BERKELEY PUBLICATION AND RESEARCH INTERNATIONAL

12.31.2022

Journal of African Research & Sustainability Studies Vol. 20 No.2

PERFORMANCE OF SOME SELECTED GRASS MULCHES ON ONION (*ALLIUM CEPA L.*) UNDER SPRINKLER IRRIGATION SYSTEM IN GWALLAMEJI, BAUCHI STATE

***SANI, M.; *SADIQ, Y.; *SAMUEL, E. B.; & **RAJI, S. G.**

*Department of Agricultural and Bio-Environmental Engineering Technology, School of Agricultural Technology, Nuhu Bamalli Polytechnic, Zaria, Kaduna State, Nigeria. **Maintenance and services Department, Bayero University Kano, Kano state, Nigeria.

ABSTRACT

There is a continual drive to conserve soil and water and improve irrigation efficiency in agriculture, especially in the Sahel and Sudan Savanna like Bauchi State, where water resources are limited and regulated. The adoption of soil and water conservation techniques has the potential to play a key role in increasing agricultural productivity, enhancing food security as well as Stimulating sustainable economic growth. Among the various methods used for soil and moisture conservation, mulching has been reported to be easiest and cheaper to the local farmer. Sprinkler Irrigation system may cause soil erosion where the application rate is high and where the soils are friable. This study aims at identifying the best mulching material and mulching thickness for the onion farmers in the state by evaluating the various types and thickness of some selected grass mulching materials under onion irrigated field using sprinkler irrigation system in Gwallameji, Bauchi State, Nigeria. The soil texture class for the study area is mainly sandy loam at the depth of 0-45cm, and partly clay loam at the depth beyond 45cm. Thus, it was concluded that the soil is homogenous within the rooting depth of the selected crop in this study. The maximum soil bulk density was 1.50 g/cm^3 and minimum of 1.37g/cm^3 which was well within the recommended range for onion production. From the results, Typha grass performed

Introduction:

The drive to conserve soil and water for improve irrigation efficiency and agriculture has continued to attract expert research for development, especially in the Sahel and Sudan Savanna where water resources are limited and regulated (Mcmillen, 2017). Bauchi State which falls within such regions has much to explore from soil and water conservation techniques. Thus, harnessing this potential can not only increase agricultural productivity but also enhance food security and stimulates sustainable economic growth (Utuk & Daniel, 2015).

Sustainable soil moisture and nutrient conservation might be attained by mulching, incorporation of manure, ridging across farm slope, mulch tillage, to mention few. However, among the various aforementioned methods, mulching has been reported to be the easiest and cheaper for the local farmer (Singh *et al.*, 2014). Nonetheless, mulching which is any material placed on the soil surface to conserve

ISSN: 1213-4977

better in terms of soil moisture retention than the other two mulches (Gamba and Jema grasses). The highest WUE (65.5kg/ha/mm) at 5cm depth was recorded from plots treated with Typha grass, and the lowest (54.6kg/ha/mm) was recorded under Gamba grass. At 10cm depth, the highest value of WUE (86.7kg/ha/mm) was recorded from plots treated with Typha grass, and the lowest (61.9kg/ha/mm) was recorded under Gamba grass. Similarly, at 15cm depth, the highest WUE (76.3kg/ha/mm) was recorded from plots treated with Typha grass, and the lowest was recorded under Gamba grass (59.0kg/ha/mm). The control however recorded the lowest WUE (47.3kg/ha/mm).

KEYWORDS: Mulching, Sprinkler Irrigation, Typha, Gamba, Jema Grass, Bauchi

moisture and nutrient can also lower the soil temperatures around plant roots, prevent erosion and reduce weed growth. Moreso, mulching is applied to reduce the impact of raindrop, sprinkler droplets and or reduces runoff and increase infiltration capacity of soil. Thus, halting the consequential loss of soil nutrient to splash and the later sheet erosions.

Sprinkler irrigation which resembles the natural rainfall is sprayed into the air through sprinklers so that it breaks up into small water droplets (Darko *et al.*, 2017). The impact of this droplets was arrested by the mulching material, ensuring proper infiltration and moisture conservation. In addition, the frequency of irrigation and energy cost was reduced. Thus, introducing sprinkler irrigation and mulching as counter measure for efficient running of the system is a win-win extension call for local farmers in Bauchi.

Statement of the Problems

Sprinkler Irrigation system may cause soil erosion where the application rate is high and where the soils are friable. Mulching practice is very low among the farming families in Bauchi state.
There is the need to identify the best mulching material based on material thickness effect for optimum onion production in the state.

Aim and Objectives

Aim

The aim of this study is to evaluate the effect of various types and thickness of some selected grass mulching materials under onion irrigated by sprinkler irrigation system in Gwallameji, Bauchi.

Specific objectives

i. To study the impact of sprinkler irrigation water droplets on some soil physical properties under different mulching regimes
ii. To study the effects of the selected grass mulches on growth parameters of onion
iii. To evaluate onion performance in terms of yield and water use efficiency under the mulching regimes.

Justification

Mulching material and thickness combination that gives the optimum moisture conservation would be identified and recommended to the farmers for adoption. This would save farmers time, energy and cost of water application. More farmers would be able to conserve soil moisture and nutrients in the field. Resulting into optimum benefit ratio in the research area.

Scope of the study

This study is limited to the trial of three types of locally available grasses as mulching materials under irrigation (sprinkler).

MATERIALS AND METHODS

Study Area

The research was conducted at the demonstration farm of the department of Agricultural and Bio-environmental Engineering of the Federal Polytechnic Bauchi, Bauchi, Nigeria. The Field-Laboratory is situated in Bauchi local government which falls within the Northern Guinea Savannah ecological zone of Nigeria. This area lies within latitude 10° 17'N and longitude 09° 49'E with a mean altitude of about 650m above the sea level.

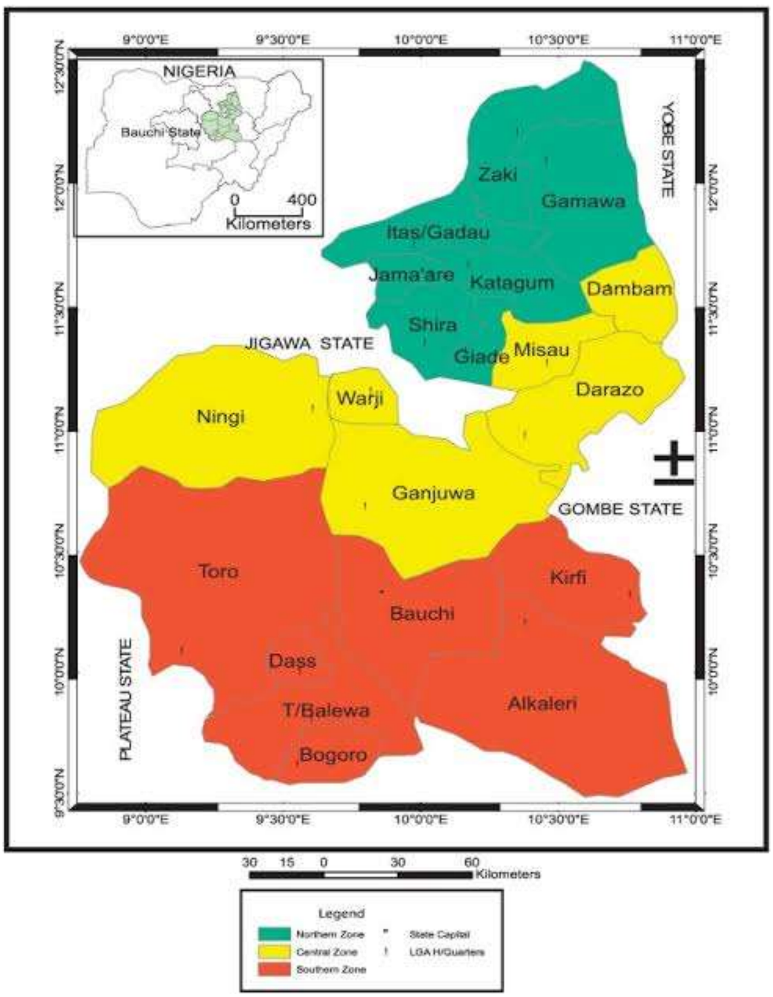

Figure 1: Map of Bauchi State
(Source: Kuhe*et al.*, 2017)

