMRT at probability level of 5%.Coefficient of variability and Standard error were used to estimate the reliability of the sampled data

Result and Discussion

Variations in weather pattern in the early and late planting season of 2018

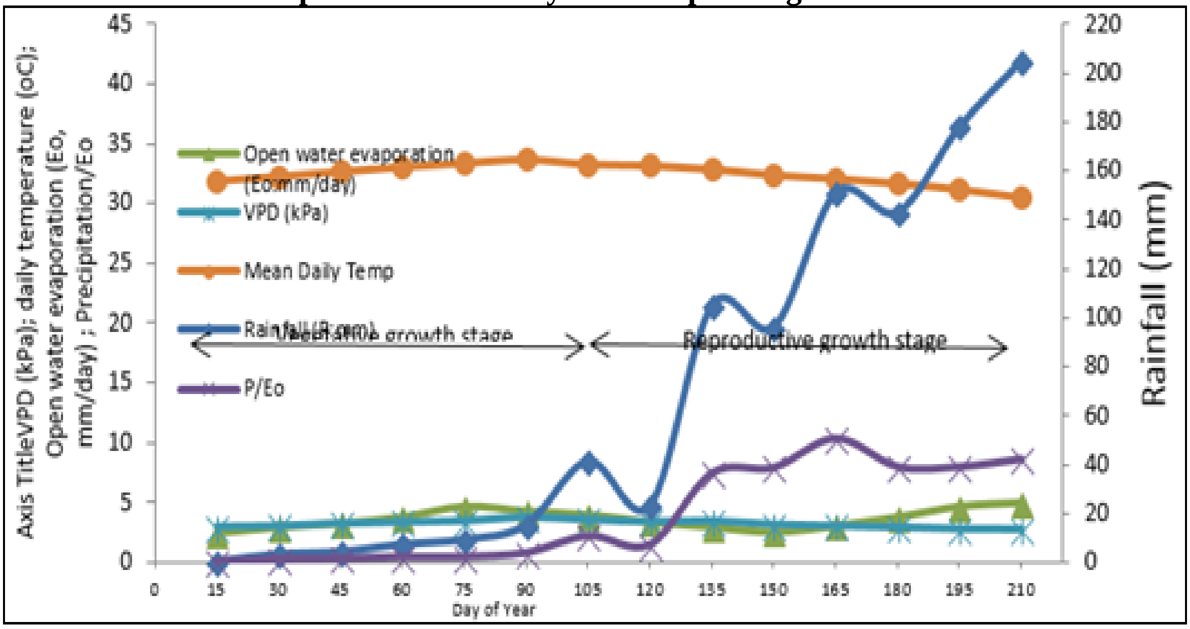

Figure 1: Important weather variables during early rainy season

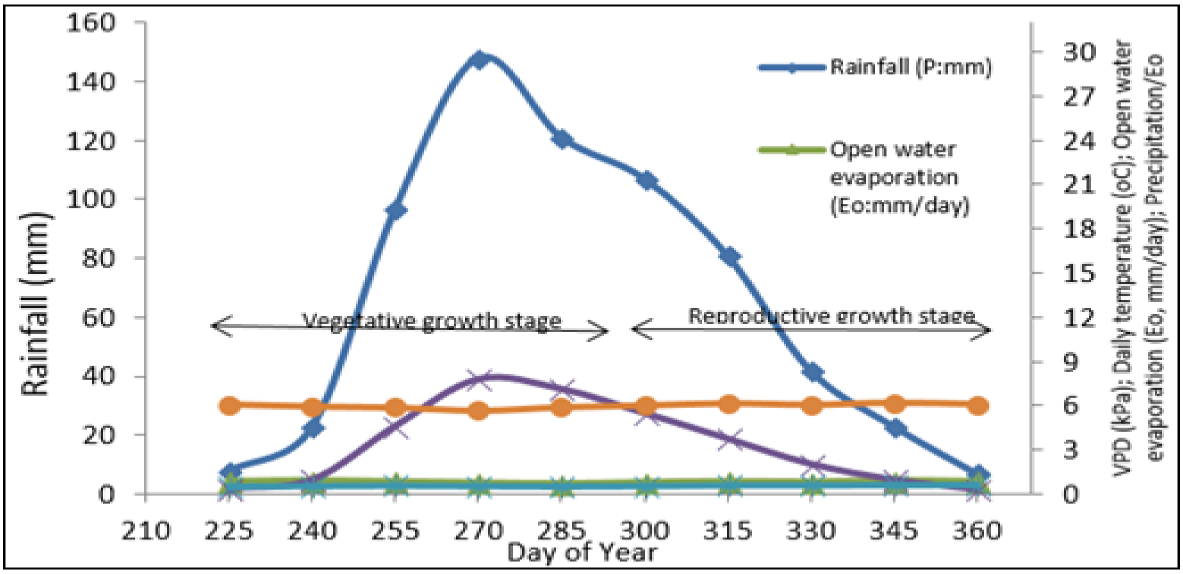

Figure 2: Important weather variables during late rainy season

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Some meteorological variables during the growth of cowpea in the respective early and late rainy cropping seasons of 2018 are presented in Figure 1 and 2. There were dry spells between rainfall episodes particularly in the early part of the early and the latter part of the late rainy seasons. Compared with the late rainy season, the late season is characterized by high climatic demand (high vapour pressure deficit: vpd), crop water demand (open water evaporation: Eo) and temperatures in addition to low and scanty rainfall particularly towards the close of the growing season which coincided with reproductive growth phase of maize and cowpea. The earlier part of the rainy and later part of the late season was characterized by concurrent stresses of high intensities of soil moisture and vapour pressure deficits (atmospheric demand). The rainy season is characterized by increasing trends in rainfall amounts and open water evaporation (Eo) and atmospheric demand during maize/cowpea vegetative and the reproductive growth phases (Figure 1).However, the earlier part of the rainy season which coincided with the establishment phase is characterized by low rainfall amount and high temperatures. However, during the late rainy season, environmental conditions were the opposite of the early rainy season; there were decreases in rainfall amounts and high temperatures, vapor pressure deficits and open water evaporation (Figure 2). However, concurrent and increasing intensities of stress factors of high evaporative demand and temperatures characterized the later part of the late season (the reproductive phase of maize/cowpea intercrop).

