



# **Influence of Grass Mulch on Soil Physical Attributes of a Luvisol and Water Requirement of Cowpea (*Vigna unguiculata*) in the Transition Zone of Ghana**

**Kwabena Kyere<sup>1\*</sup>, Kofi Agyarko<sup>1</sup>, Benette Osei Yaw<sup>1</sup>  
and Emmanuel Kwasi Asiedu<sup>1</sup>**

<sup>1</sup>College of Agriculture Education, University of Education, Winneba, Mampong Campus, Ghana.

## **Authors' contributions**

*This work was carried out in collaboration between all authors. Author KK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KA and BOY managed the analyses of the study. Author EKA managed the literature searches. All authors read and approved the final manuscript.*

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## **ABSTRACT**

The experiment was conducted to assess the influence of grass mulch on some soil physical attributes of a luvisol and water requirement of cowpea in the transition zone of Ghana at the University of Education, Winneba, Mampong campus. A Randomized Complete Block Design (RCBD) was used. The grass mulch rates were; 1 t ha<sup>-1</sup>, 3 t ha<sup>-1</sup>, 5 t ha<sup>-1</sup> and control (no mulch) with four replications. The grass mulch was applied evenly on the soil surface under a cultivated cowpea. Parameters assessed were soil aggregate stability, bulk density, soil porosity, soil gravimetric and volumetric moisture contents, cumulative infiltration, sorptivity, organic matter content and cowpea seed yield. The study showed that mulching improved cowpea seed yield, soil gravimetric moisture content, soil volumetric moisture content, cumulative infiltration amount, infiltration rate, sorptivity and soil residual moisture. The soil physical parameters measured in both the minor and major seasons were higher on the 5 t ha<sup>-1</sup> plots but lower on the control (no mulch) plots. There was a significant ( $P = .05$ ,  $r = 0.61$ ) positive correlation between the cowpea seed yield and soil gravimetric moisture content. Estimation of water requirement of cowpea using the Blaney-

\*Corresponding author: E-mail: Joessam29@yahoo.com;

Criddle method produced higher values in 2010 (629.70 mm season<sup>-1</sup>), 2011 (619.60 mm season<sup>-1</sup>) than the field graphical estimated values in 2010 (399.00 mm season<sup>-1</sup>), 2011 (357.0 mm season<sup>-1</sup>) and improvised evaporation pan values in 2010 (347.90 mm season<sup>-1</sup>), 2011 (136.11 mm season<sup>-1</sup>) seasons. Although cowpea is tolerant to water deficit to some extent, the use of 5 t ha<sup>-1</sup> mulch for sustainable soil moisture management would be important in areas of erratic and inadequate rainfall.

**Keywords:** Bulk density; Grass mulch; infiltration; soil aggregate stability; soil organic matter; sorptivity; total porosity; water requirement.

## 1. INTRODUCTION

Mulching, which is a process of covering the soil surface around a plant to create good-natured conditions for its growth has extensively proven to preserve soil moisture, reducing soil temperature and increasing nutrient uptake and crop productivity [1,2]. [3] further noted that mulching is a loose organic material such as straw, cut grass used to cover the soil around plants or between the plant rows for protection or improvement of the area covered. Cowpea (*Vigna unguiculata*) is an important legume in regions where water stress is the major constraint for its production although its water requirement per unit grain yield is relatively low compared to most crops [4]. Water is one of the most precious natural resources for agricultural production and agricultural accounts for 70% of the actual water use [5]. Mulching could be beneficial for some period during the growing season as it helps to improve infiltration rate [6] by minimizing crusting, and improving macro pores [7]. [8] explained that crop water requirement is the water used by a crop for growth and cooling purposes. [9] observed that the water requirement process is determined by two separate processes; Evaporation (E) and Transpiration (T). Evaporation is the water evaporated or "lost" from the wet soil and plant surface and transpiration is the water transpired or "lost" to the atmosphere from small openings on the leaf surfaces called stomata. In cowpea there are many studies on crop water requirement mainly in relation to seed yield. In Nigeria [10] obtained yields up to 1.9 t ha<sup>-1</sup> using 464 mm season<sup>-1</sup> of water and 2.9 t ha<sup>-1</sup> with 449 mm season<sup>-1</sup> of water was also obtained by [11]. [9] came out with a seasonal water use of cowpea as 669 mm season<sup>-1</sup> in California – Sao Joaquin area. Cowpea is usually grown under rainfed rather than irrigated condition. [12] reported that cowpea requires estimated water requirement of 175-288 mm season<sup>-1</sup>. Cowpea grows well under wide extreme of moisture conditions and once established, it is fairly drought tolerant [13]. [14] further reported that

cowpea is often grown in rain – fed agriculture receiving at least 600 mm annual rainfall. Crop water requirement may be influenced by actual soil water content. As soil dries, it becomes more difficult for a plant to extract water from the soil because there isn't much soil water for plant use. At field capacity (maximum plant-available water content) plants use water at the maximum rate. When the soil water drops below field capacity, plants use less water [8]. [8] further found that after rain or irrigation, actual crop water requirement is higher than when the soil or crop surface is dry but when the soil or crop surface is wet, the evaporation portion of crop water requirement increases significantly, resulting in a higher actual crop water requirement especially early in the growing season.

The constant decline in cowpea production as a result of shortened rainfall periods and poor soil condition have prompted farmers to employ conservative agricultural practices in order to improve the soil's condition by reducing soil evaporation, soil compaction, enhance nutrient management and incorporate additional nutrients [15]. The use of grass mulch has extensively proven to preserve soil moisture, reducing soil temperature and increasing nutrient uptake and crop productivity [1].