Materials

The following materials was used during the study;

i. Measuring tape
ii. Pegs
iii. Rope
iv. Double ring Infiltrometer
v. Core sampler
vi. Soil auger
vii. Hydrometer apparatus
viii. Weighing balance
ix. Vernier caliper and
x. Sprinkler irrigation components (Risers, fittings, pumps, nozzles)

Pre-Study Data Collection

Soil data

Particle size distribution of the soil site was determined at four depths (0-15, 15-30, 30-45, and 45-60cm) using hydrometer method as described by Gavlak *et al.* (2005).

The infiltration rate of the site was determined in three randomly selected locations on the research plot using the double ring Infiltrometer as described by Gregory (2005).

Topography of the study site was determined using the geographic positioning system (GPS) as described by FAO (2020).

Soil density was also determined at the four soil depths (0-15, 15-30, 30-45, and 45-60cm). Using the procedure suggested by Blake (1965) and FAO (2020).

Irrigation water quality

The irrigation water source was a shallow perennial stream. Water sample was collected using cleaned sterilized bottle sampler and analyzed for EC, PH and SAR.

Irrigation Frequency

Irrigation time was determined using the following formula

$$I_t = \frac{Wr}{AR} \qquad \text{...(1)}$$

Where;

I_t = Irrigation time (hours)

W_r = Water requirement (mm)

AR = Estimated application rate of the system (mm/hr)

Onion Water Requirement Estimates

The crop evapotranspiration (ETc) was estimated by using reference evapotranspiration (ETo) for Bauchi to be combined with onion crop coefficient (Kc) as described by Allen (1998)

$$ETc = Kc * ETo \qquad \text{... (2)}$$

Where;

ETc = Crop evapotranspiration (mm/day)

ETo = Reference evapotranspiration(mm/day)

Experimental Design
Randomized Complete Block Design (RCBD) was adopted for the experimental field design. The treatment variables include four (4) type of mulch (Control (M0), Gamba (M1), Jema (M2), Typha (M3)) and three mulch thickness (5cm (D1),10cm (D2), 15cm (D3)). The data was then replicated three times, making a total treatment/plots; 4x3x3 = 36plots

Data collected
The field data collected include; Soil moisture, Density, Porosity, Onion stem diameter (at selected intervals) and yield

Land Preparation and Layout
Prior to the field experiment, the field was harrowed to break the soil clods into smaller mass for better emergence, leveled and formed into beds (raised to 0.3m high). The Sprinkler risers were installed at six meters apart (see fig. 2 below). The nursery bed was formed and onion seedlings were raised for three weeks and transplanted at the fourth week. All other cultural practices are imposed as when requires.

● = Sprinkler head location

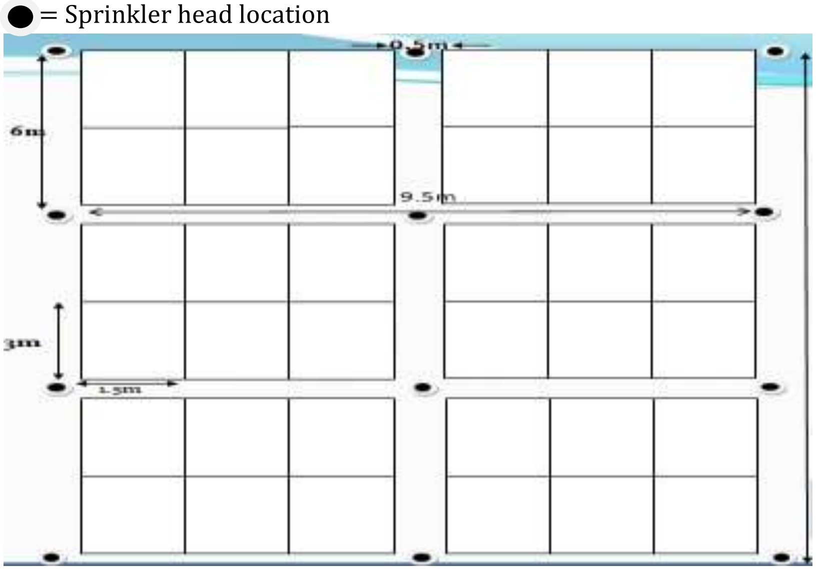

Figure 2: The field experimental layout

Cultural Practices
Planting
42 days old Bombay red onion seedlings
Transplanted manually
At a spacing of 20 cm between plants and 25 cm between rows

Weeding
Weeding was carried out manually as at when necessary.

This was performed when the soil is moist as described by (Piron *et al.,* 2008).

Fertilizer application

Fertigation was imposed through the sprinkler system using NPK (20:10:10) fertilizer, first at development stage and later during flowering stage for big bulb production.

Reproductive growth parameter

Stem diameter

Six bulbs stand were randomly selected and the top of each bulb measured using a Vernier caliper three weeks after transplanting and at harvest as described by (Nanesa, 2019).

Determination of Soil Physical Properties

Moisture content

Gravimetrically according to (Mbah, 2012)

$$M_c = \frac{w}{d} \times 100 \quad ...(3)$$

Where;
w = wet weight
d = weight after drying

Soil Bulk density

Core sampling according to (Cresswell & Hamilton, 2012)

$$Db = \frac{Ms}{Vs} \quad ...(4)$$

Where;
Ms = Mass of soil in grams
Vs = Volume of core sampler in
Db= Bulk density in g/cm3

Soil Porosity

Soil porosity was determined using the following equation as described by (Matko, 2003).

$$S_p = 1 - \frac{Pb}{Pp} \quad ...(5)$$

Where;
Pb = Bulk density in g/cm^3
Pp = particle density in g/cm^3

Harvesting and Yield Estimates

Bulb Weight:

Determined immediately after harvest
Leaves and roots was carefully chopped off from the onion bulbs
Fresh weight of the onions harvested from each plot was measured using weighing balance
By dividing the total weight of the onions in each plot with the number of bulbs (Abdissa *et al.,* 2011)

Marketable Yield:
The marketable yield was taken into consideration all bulbs excluding any bulb with <20 cm diameter.
Measured from each sub-plot and expressed in kg/ha as described by (Gateri *et al.*, 2018).

Total Yield:
Fresh weight of the bulbs was measured and converted to kg/ha as described by (Gateri *et al.,* 2018).

Estimation of Water-Use Efficiency
Water use efficiency (WUE) was estimated as suggested by (Stanhill, 1986; Kumar *et al.,* 2007)

$$WUE = \frac{Ya}{ETc} \quad \dots (6)$$

Where;
Ya = crop yield (kg/ha)
ETc = seasonal crop evapotranspiration

Results and Discussions

Pre-Study Results
The results in this research are presented below, which includes; the soil physical properties (soil texture, soil bulk density, soil infiltration rates) of the study area, and the characteristics of the sprinkler irrigation system used. The results of the irrigation water quality used in this study are also presented here.