The result of the effect of seasonal variations and different tillage and cropping systems on Nutrient Use Efficiency (NUE), Water Use Efficiency (WUE) and Leaf Relative Water Content (LRWC) on Maize, and Maize/ Cowpea intercrop is presented in Table 4. The result shows that plant nitrogen use efficiency (PNUE) and plant water use efficiency (PWUE) had higher values in a mixed cropping system compared to the sole maize indicating efficient nitrogen and water use in a mixed cropping system. Similarly, minimum tillage system under mixed cropping system had higher PNUE and PWUE over the disc plough and no tillage system.

The result of seasonal variation effect in the early and the late rainy season in Table 5 shows that the late season plant was significantly better than the early season plant for all the measured growth and yield parameters. Significantly higher values were recorded for the late season crop for plant height (121.61cm), leaf area (0.73cm^2), days to first tarselling (44.87 days), shoot fresh weigh (162.94g),shoot dry weight (86.34g), grain weight on cob (258g), 1000 grain weigh (342.78g), number of seeds/cob (265) and grain yield (0.63t/ha) over the early season crop which had lower values.

The result of the performance effect between Monocropping and mixed cropping systems in maize, maize cowpea intercrop in Table 6 shows that sole cropping system was significantly better for some of the measured growth parameters for plant height (120.85cm), leaf area (0.73cm^2), days to first tarselling (43.70 days), shoot dry weight (87.03g). Conversely however, significantly higher values were recorded for the mixed cropping system for shoot fresh weight (161.60g), grain weight on cob (249.09g), 1000 grain weigh (339.91g), number of seeds/cob.