A sustainable practice which is becoming popular to many farmers is grass mulching and it is one of the important agronomic practices in conserving the soil moisture and modifying the soil physical condition [6]. Therefore, the objective of this work was to assess the influence of grass mulch on some physical properties of a luvisol and influence on water requirement of cowpea in the transition forest zone of Ghana.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

The study was conducted from September to December, 2010 (Minor rainy season) and repeated in August to October, 2011 (Major rainy

season) at the Multi-purpose crop nursery of the College of Agriculture Education, University of Education, Winneba, Mampong, Ghana (07° 04'N, 01°24'W). Mampong lies at 457.5 m above sea level and falls within the transition zone that is between the southern rain forest and Guinea Savannah belt of the North. Rainfall distribution in the area is bimodal and classified into major and minor rainy seasons [16]. The soil is of the savannah Ochrosol type which belongs to the Bediesi series known as Chromic Luvisol in F.A.O/UNESCO classification and derived from the voltaian sandstone [17].

## 2.2 Treatments and Design

The land was ploughed and harrowed in the first week in October for the 2010 season and first week in August 2011, for the second season. The field was levelled and laid out with a hoe and a shovel. There were four treatments of different rates of grass mulch and arranged in a Randomised Complete Block Design (RCBD) with 4 replications. These treatments were (i) 1 t ha<sup>-1</sup> (ii) 3 t ha<sup>-1</sup> (iii) 5 t ha<sup>-1</sup> and (iv) Control (no mulch). Each plot measured 3 m by 2 m giving a total area of 6 m<sup>2</sup> per plot. A path of 1 m was left between each plot. The grass mulch was evenly spread on the various plots 21 days after planting cowpea. Lining and pegging was done for planting of cowpea. Seeds of cowpea 'Nhyira' variety were sown at a depth of about 2cm, and spacing of 0.6 m between rows by 0.2 m within rows. Germination was observed four days after sowing. Replanting of ingeminated seeds (filling in) was done 7 DAP. The paths between the blocks and replications were weeded with cutlass and hoe four times during the experiment, starting from 7 Days After Planting (DAP) and at 7 days intervals. Leaves eating insect pests were controlled by using cymethoate at 1L/ha 35 DAP at flower bud formation, 45DAP at flowering for both 2010 and 2011 seasons. Cymethoate was again used at 1L/ha 55 DAP at early podding, 65 DAP at Mature pods stage to control pod sucking insects in 2010 and 2011 season. The knapsack sprayer machine was used for the spraying at the same rate for all the treatments. The experiment was conducted between September-December, 2010 and was repeated between August and October in 2011.

## 2.3 Determination of Parameters

The dry bulk density was determined from soil cores collected at 0 - 15 cm depth on the field with core sampler [18]. Moisture content was

determined on gravimetric and volume basis [19] while residual moisture storage was obtained from the measurement of the gravimetric moisture content of the soil at the end of the experiment, using the method by [20]. Total porosity was calculated by the formula;  $f = 1 - \rho_b/\rho_s$  where  $f$  is the total porosity,  $\rho_b$  is bulk density and  $\rho_s$  is particle density (2.65 g cm<sup>-3</sup>) [19]. Air filled porosity was calculated by the formula,  $af = f - \theta_v$  [18], where  $af$  is air filled porosity  $f$  is the total porosity and  $\theta_v$  is volumetric water content. A modified wet sieving method was used to measure the aggregate stability (ASt) [21]. Twenty grams (20 g) of the aggregates were weighed onto a 0.25 mm sieve. The sieve was immersed in water contained in a basin and manually rotated gently for five minutes. The wet sieved aggregates were dried to a constant mass. Another 20 g sub sample was weighed and oven dried to a constant mass. After oven drying, the wet sieved aggregates were divided by the sub sample to give the aggregate stability, which was expressed as a percentage. Sorptivity was measured by dividing the first 5-minute cumulative infiltration by the square root of the time [22]. The single ring infiltrometer method [18] was used to determine the cumulative infiltration in the field.

## 2.4 Calculation of Cowpea Water Requirement

### 2.4.1 Using Blaney-Criddle method

The Blaney – Criddle method was used in the estimation of water requirement of cowpea [23]. The simplified form is expressed as:

$$ET_{\text{crop}} = ET_0 \times K_c \quad (1)$$

$$ET_0 = p (0.46 T_{\text{mean}} + 8.13) \quad (2)$$

Where  $ET_{\text{crop}}$  refers to the water requirement of reference crop (cowpea) in mm day<sup>-1</sup> or mm season<sup>-1</sup>,  $K_c$  refers to crop (cowpea) coefficient, 0.79,  $P$  is the mean daily percentage of annual day time hours;  $ET_0$  refers to reference crop evapotranspiration in mm day<sup>-1</sup>;  $T$  refers to mean daily temperature. The number of days the plants will spend in each month is then multiplied by  $ET_0$  to obtain the total  $ET_0$  [23].

### 2.4.2 Using improvised evaporation pan method

Due to the non-availability of a standard Class A pan, an improvised and simplified pan was used

at the experimental site to estimate water requirement of cowpea in the study [24]. Three (3) improvised evaporators used to collect the data were cylindrical in shape with a constant diameter of 190 mm. The containers were then graduated from zero (0) to 120 mm. The graduated containers were filled with water to the 120<sup>th</sup> millimetre level, 30 mm from the top of the containers and placed on the field at ground level. The level of water in the containers was recorded every 24 hours throughout the period the plants stayed on the field. The process was restarted if rainfall was experienced within 24 hours. The data collection was carried out from October to December 2010 and August to October 2011 during the crop's growing period for each experiment.