Soil Physical Properties

The soil textures
The textural class of the study area soil is presented in table 1. This shows that the soil is mainly sandy loam at 0-45cm depth. There was slightly changed to clay loam at the depth beyond 45cm. Hence, can be concluded that the soil texture is homogenous within the rooting depth of the selected crop in this study.

Table 1: The mean soil texture of the study site.

Soil depth(cm)	Soil Texture
0-15	Sandy loam
15-30	Sandy loam
30-45	Sandy loam
45-60	Clay loam

Soil bulk density
The result of the soil bulk density of the study area is presented in table 2 below.

Table 2: The mean soil bulk density of the study site.

Soil depth(cm)	Bulk Density(g/cm^3)
0-15	1.37
15-30	1.39
30-45	1.45

45-60	1.50

The bulk density of soil under study was found within the range of 1.50 g/cm^3 was recorded while a minimum value of 1.37g/cm^3 was observed. These values are considered within the threshold limit of 1.60g/cm^3 that is safe for crop growth (Arshad *et al.*, 1996). Onion crop with a rooting depth of 30cm appears to have a suitable density for root development in the study site considering the average bulk density record of 1.38g/cm^3. It can also be observed that soil density at the study site increased with soil depth (from 1.37g/cm^3 to 1.50g/cm^3). This finding also agrees with result obtained by (Adhikari *et al.*, 2014, Hill & Cruse, 1985).

Irrigation water quality analysis

Table 3: Results of the Quality Analysis of the Irrigation Water Used in this Study

S/NO	Parameter	Quantity	Acceptable Levels
1	Ca2+	30.1(mg/l)	<60
2	Mg2+	10.87(mg/l)	<30
3	Na+	1.62(mg/l)	<10
4	Cl^-	0.00(mg/l)	<355
5	SAR	0.38(mg/l)	<9
6	PH	5.41	6.5-8.5
7	EC	99.7	
8	Temperature	24.46	

Foot note: Values for the acceptability levels is suggested by FAO, (1994)

The result of the analysis of the irrigation water source at the study site is presented in Table 3. The results obtained from the analysis of the water collected from the stream was; Ca^{2+} (28.10 mg/l, Mg^{2+} (10.67 mg/l), Na^+ (1.67 mg/l), CL^-, (0.00 mg/l), and SAR (0.38 mg/l). EC (97.69 µ/cm) is on the average. From these results, it can be said that the irrigation water used in this study is of high quality, because all the parameters are within the range recommended by FAO, (1994).

Characterized data of the sprinkler system

Table 4: Data on the calibration of the sprinkler system

S/NO	Parameter	Manufacturer's/ Expected Value	Mean Value
1	Discharge	3.5l/s	3.4l/s
2	Application rate	0.35m/hr	0.35m/hr
3	Distance of water throw	6m	5.9m

Footnote: The system was operated at constant pressure of 100kpa during the study

Table 4 shows the characteristics of the used Sprinkler system. The Manufacturer's/Expected values for the discharge rate (3.5l/s), system application rate(0.35m/hr) and distance of water throw (6m) were found to be almost similar to the calibrated values, when the system was operated at a constant pressure of 100kpa. This reduction in distance of water throw and discharge could be as a result of partial clogging of the nozzles or as a result of the effect of wind during measurements

Soil Moisture Retained

Table 5: Mean Soil Moisture Retained on the plots at the selected mulching types and levels

Type of Mulch	Gamba				Jema				Typha			
Depth of Mulch	D0	D1	D2	D3	D0	D1	D2	D3	D0	D1	D2	D3
Moisture Retained (%)	8.81a	10.68b	12.04bc	12.13c	8.81a	11.92bc	13.39cd	14.59de	8.81a	12.67c	14.92de	16.28bc
Standard Error	0.003	0.491	0.238	0.336	0.153	0.395	0.366	0.486	0.147	0.369	0.335	0.271

Footnote: Means with the same letters are not significantly different (α, 0.05)

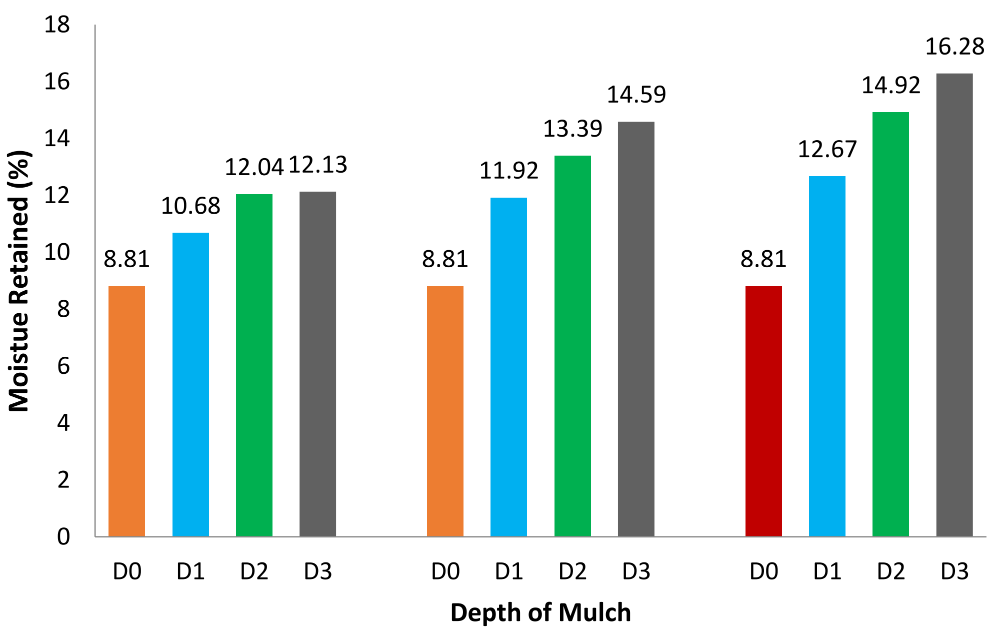

Figure 3 Moisture Retained versus Depth of Mulch by Type at 7 WAT

The result of the means of soil moisture retained on the plots with type of mulch treatment before next irrigation at 7WAT is presented in table 5 and figure 3. The highest moisture retained at 5cm depth was recorded at the treatment with Typha grass (12.67cm) and the lowest was recorded under Gamba grass (10.68 %). Subsequently, the highest moisture retained at 10cm depth was recorded at the treatment with Typha grass (14.92%) and the lowest was recorded under the treatment with Gamba grass (12.04%). Similarly, the highest moisture retained at 15cm depth was recorded at the treatment with Typha grass (16.28%) and the lowest was recorded under the treatment with Gamba grass (12.13%). From the results, Typha grass performed better in terms of soil moisture retention than the other two mulches (Gamba and Jema grasses). Simsek*et al*. (2017) also reported a significant effect on soil moisture retention between various mulch types.

However, there was an increase in soil moisture retention from 10.68% to 12.13% when Gamba grass was increased from 5cm to 15cm depth. Also, soil moisture increased from 11.92% to 14.59% when Jema grass mulching depth was increased from 5cm to 15cm. Similarly, soil moisture increased from 12.67% to 16.28% when Typha grass mulch depth was increased from 5cm to 15cm. The results showed that 15cm depth performs optimally in moisture retention compared to 0cm (control), 5cm and 10cm mulching depths in all the grass types. This could be as a result of total ground coverage which reduces evaporation by the 15cm depth of mulches. The analysis of variance showed there was a statistically significant interaction between the effects of mulching level on soil moisture retention, P= (<0.05). The results corroborate earlier findings by McMillen (2007) that mulching with at least 5cm mulch reduces soil evaporation and improves soil moisture retention compared to bare soil, and Babalola and Oshunsanya, (2007) who reported that using higher mulching depth is capable of improving soil moisture retention when compared to plots with lower mulching depths.