(275.0) and grain yield (0.72t/ha) over the sole cropping system which had lower values. Days to first tarselling were shorter under the mixed cropping system (41.37 days)

Table 7 shows the performance effects of Disc Plough, Minimum Tillage, and No Tillage systems in maize, maize cowpea intercrop. The result shows that the minimum tillage system (MTS) was significantly better over the Disc plough system (DPS) and the No tillage system (NTS) for plant height (119.62cm), leaf area (0.71cm^2) grain weight (246.76g), number of seed per cob (262.50), 1000 grain weight (346.42g) and grain yield (0.68t/ha). This was closely followed by the NTS. The interaction of effect between Seasons and Cropping systems in maize, maize cowpea intercrop is presented in Table 8. The interaction effect shows that there is a significant difference in all the measured growth parameters except for leaf area, grain yield and harvest index. The interaction effect between season tillage systems in this study shows that there is no significant difference in the leaf area, grain yield and harvest index while the interaction effect between the season, cropping system and tillage gave similar result.

According to Yelenoc *et al*, (2015), plant nitrogen/water use efficiency is a critical factor that determines crop productivity and is affected by several factors such as soil moisture, fertility status, temperature, crop genotype, and management practices. In this study, we investigated the seasonal variations in plant nitrogen and water use efficiency (PNUE and PWUE, respectively) of maize and maize/cowpea intercrop under different tillage and cropping systems. The results showed that PNUE and PWUE of maize and cowpea were significantly influenced by tillage and cropping systems. Maize/cowpea intercrop had significantly higher PNUE and PWUE compared to sole maize. The intercrop also had lower water use compared to maize alone, indicating efficient water use by cowpea. In both tillage systems, PNUE and PWUE were higher in intercropped plots, with the higher values being observed in the CA system. Dry matter yield of maize and maize/cowpea intercrop. Dry matter yield is an important parameter that determines crop productivity and is influenced by several factors such as soil fertility, plant spacing, temperature, water availability, and management practices (Mlambo *et al*, 2017). In this study, we investigated the dry matter yield of maize and maize/cowpea intercrop under different tillage and cropping systems. The results showed that dry matter yield of maize and cowpea was significantly influenced by tillage and cropping systems. Maize/cowpea intercrop had significantly higher dry matter yield compared to sole maize. The intercrop also had higher crop productivity compared to maize alone, indicating the benefits of intercropping in maximizing land use. In both tillage systems, dry matter yield was higher in intercropped plots, with the higher values being observed in the CA system. The results of this study showed that maize/cowpea intercrop had higher plant nitrogen/water use efficiency and dry matter yield compared to sole maize. Dercon *et al*, (2019). These findings are consistent with previous studies that have reported the benefits of intercropping in maximizing land use and improving soil fertility (Rahman et al 2011). Maize and cowpea have different nutrient and water requirements, and intercropping allows for efficient use of these resources. Cowpea is a legume crop that fixes atmospheric nitrogen and improves soil fertility (Oliver *et al* 2018). Maize benefits from the enhanced soil fertility and nitrogen fixation by cowpea, resulting in higher productivity. According to Chikowo *et al*, (2017), the higher plant nitrogen/water use efficiency and dry matter yield observed in intercropped plots can be attributed to several factors. First, maize and cowpea have different root systems that exploit different soil layers, resulting in efficient use of soil moisture and nutrients. Second, cowpea fixes atmospheric nitrogen, reducing the need for nitrogen fertilizer in maize. Third, intercropping reduces competition for resources, resulting in a more efficient use of water, light, and nutrients. (Mohammed *et al*, 2014, Mlambo et al, 2017). The tillage system also influenced plant nitrogen/water use efficiency and dry matter yield. (Aziz, *et al* 2013, Dapaah et al 2015). According to Nabie *et al*, (2014), Ndlovu *et al*, (2018), the CA system had higher plant nitrogen/water use efficiency and dry matter yield compared to CT. This can be attributed to several factors. First, CA improves soil quality, resulting in better plant growth and higher productivity. Second, CA reduces soil erosion and evaporation, resulting in efficient use of water and nutrients. Third, CA promotes soil biological activity, resulting in better nutrient cycling and uptake by plants.