#### 2.4.3 Using experimental field (graphical method)

The field experiment was also used to estimate the field water requirement of cowpea through establishing a graph plot of soil moisture storage in mm against the seed yield of cowpea in  $t\ ha^{-1}$ . The optimum moisture storage (mm) that gave the maximum seed yield ( $t\ ha^{-1}$ ) of cowpea was taken to be the estimated water requirement of cowpea under the conditions at the experimental site (Bonsu, M. KNUST, Ghana, personal communication). This was another technique used in this experiment.

#### 2.5 Rainfall Amount at the Experimental Site

Rainfall data was collected with the help of an improvised rain gauge. The inner passage of the funnels was corked with cotton wool, to prevent any foreign material from entering the cylinder. Three (3) improvised rain gauges were set on the

field; the height of water in the cylinders was measured after each rainy day in 2010 and 2011 seasons. The amount of rainfall for the period was calculated by using the following formula according to [25]:

$$R = (d^2 / D^2) \times h \quad (3)$$

Where:

R = the amount of Rainfall

D = the diameter of the funnel

d = the diameter of the bottle

h = the height of the rain water in the bottle (mm)

#### 2.6 Data Analysis

The data collected on the various parameters were subjected to analysis of variance (ANOVA) using GenStat (11<sup>th</sup> Edition) statistical package, [26]. The means were separated using the Least Significant Difference (LSD) test at 5% probability level.

### 3. RESULTS

#### 3.1 Temperature, Relative Humidity, Estimated Total Rainfall Amount and Potential Evapotranspiration (ET<sub>o</sub>) at the Experimental Site

In 2010 between October and December, the maximum average temperature during the experiment was 32.2 °C and the minimum was 22.5°C. In 2011, the maximum and minimum average temperatures in 2010 were 29.6 °C and 2.1°C respectively. The maximum and minimum temperatures in 2010 were higher than 2011 season readings, so this made 2010 the hotter and drier season than 2011 (Table 1).

**Table 1. Temperature and Relative Humidity (2010 and 2011)**

	2010			
	October	November	December	Mean
Maximum Temperature (°C)	31.7	32.0	32.8	32.2
Minimum Temperature (°C)	22.5	22.4	22.7	22.5
Highest Rel. Humidity (%) (16h)	98.0	98.0	97.0	97.7
Lowest Rel. Humidity (%) (15h)	65.0	62.0	53.0	60.0
	2011			
	August	September	October	Mean
Maximum Temperature (°C)	28.5	29.4	30.9	29.6
Minimum Temperature (°C)	21.8	22.3	22.3	22.1
Highest Rel. Humidity (%) (16h)	97.0	97.0	97.0	97.0
Lowest Rel. Humidity (%) (15h)	65.0	70.0	67.0	67.3

The total average minimum relative humidity in 2011 from August to October was 67.3% and a maximum of 97.0%. The relative humidity of 2010 was lower than the relative humidity in 2011 (Table 1).

In 2011 season from August to October, the average total rainfall 895.29 mm for 31 rainy days and was higher than rainfall recorded in 2010 (420.26 mm for 24 rainy days) (Table 2).

Evapotranspiration rate recorded from August to October in 2011 was 136.11 mm season<sup>-1</sup> for 39 days and was lower than 2010 (347.90 mm season<sup>-1</sup>) evapotranspiration rate recorded (Table 2).

### 3.2 The Effect of Mulch on Some Soil Physical Properties

The 5 t ha<sup>-1</sup> mulched plot recorded 56.22% aggregate stability followed by the 3 t ha<sup>-1</sup> mulched plot recording 54.70% stable soil aggregate. The 1 t ha<sup>-1</sup> mulch treatment recorded 51.87% while the control plot had 31.25% stable aggregate in that decreasing order. The value for 5 t ha<sup>-1</sup> treatment plots was significantly higher than that of the 1 t ha<sup>-1</sup> treatment plots and the control plots.

Bulk density (BD) values in season one (2010) were found to be lowest on the 5 t ha<sup>-1</sup> mulch plot (1.11 g cm<sup>-3</sup>) followed by 3 t ha<sup>-1</sup> mulch plot (1.12 g cm<sup>-3</sup>), 1 t ha<sup>-1</sup> mulch plot (1.13 g cm<sup>-3</sup>) and the

control plots (1.20 g cm<sup>-3</sup>) in that increasing order in 2010 season. It was observed that the control plots recorded the highest bulk density in seasons one and two. The bulk density values for 5 t ha<sup>-1</sup> plot and 3 t ha<sup>-1</sup> plot were significantly different ( $P = .05$ ) from that of the 1 t ha<sup>-1</sup> plots and control plot in season one. In season two (2011), the bulk density for the 5 t ha<sup>-1</sup> (1.12 g cm<sup>-3</sup>) plot was significantly ( $P = .05$ ) different from the 1 t ha<sup>-1</sup> (1.18 g cm<sup>-3</sup>) and the control (1.19 g cm<sup>-3</sup>) plots (Table 3).