The highest soil moisture (16.8%) was conserved in the treatment with 15cm Typha grass, followed by Jema grass mulch (14.59%). On the other hand, the lowest moisture retention was obtained in the control treatment (8.81%) followed by 5cm Gamba grass (10.68%). This result showed that mulching with 15cm depth of Typha grass performed optimally when compared to the other treatments. In general, there was a statistically significant interaction between the combined effects of mulch type and mulching level on soil moisture retention (P= <0.05). Earlier studies such as Li *et al*. (2013), Thankameni (2016) and Sinkeviciene (2009) have also suggested that mulches, including plastic, gravel, barks, wood chips, and grass can retain the moisture content of soil by reducing the rate of evaporation.

Soil Bulk Density

Table 6: Mean Soil Bulk Density at the selected mulching types and levels

Mulch Type	Gamba				Jema				Typha			
Depth of Mulch	D0	D1	D2	D3	D0	D1	D2	D3	D0	D1	D2	D3
Bulk density (g/cm^3)	1.78f	1.74ef	1.55c	1.47ab	1.78f	1.70de	1.51bc	1.45ab	1.78f	1.67d	1.49abc	1.43a
Standard Error	0.009	0.028	0.019	0.015	0.008	0.007	0.020	0.006	0.018	0.018	0.020	0.003

Means with the same letters are not significantly different (α, 0.05)

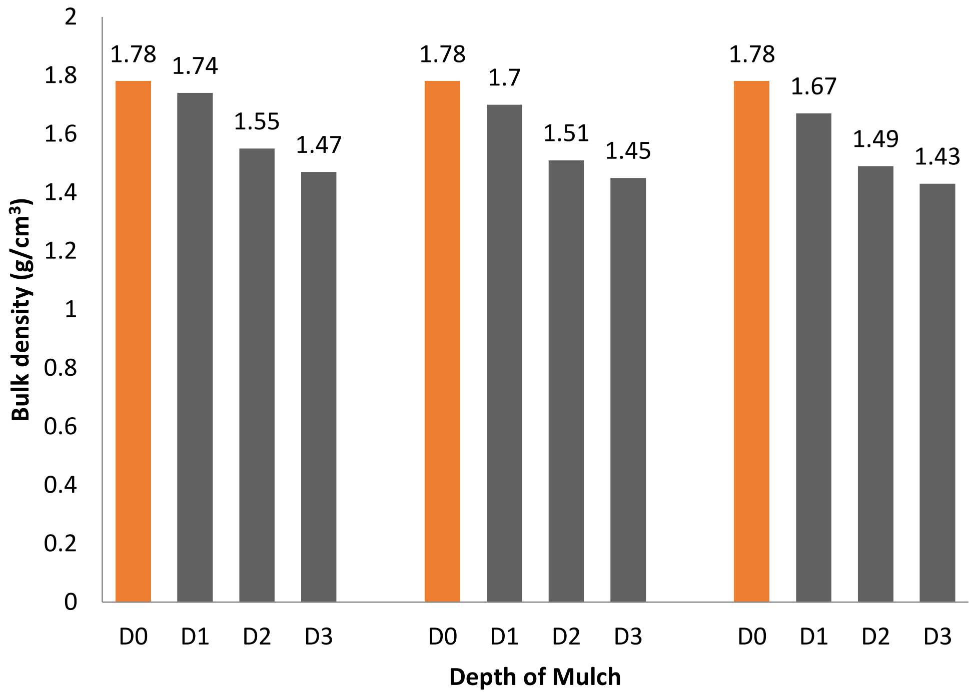

Figure 4: Soil Bulk Density versus Depth of Mulch by Type at 9 WAT

The results of soil bulk density recorded at 9WAT was shown in table 6 and presented in figure 4 above. From the table, the un-mulched plot recorded the highest value of bulk density ($1.78g/cm^3$). The highest value of bulk density at 5cm depth ($1.74g/cm^3$) was recorded at the plot with Gamba grass, and the lowest ($1.67g/cm^3$) was recorded at the plot treated with Typha grass. Also, the highest value of bulk density at 10cm depth ($1.55g/cm^3$) was recorded at the treatment with Gamba grass and the lowest ($1.49g/cm^3$) was recorded at the treatment with Typha grass. Similarly, at 15cm mulching depth, Gamba grass also recorded the highest ($1.47g/cm^3$) bulk density and Typha grass recorded the lowest bulk density ($1.43\ g/cm^3$). From the values recorded, all the grasses performed optimally at 10cm and 15cm depth, which are within the limit (<1.63) that do not affect root growth for sandy loam soils as suggested by (USDA, 1987). This result could be attributed to lower compaction caused by reduced impact of sprinkler water droplets in the plots treated with higher mulching depths. Bulk density was significantly ($p<0.05$) affected by mulch type as shown in Appendix…. However, decreased bulk densities in mulched soils have also been reported by Oliveira and Merwin (2001) and Ghuman and Sur (2001)

However, there was a decrease in soil bulk density from $1.74\ g/cm^3$ to $1.47\ g/cm^3$ when Gamba grass was increased from 5cm to 15cm depth. Also, soil bulk density decreased from $1.70\ g/cm^3$ to $1.45\ g/cm^3$ when Jema grass mulching depth was increased from 5cm to 15cm. Similarly, soil bulk density decreased from $1.67\ g/cm^3$ to $1.43\ g/cm^3$ when Typha grass mulch depth was increased from 5cm to 15cm. The results showed that 15cm depth performs optimally in bulk density compared to 0cm (control), 5cm and 10cm mulching depths in all the grass types. This could be as a result of decomposition of the grass mulches which might have served as a source

of organic matter, which improves soil aeration and reduces soil bulk density. Also, (Doa, 1996), found that soil bulk density decreases with increasing mulching depth.
The table showed that the highest soil bulk density (1.78) was recorded at the control (un-mulched) treatments, while the lowest bulk density (1.43) was recorded in the plots treated with 15cm Typha grass.
From the results, mulching with 15cm Typha grass performs better than the other treatments in improving the soil bulk density, which could be as a result of a better ground coverage by the Typha grass coupled with higher mulching thickness which reduces the effect of compaction, caused by the impact of sprinkler water droplets. The analysis of variance showed that there was no statistically significant interaction between the combined effects of mulch type and mulching levels on soil bulk density (p= 0.420). This is consistent with some studies such as (Ni *et al.*, 2016; Nzeyimana *et al.,* 2017) whom have also shown that mulches can insignificantly improve the bulk density of soil.