Conclusion and recommendations

In conclusion, maize/cowpea intercropping can improve plant nitrogen/water use efficiency and dry matter yield compared to sole maize. The intercrop allows for efficient use of soil moisture and nutrients, resulting in higher productivity. The MT system can enhance plant nitrogen/water use efficiency and dry matter yield compared to CT. This can be attributed to the improved soil quality, reduced soil erosion and evaporation, and enhanced soil biological activity in the MT system. The findings of this study have important implications for sustainable agriculture in Sub-Saharan Africa, where soil fertility and water scarcity are major constraints to crop productivity and food security.

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Table 1: Physical and chemical properties of the soil at experimental site

Properties	value
PH	6.95
Total N (%)	0.38
Available P (mg/kg)	16.1
Ca^{2+} (Cmol/kg)	5.40
Mg^{2+} (Cmol/kg)	2.50
K^{+} (mg/kg)	24.9
Na^{2+} (Cmol/kg)	0.34
Organic carbon (%)	2.14
Organic matter (%)	2.15
Particle size distribution	
Sand	62.80
Silt	12.00
Clay	25.20
Texture	Sandy lo am
Bulk density)g/cm^3)	1.32

Table 2: **Seasonal variations, dry matter yield of Maize, and Maize/ Cowpea intercrop under different tillage and cropping systems in the early rainy season**

Tillage systems	Cropping System	Plant Height (cm)	Leaf Area cm^2	Days to first tarselling	Shoot fresh weight	Shoot dry Weight	Grain weight on cob (g/pcs)	1000 Grain weight (g)	Number of seeds/cob	Grain yield (t/ha)	Harvex Index
DPS	SM	110.80^{c}	0.61^{a}	43.03^{a}	160.34^{c}	101.09^{a}	219.00^{c}	322.01^{a}	229.00^{f}	0.69^{c}	0.43
MTS	SM	117.30^{b}	0.71^{a}	40.90^{b}	148.90^{e}	78.08^{d}	230.06^{b}	305.21^{a}	245.00^{d}	0.54^{d}	0.36
NTS	SM	114.90^{a}	0.68^{a}	38.66^{c}	152.59^{d}	66.58^{e}	215.95^{c}	307.00^{a}	240.00^{e}	0.44^{e}	0.29
DPS	MCS	98.60^{d}	0.51^{a}	40.10^{a}	174.34^{a}	89.08^{c}	247.90^{a}	332.21^{a}	268.00^{c}	0.74^{b}	0.42
MTS	MCS	111.90^{c}	0.61^{a}	38.34^{c}	168.10^{b}	76.00^{d}	212.34^{c}	365.46^{a}	275.00^{a}	0.78^{a}	0.46
NTS	MCS	109.54^{c}	0.54^{a}	40.18^{b}	151.55^{d}	94.07^{b}	201.17^{d}	337.01^{a}	270.00^{b}	0.54^{d}	0.36
SD		14.53	0.17	3.75	23.79	27.26	34.60	49.72	42.51	0.30	
SE±		5.92	0.07	1.53	9.71	11.13	14.12	20.29	17.35	0.12	
X		110.51	0.61	40.20	160.00	84.15	221.06	328.15	256.00	0.62	

Table 3: **Seasonal variations and dry matter yield of Maize, and Maize/ Cowpea intercrop under different tillage and cropping systems in the late rainy season**