Generally the total porosity values increased with the rate of mulch. The highest on the 5 t ha<sup>-1</sup> mulch (58.43%) plot followed by 3 t ha<sup>-1</sup> mulch (57.74%) plot, the 1 t ha<sup>-1</sup> mulch (57.23%) and the control (54.84%) plots in that decreasing order in season one. A similar trend was observed in season two. The total porosity values increased as mulch rate increased in both seasons one and two (Table 3).

### 3.3 Effect of Mulch on Soil Organic Carbon and Organic Matter

In 2011 season the 5 t ha<sup>-1</sup> mulch plot produced the highest organic carbon (2.26%) and organic matter (3.91%) contents followed by the 3 t ha<sup>-1</sup> mulch rate giving 2.21% of organic carbon and organic matter of 3.82%. The 1 t ha<sup>-1</sup> mulch rate had 2.17% organic carbon and 3.76% organic matter. The control had 1.31% organic carbon and 2.26% organic matter as the lowest values.

**Table 2. Estimated total rainfall amount and potential evapotranspiration (ET<sub>o</sub>) at the experimental site**

Rainfall Amount (mm/season)		ET (mm/season)	
2010	2011	2010	2011
420.26(24)#	895.29 (31)#	347.90 (49) #	136.11(39) #

# Figures in parenthesis represent the number of rainy days and evapotranspiration reading days during the growing period

**Table 3. Effect of Mulch on Soil Aggregate Stability, Bulk density and Total Porosity in 2010 and 2011**

Mulch rate (t ha <sup>-1</sup> )	Soil aggregate stability (%)	Bulk density (g cm <sup>-3</sup> )		Total Porosity (%)	
		2010	2011	2010	2011
Control (no mulch)	31.25	1.20	1.19	54.84	55.77
1	51.87	1.13	1.18	57.23	56.76
3	54.70	1.12	1.14	57.74	57.26
5	56.22	1.11	1.12	58.43	57.86
LSD ( $P = .05$ )	3.22	0.01	0.04	2.46	0.33
CV (%)	2.40	0.40	1.00	1.60	0.10

**Table 4. Effect of mulch on soil organic carbon and organic matter**

Mulch rate (tha <sup>-1</sup> )	Organic	Carbon (%)	Organic	Matter (%)
	2010	2011	2010	2011
Control	1.30	1.31	2.26	2.27
1	2.15	2.17	3.73	3.75
3	2.18	2.21	3.79	3.82
5	2.22	2.26	3.87	3.91
LSD ( <i>P</i> = .05)	0.40	0.06	0.30	0.07
CV (%)	0.01	0.50	0.00	0.70

The values from the 5 t ha<sup>-1</sup> plot were significantly (*P* = .05) different from those values from the 1 t ha<sup>-1</sup> treatment plot and the control plot (Table 4) respectively. The organic matter followed a pattern that is directly related to the amount of mulch rate applied to the plot.

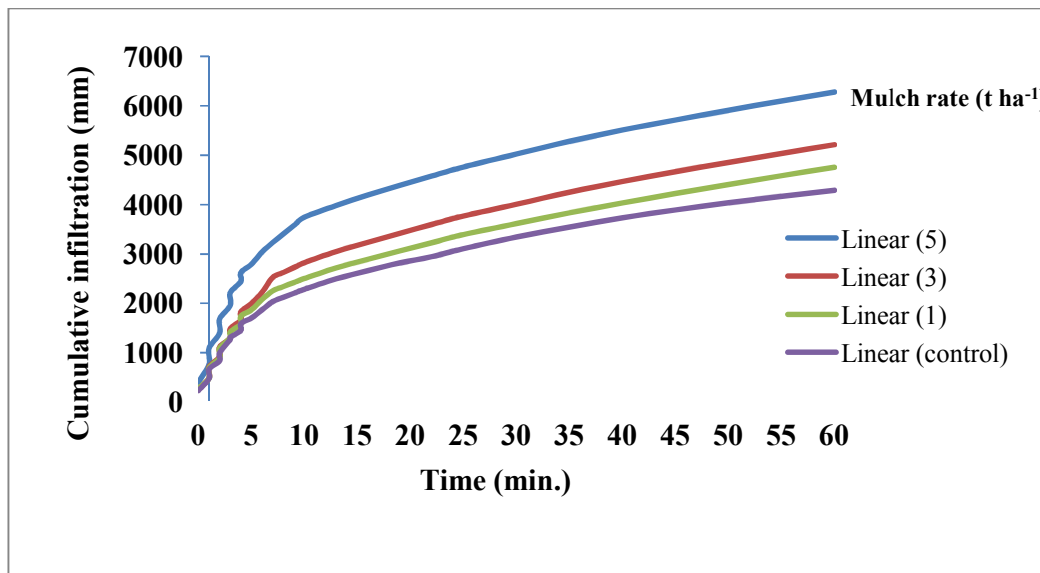
### 3.4 Effect of Different Rates of Mulch on Soil Moisture

The data for soil residual moisture of the various plots obtained indicated that, the 5 t ha<sup>-1</sup> mulch plot contained the highest level of residual moisture (5.70 mm) followed by the 3 t ha<sup>-1</sup> mulch plot (4.75 mm), 1 t ha<sup>-1</sup> mulch plot (4.50 mm) and the lowest being the control (3.32 mm) plot in 2010 season. A similar trend was observed in 2011 when the 5 t ha<sup>-1</sup> mulch plot recorded the highest residual moisture (5.01 mm) the followed by 3 t ha<sup>-1</sup> mulch (3.16 mm) plot, 1 t ha<sup>-1</sup> mulch plot (2.21 mm), and the control (1.53 mm) as the lowest residual moisture (Table 5).