Soil Porosity

Table 7: Mean Soil Porosity at the selected mulching types and levels

Mulch Type	Gamba				Jema				Typha			
Depth of Mulch	D0	D1	D2	D3	D0	D1	D2	D3	D0	D1	D2	D3
Porosity (g/cm^3)	32.8a	34.2ab	41.6d	44.6efg	32.8a	36.0bc	43.0de	45.9fg	32.8a	37.1c	43.9def	46.8g
Standard Error	0.550	1.073	0.689	0.578	0.321	0.233	0.733	0.120	0.674	0.681	0.078	0.367

Means with the same letters are Statistically Significant

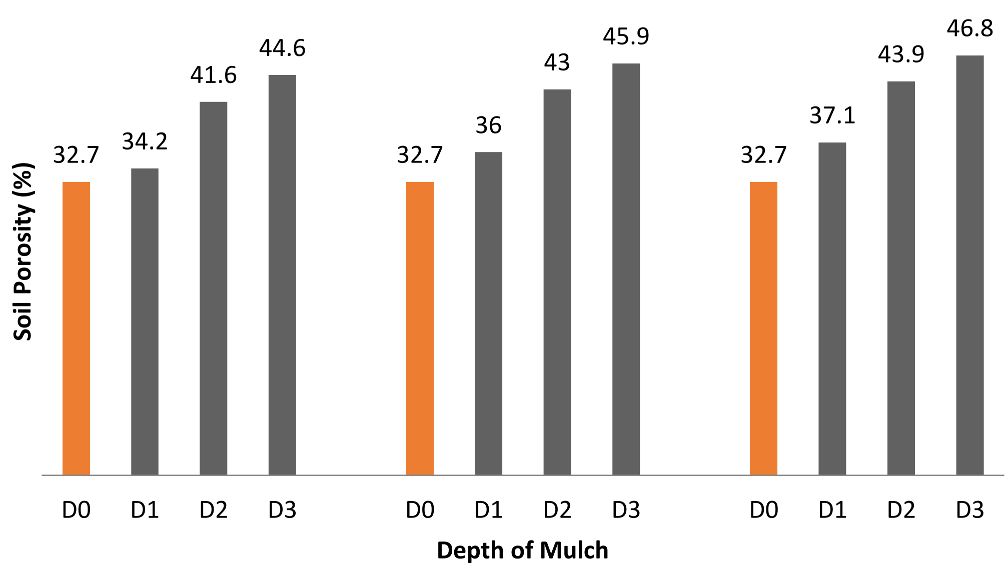

Figure 5: Soil Porosity versus Depth of Mulch by Type at 9WAT

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The effect of different mulching types on soil porosity recorded at 9WAT is presented in table 7 And figure 5. The highest soil porosity (37.1%) at 5cm mulching depth was recorded on the plots treated with Typha grass, and the lowest (32.7%) was recorded at the treatment treated with Gamba grass. Also, the highest porosity (43.9%) at 10cm depth was recorded on the plots treated with Typha grass, and the lowest (41.6%) was recorded on the plots treated with Gamba grass. However, the control treatment (32.7) tends to have the lowest impact in terms of improving soil porosity. From the results, Typha grass tends to better in terms of improving soil porosity in all the mulching levels. The higher soil porosity recorded from the plots treated with Typha grass could be as a result of lower bulk density caused by reduced soil compaction. There was a highly statistically significant interaction between the effects of mulch type on soil porosity (p= 0.01). Similar studies such as Mulumba and Lal (2008) also found out that total porosity increased significantly with increase in mulching rate.

The result showed that Soil porosity increased from 34.2% to 44.6% when depth of Gamba grass was increased from 5cm to 15cm. Also, porosity increased from 36.0% to 45.9% when Jema grass mulching depth was increased from 5cm to 15cm depth. Similarly, porosity increased from 37.1% to 46.8% when the depth of Typha grass was increased to 15cm from 5cm. However, the lowest value of soil porosity was recorded at the control (un-mulched) plots. 15cm Typha grass tends to do better in terms of soil porosity improvement in all the grass types. The higher value of soil porosity recorded from the 15cm depth of mulches could be as a result of lesser soil compaction which was achieved due to total soil coverage compared to the other (lower) soil depths. There was a highly statistically significant interaction between the effects of mulching levels on soil porosity (p= 0.01). Similar results were recorded from similar studies such as Jordan *et al*., (2011) who also reported that mulching level significantly affect soil porosity.

Table 7 shows the effect of three different mulch types, Gamba, Jema, and Typha grasses at three different depths (5cm, 10cm, and 15 cm) on soil porosity prior to harvest (at 9WAT). Soil porosity was highest in the treatment with 15cm depth of Typha mulch (46.8%), and the lowest was recorded at the control (32.7%) followed by 5cm Gamba grass (34.2%). This result could be attributed to decrease in soil bulk density in all the plots treated with 15cm mulches. The result agrees with (Id *et al*., 2019) who reported that soil porosity is improved with the application of mulch.

Onion Stem Diameter

Table 8: Mean Stem Diameter at the selected mulching types and levels

Mulch Type	Gamba				Jema				Typha			
Depth of Mulch	D0	D1	D2	D3	D0	D1	D2	D3	D0	D1	D2	D3
Stem Diameter (mm)	6.36a	9.31b	9.56b	8.67ab	6.36a	9.56b	12.44cd	10.04b	6.36a	10.80bc	13.30d	10.39bc
Standard Error	0.551	1.073	0.689	0.578	0.321	0.233	0.733	0.120	0.674	0.681	0.781	0.367

Means with the same letters are Statistically Significant.

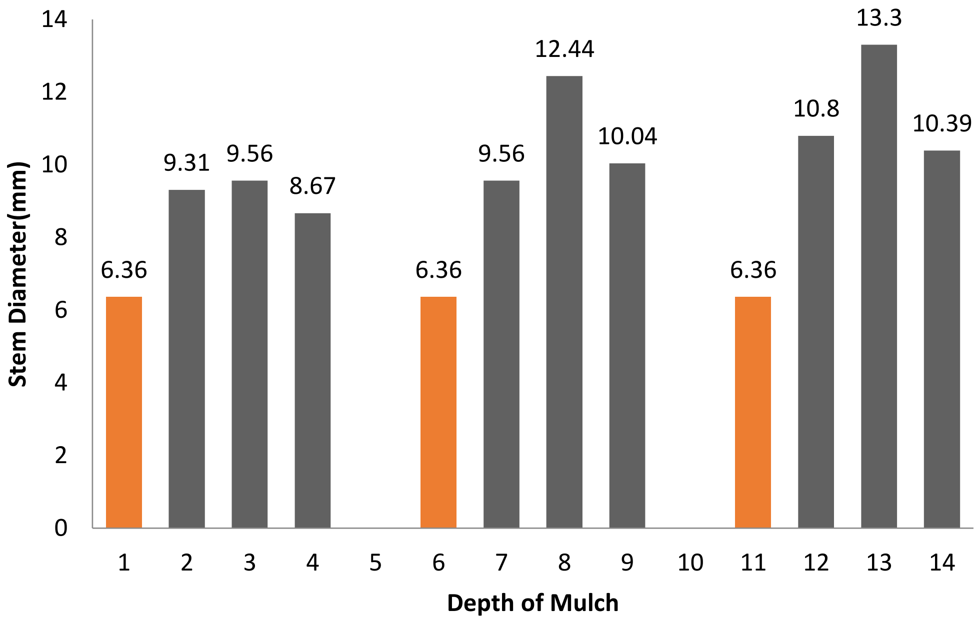

Figure 6: Onion Stem Diameter versus Depth of Mulch by Type at 9WAT

There result of the effects of mulching type and levels on onion stem diameter recorded at 9WAT is shown in table 8 and figure 6 above. The highest stem diameter (10.80mm) at 5cm mulching depth was recorded on the plots treated with Typha grass, and the lowest (9.31mm) was recorded at the treatment treated with Gamba grass. Also, the highest stem diameter (13.30mm) at 10cm depth was recorded on the plots treated with Typha grass, and the lowest (9.50mm) was recorded on the plots treated with Gamba grass. However, the control treatment (6.36mm) recorded the lowest value in terms of onion stem diameter. From the results, Typha grass tends to better in terms of achieving larger stem diameter compared to the other mulching materials. The larger stem diameter recorded from the plots treated with Typha grass could be as a result of higher soil porosity which gave a better aeration that aids root's and stem growth. Analysis of variance showed that there was a statistically significant interaction between the effects of mulch type on stem diameter ($p<0.05$). This agrees to Rachel *et al.*, (2018) who reported that mulching types and levels induced significant variation in stem diameter of onion.