Tillage systems	Cropping System	Plant height (cm)	Leaf Area cm^2	Days to first tarselling	Shoot fresh weight	Shoot dry eight (g)	Grain weight on cob (g/pcs)	1000 Grain weight (g)	Number Of Seeds/cob	Grain yield (t/ha)	Harvest Index
DPS	SM	129.81^{a}	0.71^{a}	48.03^{a}	175.34^{a}	102.27^{d}	228.66^{e}	314.01^{a}	260.00^{d}	0.64^{c}	0.30
MTS	SM	127.32^{a}	0.80^{a}	47.90^{a}	167.90^{b}	93.04^{b}	256.74^{d}	339.90^{a}	240.00^{f}	0.48^{d}	0.28
NTS	SM	124.94^{b}	0.87^{a}	43.66^{b}	160.59^{c}	81.01^{b}	231.06^{e}	398.00^{a}	250.00^{e}	0.44^{d}	0.27
DPS	MCS	108.63^{d}	0.61^{a}	48.10^{a}	168.34^{b}	78.09^{a}	264.00^{c}	322.03^{a}	269.00^{c}	0.65^{c}	0.39
MTS	MCS	121.97^{b}	0.71 a	40.34^{c}	155.90^{d}	97.17^{a}	287.89^{a}	375.12^{a}	290.00^{a}	0.84^{a}	0.54
NTS	MCS	117.00^{c}	0.65^{a}	41.18^{c}	149.50^{e}	66.40^{c}	281.21^{b}	307.60^{a}	281.00^{b}	0.74^{b}	0.49
SD		17.15	0.22	7.94	21.31	12.17	55.13	92.08	60.40	0.35	
SE±		7.00	0.09	3.24	8.70	4.97	22.50	37.58	24.65	0.14	
X		121.61	0.73	44.87	163.00	111.84	258.27	324.78	265.00	0.63	

Mean followed by the same superscript significantly different at 0.05% probability on the same row using Duncan's Multiple Test (DMRT)

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Table 4. Effect of seasonal variations and different tillage and cropping systems on Nutrient Use Efficiency (NUE), Water Use Efficiency (WUE) and Leaf Relative Water Content (LRWC) on Maize, and Maize/ Cowpea intercrop

Tillage systems	Cropping System	Season	Nitrogen use efficiency (kg grain/kg total N	Water use efficiency (kg/m³)	Leaf Relative Water Content (%)
DPS	SM	Early season	0.03[b]	1.00[a]	19.48[d]
		Late season	0.03[b]	1.00[a]	30.27[a]
MTS	SM	Early season	0.03[b]	0.48[a]	17.34[d]
		Late season	0.02[b]	1.00[a]	20.76[c]
NTS	SM	Early season	0.02[b]	0.49[b]	22.93[c]
		Late season	0.02[b]	1.00[a]	24.60[b]
DPS	MCS	Early season	0.04a	1.00[a]	33.99[a]
		Late season	0.03[b]	1.00[a]	23.90[c]
MTS	MCS	Early season	0.04[a]	1.00[a]	22.96[c]
		Late season	0.04[a]	1.00[a]	27.40[b]
NTS	MCS	Early season	0.03[b]	0.48[b]	22.11[c]
		Late season	0.04[a]	0.48[b]	26.92[b]
SD			0.17	1.04	15.00
SE±			0.05	0.30	4.33

Mean followed by the same superscript significantly different at 0.05% probability on the same row using Duncan's Multiple Test (DMRT)

Table 5: Seasonal variation effect in the early and the late rainy season

	Plant height (cm)	Leaf Area cm²	Days to first tarselling	Shoot fresh weight	Shoot dry Weight (g)	Grain weight on cob (g/pcs)	1000 Grain weight (g)	Number of seeds/cob	Grain yield (t/ha)	Harvest Index
Early season	110.51	0.61	40.21	159.60	84.15	221.07	326.65	254.50	0.62	0.39
Late season	121.61	0.73	44.87	162.94	86.34	258.27	342.78	265.00	0.63	0.38
LSD (0.05)	1.37	0.02	3.06	16.75	7.08	50.60	14.08	2.72	0.02	0.03

Table 6 Performance effect between Monocropping and mixed cropping systems in maize, maize/cowpea intercrop