With the addition of mulch, the soil gravimetric moisture rose from 10.50% in the control plot to 28.24% on 5 t ha<sup>-1</sup> mulch plot in 2010 and from 14.72% to 26.15% on 5 t ha<sup>-1</sup> mulch plot in 2011. On volumetric basis, there was an increase from 12.36% on control plot to 31.44% on 5 t ha<sup>-1</sup> mulch plot in 2010 and from 17.29% on control plot to 29.46% on 5 t ha<sup>-1</sup> mulch plot in 2011 (Table 5).

### 3.5 Effect of Mulch on Infiltration Amount, Infiltration Rate and Sorptivity

The cumulative infiltration amount and infiltration rate as a function of time for 2011 of the various mulch plots are presented in Figs. 1 and 2, respectively. It was observed in Fig. 1 that, the cumulative infiltration was highest in the 5 t ha<sup>-1</sup> mulch plots. This was followed by the 3 t ha<sup>-1</sup> mulch plot, the 1 t ha<sup>-1</sup> mulch plots and the control plots in that decreasing order.

**Fig. 1. Cumulative infiltration curves for treatments (2011)**

**Table 5. Effect of different rates of mulch on soil moisture status**

Mulch rate (tha <sup>-1</sup> )	Residual Moisture (mm)		Gravimetric water content (%)		Volumetric water content (%)	
	2010	2011	2010	2011	2010	2011
Control	3.32	1.53	10.50	14.72	12.36	17.29
1	4.50	2.21	17.21	19.80	19.74	22.94
3	4.75	3.16	20.63	22.07	23.28	25.23
5	5.70	5.01	28.24	26.15	31.44	29.46
LSD ( <i>P</i> = .05)	0.37	6.50	1.16	1.58	1.28	1.81
CV (%)	6.50		3.40	4.00	3.20	4.10

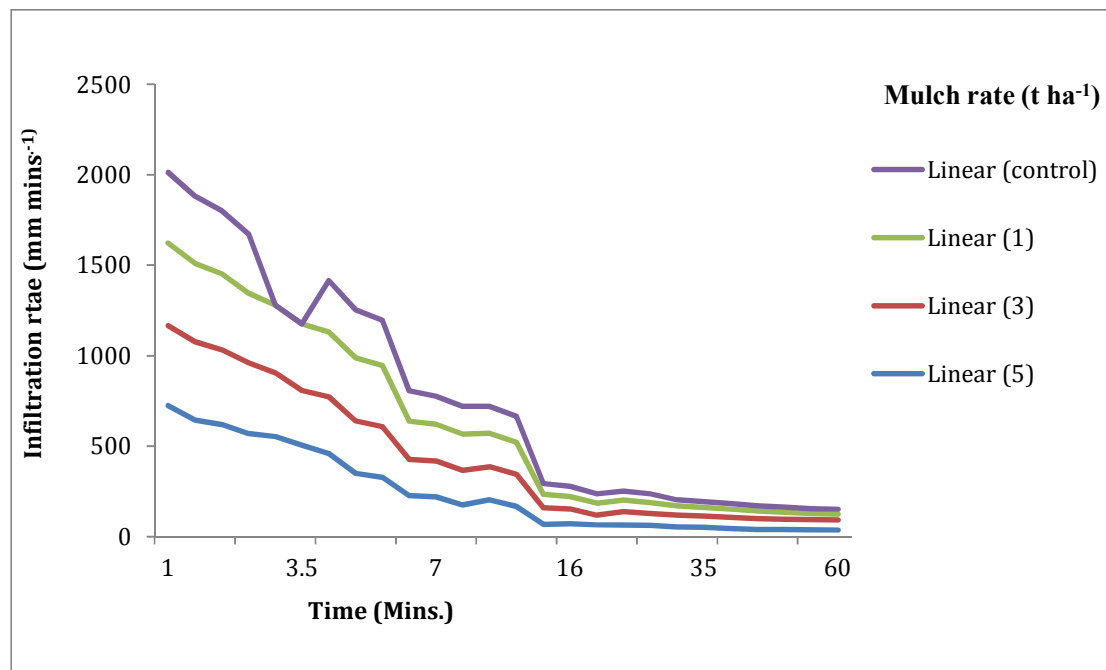
For example, after 40 minutes of cumulative infiltration, approximately 5508.8 mm of water entered the 5 t ha<sup>-1</sup> mulch plot; 4468.5 mm entered the 3 t ha<sup>-1</sup> mulch plot; 4031.5 mm entered the 1 t ha<sup>-1</sup> plots and only 3734.3 mm entered the control (no mulch) plots.

Infiltration rates as a function of time of the various mulch plots followed the order 5 t ha<sup>-1</sup> mulch > 3 t ha<sup>-1</sup> mulch > 1 t ha<sup>-1</sup> mulch > control (Fig. 2).

The 5 t ha<sup>-1</sup> mulch plot had the highest infiltration rate (92.3 mm min<sup>-1</sup>), followed by the 3 t ha<sup>-1</sup> (68.5 mm min<sup>-1</sup>) plot, 1t ha<sup>-1</sup> (40.2 mm min<sup>-1</sup>) plot and the control (31.5 mm min<sup>-1</sup>) plot in that decreasing order (Fig. 2).