The highest (9.56mm) Stem diameter of onion from the plots treated with Gamba grass was recorded when 10cm depth of mulch was used, and the lowest(8.67mm) was recorded when 15cm depth was used. Under Jema grass treatments, the highest value of stem diameter was observed when 10cm depth of mulch was used and the lowest (9.56mm) was observed when 5cm depth was used. Also, under Typha grass, the highest (13.30mm) value was observed when 10cm depth was used, and the lowest (10.39mm) was observedwhen15cm mulching depth was used. Overall, the control treatment recorded the lowest (6.36mm) stem diameter than all other treatments. From the results, 10cm performed optimally when compared to other mulching levels. The lower values observed from 5cm depth could be as a result of lower effect of

maintaining soil temperature associated with lower soil moisture retention. Also, under 15cm mulching levels, the lower values recorded could be as a result of much interference with the vegetative growth by the higher mulching levels. The above findings corroborate earlier findings by Lakew *et al.,* (2014).
The maximum (13.30mm) value of stem diameter was observed from the plots treated with 10cm depth of Typha grass, while the lowest (6.36mm) was observed from the control. Earlier studies reported a positive correlation between stem diameter and total yield of onion. 10cm Typha grass performs optimally compared to other treatments. The Increased stem diameter due to mulching effects might have resulted from retention of more soil moisture in association with lower soil temperature throughout the growth period. This corroborates earlier reports by Inusah *et al.*, (2013) that mulches improve the vegetative growth of onions.

Total Yield

Table 9 Mean Total Yield at the selected mulching types and levels

Mulch Type	Gamba				Jema				Typha			
Depth of Mulch	D0	D1	D2	D3	D0	D1	D2	D3	D0	D1	D2	D3
Total Yield (t/ha)	14.41a	16.66ab	18.89bcd	17.97bc	14.41a	19.48cd	24.47fg	21.17de	14.41a	19.96cd	26.42g	23.29ef
Standard Error	0.651	0.413	0.237	0.133	0.243	0.044	0.417	0.313	0.439	0.191	0.837	0.338

Means with the same letters are Statistically Significant

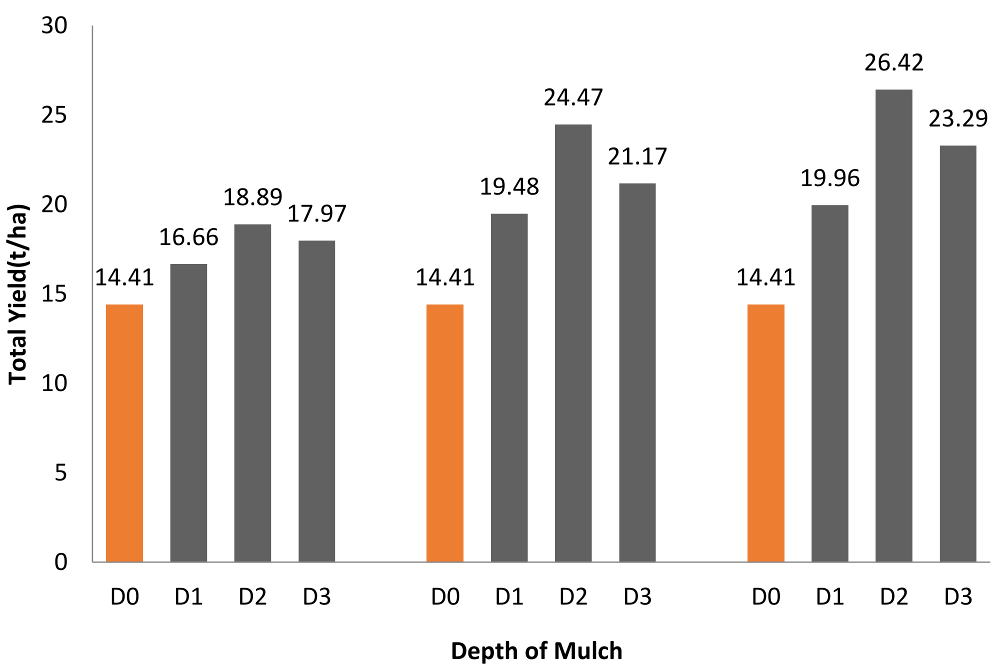

Figure 7: Total yield *versus Depth of Mulch* by *Type at 9 WAT*

The result of the effect of mulching type and levels on the total yield of onion recorded at 9WAT is presented in table 9 and figure 7 above. From the table, the highest (19.96t/ha) onion yield at 5cm mulching depth was observed at the plots treated with Typha grass, and the lowest (16.66 t/ha) was observed from the plots treated with Jema grass. Also, at 10cm mulching depth, the highest (26.42 t/ha) yield was observed from the plots treated with Typha grass and the lowest (18.89 t/ha) was observed at the plots treated with Gamba grass. Lastly, the highest (23.29 t/ha) yield at 15cm mulching depth was recorded at the plots treated with Typha grass and the lowest (17.97 t/ha) was recorded at the plots treated with Gamba grass. However, Typha grass tends to do better in terms of yield performance when compared to other grass mulches. Field observations during the study indicated that Typha grass as mulch was more stable on the onion beds and spread more compactly and uniformly than the other mulches and was thus more effective mulch in this regard. More active vegetative growth (Stem diameter) of the Typha grass, in comparison to the other mulches may have led to enhanced bulb size and weight as more assimilates were trans-located into bulb formation than in the other treatments. Appendix… showed a statistically significant difference between type of mulch and onion yield ($P<0.05$). This is in agreement with Rachel *et al.*, (2018) who reported that different mulches under various depths improve the onion yields.

Minimum (14.41 t/ha) value was recorded from all the plots was when no-mulch was used. Under Gamba grass, the highest yield (18.89 t/ha) was recorded when Gamba grass was under 10cm mulching depth and the lowest (16.66 t/ha) was recorded when 5cm depth was used. Under Jema grass, the highest yield was recorded when10cm mulching depth was used, and the lowest (19.48 t/ha) was recorded when 5cm depth was used. Similarly, under Gamba grass, the highest (26.42 t/ha) was recorded when 10cm mulching depth was used. The general trend of variation amongst the various depths with regards to total yield shows 10cm>15cm>5cm>0cm. The higher yield recorded at 10cm mulching depth from all the mulches could be as a result of a better soil coverage than 0 and 5cm depth which improves the soil physical properties, and also minimal interference of the grasses which could suffocate and even bury the plants compared to 15cm mulching depth. shows there was a significant difference observed in performance of yields among the effects of mulching levels ($p< 0.05$). These findings are similar to those of Ma (2011) who attained optimal value at 10 cm mulch thickness while Makki (1987) found that any more mulch additions could not benefit the soils in any form but leads to degradation and identified 6 cm thickness as the bench mark.