Cropping systems	Plant height (cm)	Leaf Area cm²	Days to first tarselling	Shoot fresh weight	Shoot dry Weight (g)	Grain weight on cob (g/pcs)	1000 Grain weight (g)	Number of seeds/cob	Grain yield (t/ha)	Harvest Index
Sole cropping	120.85	0.73	43.70	160.94	87.03	230.25	331.02	244.00	0.54	0.32
Mixed cropping	111.27	0.61	41.37	161.60	83.45	249.09	339.91	275.50	0.72	0.44
LSD (0.05)	11.86	0.12	1.53	11.88	5.37	21.67	17.93	25.24	0.19	0.11
	*	*	*	NS	NS	NS	NS	*	*	*

* Significant at 5% level of probability. NS: Not significant

Table 7 Performance effects of Disc Plough, Minimum Tillage, and No Tillage systems in maize, maize/cowpea intercrop

Tillage systems	Plant height (cm)	Leaf Area cm^2	Days to first tarselling	Shoot fresh weight	Shoot dry Weight (g)	Grain weight on cob (g/pcs)	1000 Grain weight (g)	Number of seeds/cob	Grain yield (t/ha)	Harvest Index
Disc plough	111.96	0.61	44.82	170.00	92.63	239.40	322.57	251.90	0.66	0.39
Minimum tillage	119.62	0.71	41.87	160.2	86.07	246.76	346.42	262.50	0.68	0.41
No tillage	116.60	0.68	40.92	153.56	77.02	232.35	337.40	260.25	0.54	0.35
LSD (0.05)	3.39	0.08	2.09	6.87	4.11	12.97	10.17	36.32	0.09	0.12
	*	*	*	*	*	*	*	*	*	*

* Significant at 5% level of probability. NS: Not significant

Table 8: Interaction effect of Seasons, Cropping and Tillage systems in maize, maize /cowpea intercrop

Interaction	Plant height (cm)	Leaf Area cm^2	Days to first tarselling	Shoot fresh weight	Shoot dry Weight (g)	Grain weight on cob (g/pcs)	1000 Grain weight (g)	Number of seeds/cob	Grain yield (t/ha)	Harvest Index
Seasons (S)										
Early	110.51	0.61	40.21	159.60	84.15	221.07	326.65	254.50	0.62	0.39
Late	121.61	0.73	44.87	162.94	86.34	258.27	342.78	265.00	0.63	0.38
LSD (0.05)	1.37	0.02	3.06	16.75	7.08	50.60	14.08	2.72	0.02	0.03
	*	NS	*	*	*	*	*	*	NS	NS
Cropping systems (CS)										
Sole cropping (SC)	120.85	0.73	43.70	160.94	87.03	230.25	331.02	244.00	0.54	0.32
Mixed cropping (MC)	111.27	0.61	41.37	161.60	83.45	249.09	339.91	275.50	0.72	0.44
LSD (0.05)	11.86	0.12	1.53	11.88	5.37	21.67	17.93	25.24	0.19	0.11
Tillage systems (TS)	*	*	*	NS	NS	NS	NS	*	*	*
DPS	111.96	0.61	44.82	170.00	92.63	239.40	322.57	671.90	0.68	0.39
MTS	119.62	0.71	41.87	160.2	86.07	246.76	346.42	262.50	0.66	0.41
NTS	116.60	0.68	40.92	153.56	77.02	232.35	337.40	260.25	0.54	0.35
LSD (0.05)	3.39	0.08	2.09	6.87	4.11	12.97	10.17	36.32	0.09	0.12
	*	*	*	*	*	*	*	*	*	*
SxCS	*	NS	*	*	*	*	*	*	NS	NS
SxTS	*	NS	*	*	*	*	*	*	NS	NS
SxCSxTS	*	NS	*	*	*	*	*	*	NS	NS

(S)-Season, (CP)-Cropping system,(TS)-Tillage system,(DP)-Disc plough system, (MTS)-Minimum tillage system, (NTS)-No tillage system. (*)-Significant. (Ns)-Not significant