Sorptivity is a measure of the soils ability to absorb water without reference to gravitational effects. Sorptivity values were obtained from the slope of curves obtained by plotting cumulative infiltration (*I*) against the square root of time (*t*), for a 5-minute duration only.

Sorptivity for the 5 t ha<sup>-1</sup> mulch plot was highest with 1249.11 mm min<sup>-1</sup>. This was followed by the 3 t ha<sup>-1</sup> mulch plot with 893.78 mm min<sup>-1</sup> and 1 t ha<sup>-1</sup> mulch plot (833.99 mm min<sup>-1</sup>) in that decreasing order with the control plot (765.3 mm min<sup>-1</sup>) giving the lowest sorptivity value (Fig. 3). The 5 t ha<sup>-1</sup> mulch plot was the well-drained; The 3 t ha<sup>-1</sup> and 1 t ha<sup>-1</sup> mulch plots were intermediate in their behaviour.

**Fig. 2. Infiltration rate curves for treatments (2011)**

### 3.6 Effects of Mulch on Water Requirement of Cowpea

(mm day<sup>-1</sup>) on the various mulch plots. The plot of cowpea seed yield against soil moisture indicated that the relationship was almost linear.

Fig. 4 shows a relationship between cowpea seed yield (t ha<sup>-1</sup>) and soil moisture

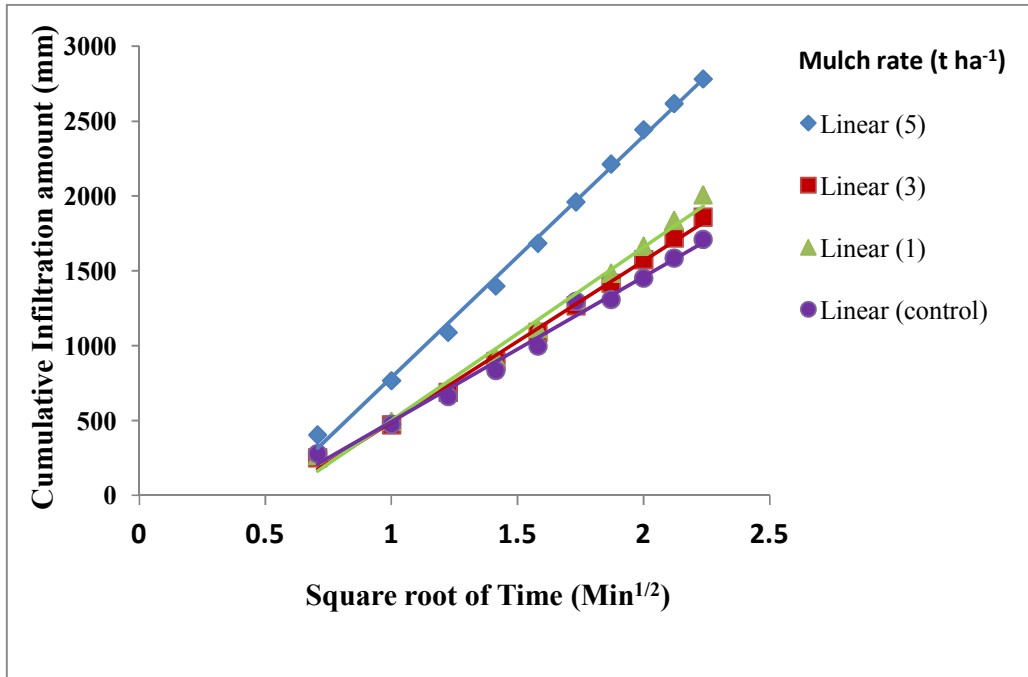


Fig. 3. Sorptivity for treatments (2011)

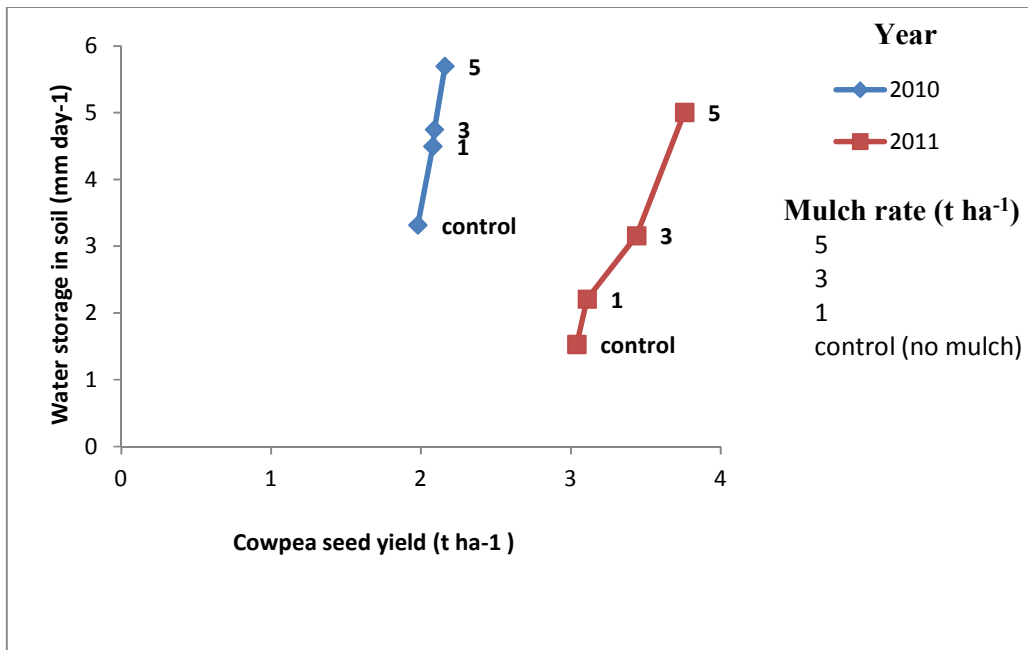


Fig. 4. Effect of mulch on water requirement of cowpea



**Table 6. Blaney-Criddle's value and Field graphical value of water requirement of cowpea**

Blaney-Criddle value (mm season <sup>-1</sup> )		Field graphical value (mm season <sup>-1</sup> )	
2010	2011	2010	2011
629.70	619.60	399.00	350.70