The maximum onion yield (26.42t/ha) was recorded under the plots treated with 10cm depth Typha grass mulch while the lowest yield (14.41 t/ha) was recorded under the control (un-mulched) plots. The better onion yield recorded from the plots treated with 10cm Typha grass could be as a result of improved soil moisture conservation, improved soil bulk density and porosity while at the same time causing minimal injury to the plants. These conditions encourage additional root development and biological activity (Donald 1989; Mosh, 2006). shows there was a highly significant difference observed in performance of yields among the combined effects of mulching types and levels ($P< 0.01$). Mulching with many types of organic materials, including chopped grass and clover material has been demonstrated to positively contribute to improved plant growth, development and enhanced bulb yield of onions (Russo *et al.,* 1997; Hanson *et al.,* 2001; Hugh *et al.,* 2003; Riley *et al.,* 2003). Further, earlier researchers have demonstrated that in comparison to un-mulched soils, the crop yields of mulched soils (depending on factors such as geographic location, soil type and nature of mulch) can be enhanced two- or three-folds in vegetables (Stephenson and Bergman, 1963; Pollack *et al.,* 1969; Bhella, 1986). Knowler and Bradshaw (2007) and Hopps *et al.* (2008) and other researchers have corroborated the findings in this work which underscores that mulching irrigated vegetables with organic materials such as Andropogan grass is a critical strategy for enhancing and sustaining the productivity of small and medium onion cultivation

Marketable Yield

Table 10: Mean Marketable Yield at the selected mulching types and levels

Mulch Type	Gamba				Jema				Typha			
Depth of Mulch	D0	D1	D2	D3	D0	D1	D2	D3	D0	D1	D2	D3
Marketable Yield (t/ha)	10.32a	13.66ab	15.66bcd	15.27bc	10.32a	16.12cd	21.05e	17.78d	10.32a	16.42cd	23.52f	20.18e
Standard Error	0.271	0.337	0.183	0.113	0.437	0.188	0.360	0.265	0.007	0.088	0.738	0.364

Footnote: Means with the same letters are Statistically Significant

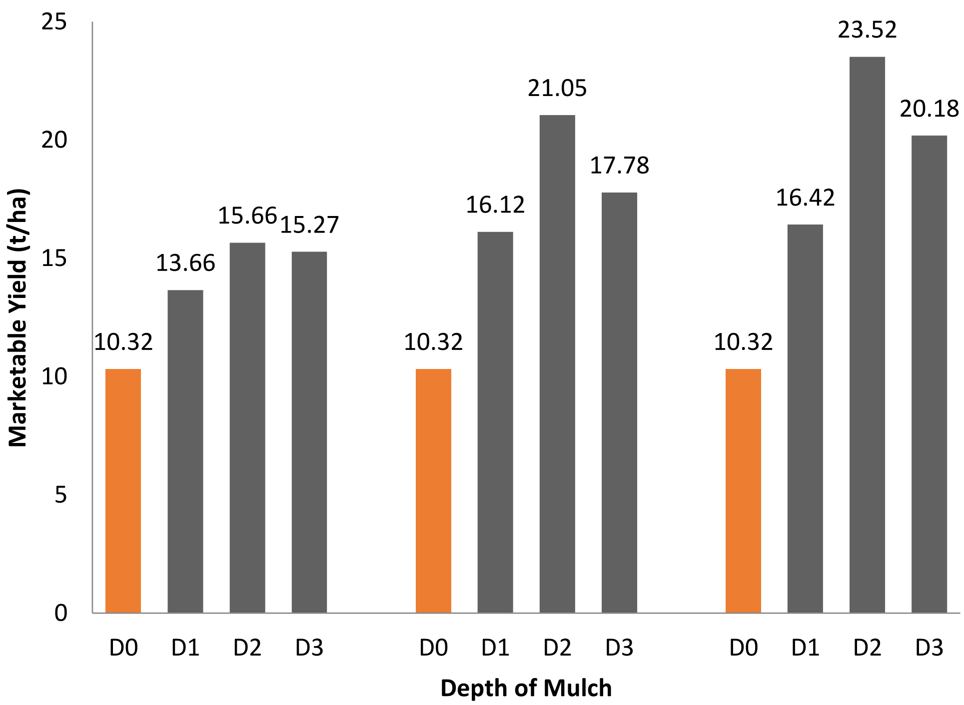

Figure 8: Marketable yield versus Depth of Mulch by Type at 9WAT

The means of marketable yield under various mulching types and levels recorded at 9WAT was presented in Table 10 and Figure 8. From the table, the lowest value of marketable yield (10.32t/ha) was recorded at the control. At 5cm mulching depth, the highest marketable yield

ISSN: 1213-4977

(16.42t/ha) was recorded under Typha grass, and the lowest (13.66t/ha) was recorded under plots treated with Gamba grass. At 10cm, the highest marketable yield (23.52t/ha) was recorded under plots treated with Typha grass, while the lowest (15.66t/ha) was recorded under plots treated with Gamba grass. Similarly, at 15cm, the highest marketable yield (20.18t/ha) was recorded under plots treated with Typha grass and the lowest (15.27t/ha) was recorded under Gamba grass. This shows that Typha grass performs better in terms of marketable yield compared to the other mulches. This increase in marketable yield might be as a result of larger onion bulbs, and larger stem diameter observed from the plots treated with Typha grass. Analysis of variance showed that here was a statistically significant (P<001) difference in marketable yield among the mulching types.

Minimum (10.32 t/ha) value of marketable yield was recorded from the plots where no-mulch was used. Under Gamba grass, the highest marketable yield (15.66 t/ha) was recorded under 10cm mulching depth and the lowest (13.66 t/ha) was recorded when 5cm depth was used. Under Jema grass, the highest marketable yield (21.05 t/ha) was recorded when 10cm mulching depth was used, and the lowest (16.12 t/ha) was recorded when 5cm depth was used. Similarly, under Typha grass, the highest (23.52t/ha) was recorded when 10cm mulching depth was used and the lowest (16.42t/ha) was recorded when 5cm mulching depth was applied. The general trend of variation amongst the various depths with regards to marketable yield also shows 10cm>15cm>5cm>0cm. This increase in marketable yield from the 10cm mulching depth could also be attributed to a better soil coverage than 0 and 5cm depth which improves the soil physical properties, and also minimal interference of the grasses which might have suffocated and even buried the plants compared to 15cm mulching depth. Statistical analysis showed a highly statistically significant difference (P<0.05) between the various mulching levels on marketable yield. This result agrees with Igbadun *et al.* (2012) who found gains in the marketable yield of onion using various organic mulch types.

The highest marketable yield (23.52t/ha) was produced by 10cm Typha grass and the lowest (10.32 t/ha) by the control (no-mulch). The higher marketable yield recorded from 10cm depth of Typha grass could be as a result of higher onion yield recorded from the same plots. There was a statistically significant (P<0.05) difference in marketable yield among the mulching types and levels. This result also corroborates the earlier findings by Igbadunet *al.* (2012) who found gains in the marketable yield of onion using organic mulch.

Water-Use Efficiency (WUE)

Table 11: Means of Water-Use Efficiency at the selected mulching types and levels

Mulch Type	Gamba				Jema				Typha			
Depth of Mulch	D0	D1	D2	D3	D0	D1	D2	D3	D0	D1	D2	D3
WUE (kg/ha/mm)	47.3a	54.6ab	61.9bcd	59.0bc	47.3a	63.9cd	80.3fg	69.4e	47.3a	65.5d	86.7g	76.3ef
Standard Error	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016