There was an increase in the soil water status when the mulch increased from the control plot (no mulch) to 1 t ha<sup>-1</sup>. The further increase of mulch from 3 t ha<sup>-1</sup> to 5 t ha<sup>-1</sup> indicated a similar increasing trend in both 2010 and 2011 seasons. The optimum water storage that gave the maximum cowpea seed yield was taken to be the water requirement (399.00 mm season<sup>-1</sup> or 5.70 mm day<sup>-1</sup>) of cowpea in 2010 and that of 2011 (350.70 mm season<sup>-1</sup> or 5.01 mm day<sup>-1</sup>) (Fig. 4). Comparing the experimental field (graphical method) to the Blaney-Criddle estimated value of 629.70 mm season<sup>-1</sup> or 9.10 mm day<sup>-1</sup> (2010 season) and 619.60 mm season<sup>-1</sup> or 8.90 mm day<sup>-1</sup> (2011 season), the study showed that the Blaney-Criddle method gave a higher value than the estimated field values (Table 6).

The improvised pan gave the lowest estimated evapotranspiration values of 274.84 mm season<sup>-1</sup> in 2010 and 107.53 mm season<sup>-1</sup> in 2011.

### 3.7 Correlation of Cowpea Yield with Soil Organic Matter, Soil Gravimetric Moisture and Grass Mulch

Correlation analysis between the cowpea seed yield and some other parameters in season one indicated that, cowpea seed yield positively correlated with soil gravimetric moisture content ( $r = 0.32$ ) in 2010.

In season two, cowpea seed yield positively and significantly ( $P = .05$ ) correlated with soil organic matter ( $r = .61$ ) and positively and weakly correlated with soil gravimetric moisture content ( $r = .23$ ). Seed yield also positively and significantly correlated with mulch in 2010 and 2011 ( $r = .56$ ,  $r = .73$ ) (Table 8).

### 3.8 Effect of Mulch on Cowpea Seed Yield

Cowpea seed yield decreased as the mulch rate decreased in 2010 and 2011 seasons.

Generally, the seed yield values were highest on the 5 t ha<sup>-1</sup> plots (2.16 t ha<sup>-1</sup>) followed by 3 t ha<sup>-1</sup> plots (2.09 t ha<sup>-1</sup>), 1 t ha<sup>-1</sup> plots (2.08 t ha<sup>-1</sup>) and control plots (1.98 t ha<sup>-1</sup>) in 2010 season. The

2011 season generally gave higher values but in a similar trend (Table 9).

**Table 7. Improved evaporation pan readings under cowpea at the experimental site**

ET (mm season <sup>-1</sup> )	
2010	2011
347.90 (49) #	136.11 (39) #

# Figures in parenthesis represent number of days ET readings was done on the field.

**Table 8. Correlation coefficient of cowpea seed yield with soil organic matter, soil gravimetric moisture and grass mulch in 2010 and 2011**

Correlation (linear) of Seed yield with	Correlation coefficient (r)	
	2010	2011
Soil organic matter	0.346	0.606*
Soil gravimetric moisture	0.320	0.230
Mulch rate	0.563*	0.725*

\* Significant ( $P = .05$ )

**Table 9. Effect of mulch on cowpea seed yield**

Mulch rate (t ha <sup>-1</sup> )	Cowpea seed yield (t ha <sup>-1</sup> )	
	2010	2011
Control (no mulch)	1.98	3.04
1	2.08	3.31
3	2.09	3.44
5	2.16	3.76
LSD ( $P = .05$ )	0.11	0.60
CV (%)	2.20	2.40

## 4. DISCUSSION

Soil aggregate of the mulch plots at the experimental site showed an increasing trend of stability and this is confirmed by an earlier report by [27] which found that soil aggregation is largely influenced by soil management practices like mulching. [28], observed decreased aggregate stability on no mulched plots than mulched plots. [29] found that soil aggregate stability within the agricultural field is inherent in

nature due to geologic and pedologic factors, but these factors may be induced as a result of a management practice as mulching. The trend in Aggregate Stability in this study could also be attributed to the presence of organic matter since organic matter acts as a cementing agent that binds soil particles together. Consequently, the 5 t ha<sup>-1</sup> plot which contained the highest amount of organic matter also gave the highest aggregate stability and vice versa.