Footnote: Means with the same letters are Statistically Significant

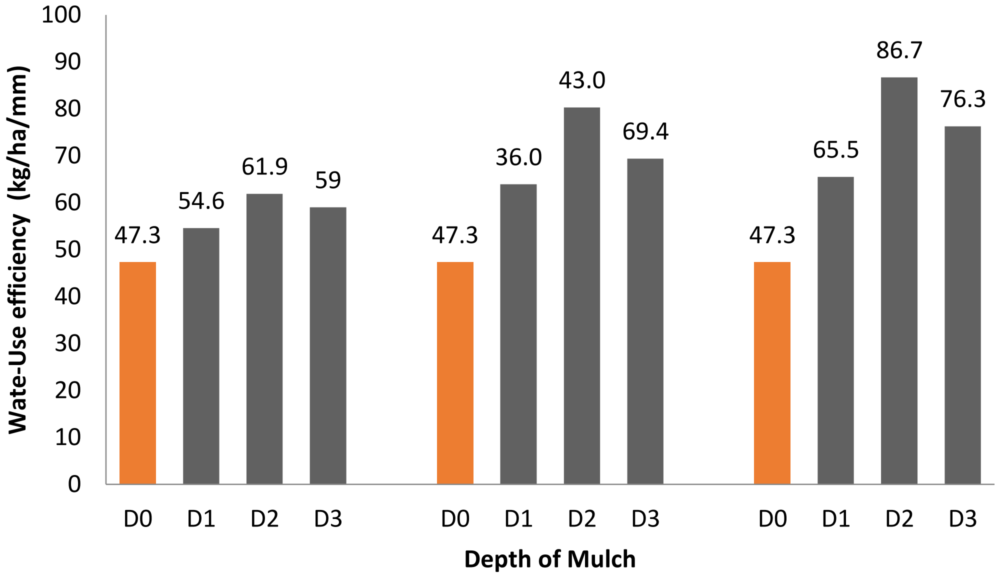

Figure 9: Water-Use Efficiency versus Depth of Mulch by Type at 9WAT

Water-Use efficiency obtained for different mulching treatments recorded at 9WAT are presented in table 11 and figure 9. The highest WUE (65.5kg/ha/mm) at 5cm depth was recorded from plots treated with Typha grass, and the lowest (54.6kg/ha/mm) was recorded under Gamba grass. At 10cm depth, the highest value of WUE (86.7kg/ha/mm) was recorded from plots treated with Typha grass, and the lowest (61.9kg/ha/mm) was recorded under Gamba grass. Similarly, at 15cm depth, the highest WUE (76.3kg/ha/mm) was recorded from plots treated with Typha grass, and the lowest was recorded under Gamba grass (59.0kg/ha/mm). The control however recorded the lowest WUE (47.3kg/ha/mm). The higher WUE recorded under Typha grass mulch could be as a result of higher moisture retained from the plots treated with Typha grass which might have improved the yield which is proportional to the WUE. The analysis of variance showed a significant ($p< 0.05$) difference between grass mulching type for Water-Use Efficiency (WUE). Similar findings were reported by (Lakew *et al.,* 2014; Kumar, 2007).

Minimum (47.3kg/ha/mm) value of WUE yield was recorded from the plots where no-mulch (control) was used. Under Gamba grass, the highest marketable yield (61.9kg/ha/mm) was recorded under 10cm mulching depth and the lowest (54.6 kg/ha/mm) was recorded when 5cm depth was used. Under Jema grass, the highest WUE (80.3kg/ha/mm) was recorded when 10cm mulching depth was used, and the lowest (63.9kg/ha/mm) was recorded when 5cm depth was used. Similarly, under Typha grass, the highest (86.7kg/ha/mm) was recorded when 10cm mulching depth was used and the lowest (65.5kg/ha/mm) was recorded when 5cm mulching depth was applied. This increase in WUE from the 10cm mulching depth could also be attributed to the Improve in onion yield recorded from the plots. The analysis of variance showed significant ($p< 0.05$) difference between grass mulching levels for Water-Use Efficiency (WUE).

The highest WUE (86.7kg/ha/mm) was produced by 10cm Typha grass and the lowest (47.3kg/ha/mm) by the control (no-mulch). The higher WUE recorded from 10cm depth of Typha grass could be as a result of higher onion yield recorded from the same plots. There was highly significant difference ($P<0.05$) in WUE among the mulching types and levels. Thus, agree with Lakew *et al*., (2014).

CONCLUSION

The highest WUE (65.5kg/ha/mm) at 5cm depth was recorded from plots treated with Typha grass, and the lowest (54.6kg/ha/mm) was recorded under Gamba grass. At 10cm depth, the highest value of WUE (86.7kg/ha/mm) was recorded from plots treated with Typha grass, and the lowest (61.9kg/ha/mm) was recorded under Gamba grass. Similarly, at 15cm depth, the highest WUE (76.3kg/ha/mm) was recorded from plots treated with Typha grass, and the lowest was recorded under Gamba grass (59.0kg/ha/mm). The control however recorded the lowest WUE (47.3kg/ha/mm).

RECOMMENDATION

The following recommendations were made:

i. Nitrogenous fertilizer N.P.K. and organic fertilizer should always be applied in order to improve the nutrients content of the irrigated soil.

ii. The main source of irrigation water should be properly protected from the discharge of effluents and sewage that may pollute the quality of the water and in-turn affect the soil when used for the irrigation.

iii. There should be strict monitoring of the soil quality within the study area at regular intervals, for proper management of the soil and also to ascertain the status of the soil.

iv. Further research work should be conducted on the organic matter content of the soil and few of the physical and chemical properties that were not captured on this research work.

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Plate I: Sprinkler irrigation systems
Source: Sanosil.com

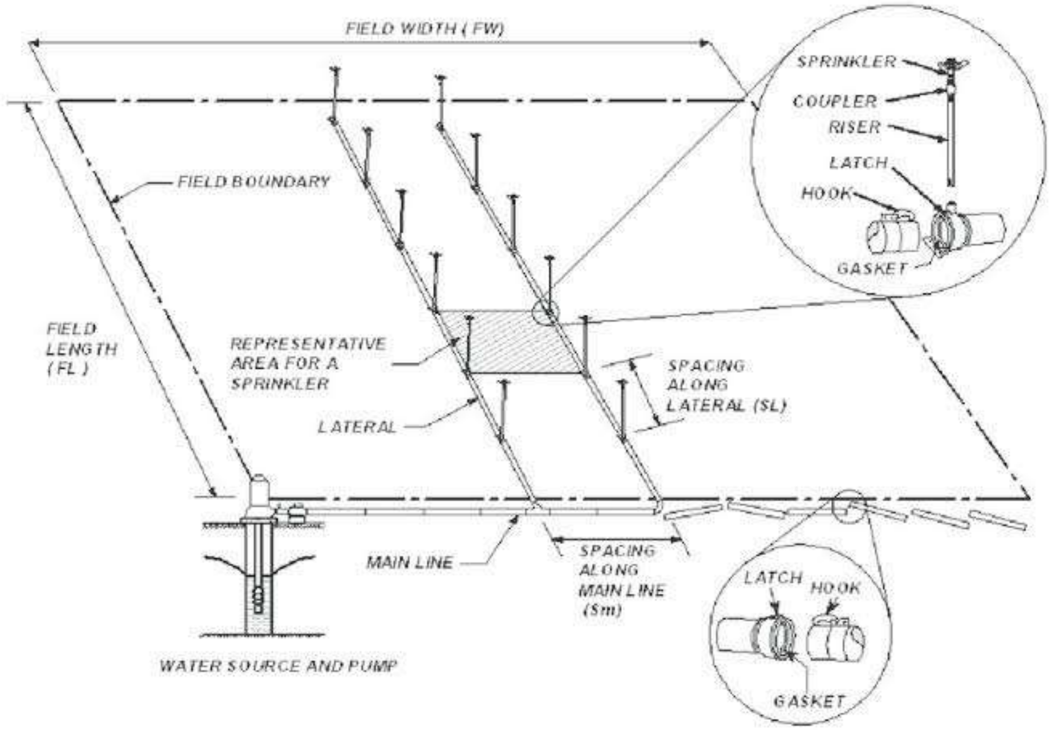

Figure 1: Components and general layout of Sprinkler irrigation systems
Source: Martin *et al.*, 2007.