The least bulk densities produced by mulch plots especially the 5 t ha<sup>-1</sup> plots in seasons one and two could be attributed to effective biological activities by beneficial macro and microorganisms in the soil as reported by [30] earlier that 4.0-10 t ha<sup>-1</sup> mulch cover improves soil condition, [6] has a similar report. The differential bulk densities obtained for the various mulch plots are similar to the results obtained for luvisols by [15] that mulching effect on soil bulk density is often variable. All the treatment plots can support crop production since their values are less than 1.6 g cm<sup>-3</sup> reported earlier by [31] as the critical bulk density that limits plant growth. The control plot which recorded the highest bulk density might be due to low organic matter (Table 4), coupled with, low porosity (Table 3) and is in agreement with an assertion made by [32] that high bulk densities correspond to low porosities. 5 t ha<sup>-1</sup> mulch plot with the least bulk density is preferred most to help conserve soil moisture to meet crop's water needs since the lower the bulk density, the less the degree of compaction and the better the aeration porosity. Root development and crop growth would normally be enhanced in the least compacted soils as was the case for the 5 t ha<sup>-1</sup> mulch plot.

The control plot in 2010 and 2011 recorded lowest porosity values which were within the range of 30-60% reported by [20] and could be due to higher bulk density values (Table 3), low organic matter content in season one and moderate organic matter content in season two. [33] explained that pore space in a soil enhanced gas exchange, microbial activity and water retention. On the basis of porosity, all the treatment plots investigated were within the normal range for crop production [20]. The 5 t ha<sup>-1</sup> mulch plot, which had the highest porosity, was, however, the most desirable technology while the control (no mulch) plot was the least desirable technology for conserving soil moisture in order to meet cowpea's water requirement.

Organic matter contents of the various mulch plots were higher than the control plots and they followed a pattern that is directly related to the amount of mulch rate applied to the plots. This suggests that soil surface treatment through mulching can increase organic matter content which in turn can serve as a major source of plant nutrient in low-input agriculture systems [34,35]. The insignificant difference ( $P = .05$ ) between 3 t ha<sup>-1</sup> mulch plot and 1 t ha<sup>-1</sup> mulch plot could be explained by the short period of the experiment [36]. The positive but low correlation between cowpea seed yield and soil moisture content in this study shows that, an increased seed yield to an extent might relate to soil moisture status in both 2010 and 2011 seasons. [37,38] confirmed that less moisture depletion occurred when mulching had prevented a contact between soil and dry air which reduced water loss through evaporation. [35] also reported that 34 to 50% reduction in evaporation and a considerable decrease of soil temperature may occur as a result of mulching.

Cumulative infiltration, infiltration rates and sorptivity followed the order 5 t ha<sup>-1</sup> mulch > 3 t ha<sup>-1</sup> mulch > 1 t ha<sup>-1</sup> mulch > control. The mulched plots were observed to have left high amounts of organic matter to the soil than the control plots and this might have contributed the greater amount of soil water content (Table 5). [30], is in agreement that mulching improves soil water storage through reduced runoff, reduced soil evaporation and increased infiltration. [39] further reported that mulch application is more sustainable and more affordable option for farmers to improve soil water infiltration.

There is a less mulch effect on water requirement of cowpea (2010 and 2011) by the three methods at lower levels of mulch application than at the highest mulch application rates. However, cowpea seed yield (t ha<sup>-1</sup>) increased as mulch application increased in both 2010 and 2011 seasons. The seed yield which is in response to soil water storage (mm) conforms to an earlier work by [40]. [40], further observed that relating cowpea water requirement (mm season<sup>-1</sup>) to its seed yield (t ha<sup>-1</sup>) has been found to be consistent with good management practice. The reduction in yield in the low water storage plots could be associated with their low mulch application rate which influenced water availability to plants.

Though the least soil water storage by the control (no mulch) plot in 2010 and 2011 recorded the lowest seed yield ( $t\ ha^{-1}$ ), the seed yield for this treatment was reasonable because [10] obtained yields up to  $1.9\ t\ ha^{-1}$  using water of  $449\ mm\ season^{-1}$ . The estimated water requirement values by the field graphical and the improvised evaporation pan methods were within the range given by [10] but Blaney-Criddle method gave higher values and appears to be unreliable. The yield reported by [10] is lower than the lowest of 2010 ( $1.98\ t\ ha^{-1}$ ) and 2011 season ( $3\ t\ ha^{-1}$ ). Therefore, in managing water for cowpea production, it is appropriate to bear in mind that cowpea is tolerant to water deficit to some extent, but it is at the same time responsive to considerable available moisture.

Cowpea seed yield from all the mulched plots confirmed that though cowpea is drought tolerant when mulch is applied under limiting moisture condition, it may increase yield as the mulch make soil's moisture readily available within the active root zone which might create a conducive soil atmosphere for good water balance in leaves. These results are similar to those reported earlier by many authors [37,30] and [35].

## 5. CONCLUSION

From the findings of the present experiment, it is clear that grass mulch can be applied to improve soil physical condition. The  $5\ t\ ha^{-1}$  mulch improved soil aggregate stability, bulk density, soil porosity, soil organic matter content, gravimetric and volumetric moisture contents, soil infiltration, sorptivity, residual soil moisture and cowpea seed yield. The field method used to estimate water requirement in which a graph of cowpea seed yield ( $t\ ha^{-1}$ ) was plotted against soil moisture storage (mm) proved to be an effective and easier method for the estimation of water requirement of cowpea. An estimation of water requirement of cowpea using Blaney-Criddle method gave higher values than the field method for both 2010 and 2011 seasons and appears to overestimate water requirement of cowpea. The improvised evaporation pan readings also gave lowest values which seem to have underestimated the field values and cannot be relied on for future predictions.

These results recommend that though cowpea is tolerant to water deficit to some extent, the use of  $5\ t\ ha^{-1}$  mulch for sustainable soil moisture

management is important in areas of inadequate rainfall and poor soil physical condition.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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