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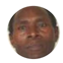

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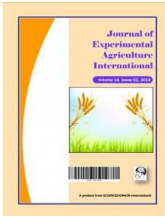

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Effect of Tillage Practice on Growth and Yield of Three Selected Cowpea Varieties

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Authors' contributions

This work was carried out in collaboration between all authors. Authors RNK and GNC designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors RNK and JMK reviewed the experimental design and all drafts of the manuscript. Authors RNK, JMK and GNC managed the analyses of the study. Authors RNK and GNC performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To evaluate the influence of tillage practice on growth and yield performance of three cowpea varieties.
Study Design: The treatments were laid out in a randomized complete block design with a factorial arrangement and replicated three times.
Place and Duration of Study: Study was carried out at St. Theresa demo farm and Nakamane irrigation scheme in Turkana county between November 2014 and January 2015.
Methodology: Treatments comprised three tillage practices: conventional tillage (control), conventional tillage + mulch and zero tillage and three cowpea varieties: M66, K80 and Kenkunde. Data collected included: Plant height, nodule count, total leaf vegetable yield, pod length, number of pods per plant, number of seeds per pod, grain yield,100 seed weight, total biomass and harvest index.

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Results: Tillage practice and variety had no effect on plant height. Conventional tillage+ mulch increased the number of nodules per plant by 42.98%, while zero tillage reduced it by 27%. Conventional tillage + mulch increased fresh leaf weight, total grain yield, total biomass and harvest index. Tillage practice and variety had no significant influence on 100 seed weight at St Theresa demo farm. However, at Nakamane irrigation scheme, tillage+mulch increased 100 seed weight by 12.6% while zero tillage reduced it by 7.2%. Nodule count and pod length were different among varieties; however, the effect of variety on the number of pods per plant, total biomass and harvest index were not significant. Variety had significant effect on total grain weight at St Theresa demo farm Kenkunde out yielded K80 and M66 by 10.1% and 16.9% respectfully.

Conclusion: Conventional tillage + mulch significantly outperformed conventional tillage and zero tillage in growth, nodule number, total biomass, grain yield and yield components. Zero tillage produced higher grain yield and harvest index than conventional tillage. Based on these results generally, Kenkunde variety was superior to the other two varieties in nodulation, fresh leaf weight and grain yield. The effects of variety on biomass and harvest indices were not significant implying little genetic variability among varieties on these yield attributes.

Further work is required on the effect of tillage practice on soil moisture retention in Turkana County.

Keywords: Cowpea; varieties; growth; yield; tillage practice.

1. INTRODUCTION

Cowpea is widely grown by the resource-poor farmers in the semi-arid parts of Kenya for subsistence and as a source of income [1]. Cowpea has protein of up to 35% and therefore it can replace animal protein in the world where plant production is far more important than animal production [2]. It flourishes where other crops wilt during droughts hence is a crop of choice to fight nutritional and food insecurity in the country [3]. Although it is drought tolerant its performance depends on the amount of water stored in the soil at critical time when it is needed [4]. However, the available soil moisture is influenced by tillage practice [5], soil physical properties and climatic factors especially rainfall distribution and reliability [6]. When plenty of water is available it is less important to impose strict tillage practices, but when water is limited only suitable tillage practice and high yielding varieties will ensure fair water utilization and increase in productivity. Although cowpea is being promoted in Turkana, its yield has remained low. This has been attributed to several factors including unreliable rainfall within seasons. If this occurs, growth and yield are greatly affected. Although it is generally accepted that use of appropriate tillage practice and variety can increase cowpea productivity, similar studies have not been carried out in Turkana where food security is a challenge and a large part of the population relies on food aid. Knowledge of the effect of tillage practice and variety on growth and yield components of cowpea in Turkana County is important for development of management options for enhancing cowpea productivity.

2. MATERIALS AND METHODS

2.1 Experimental Site Description

The field experiments were carried out at St. Theresa demo farm and Nakamane irrigation scheme along river Turkwel in Turkana County, North west of Kenya. The field stations are within an elevation range of 597 m to 800 m above sea level with an annual rainfall of between 150 mm and 500 mm and a temperature range of between 24℃ to 38℃. The predominant soils in St Theresa demo farm and Nakamane irrigation scheme sites are undifferentiated tertiary volcanic soils, derived from colluvial and alluvial deposits. They are shallow to moderately deep, well drained and dark reddish brown/dark greyish brown in colour. The soils are classified as riverine alluvium and are pale brown to dark brown in colour. They are deep, non-saline and locally calcareous. The soils at St. Theresa are stratified fine sand to loam with a high infiltration rate while those at Nakamane irrigation scheme are stratified fine sand to clay [7].

2.2 Experimental Design and Crop Husbandry

The treatments were laid out in a randomized complete block design with a factorial arrangement and replicated three times. Treatments comprised three tillage practices, namely: conventional tillage (control), conventional tillage+ mulch and zero tillage, which were evaluated against three cowpea varieties (M66, K80 and Kenkunde). The plots were 4 x 3 m and were separated by 0.5 m paths. Individual blocks measured 43 x 3 m and were separated from the adjacent blocks by 1 m buffer zones. In conventional tillage (control treatment) land was prepared to a fine tilth before sowing at 50 mm depth [8]. In the second treatment (tillage+mulch), land was prepared to a fine tilth before sowing at 50 mm depth and mulch applied at the rate of 4tha^{-1} [9,10]. In the third treatment (zero tillage), weeds were cleared from the land before sowing at a depth of 50 mm. Water was applied at a depth of 40 mm at an interval of seven days using basin irrigation however when it rained, irrigation was delayed sometimes up to a period of one week. Application of P was done at the rates of 40 kg/ha using Di-ammonium phosphate (18:46:0) as the source. Manure was applied at the rate of 5 tons per hectare [11]. Sowing was done at a spacing of 40×20 cm at a rate of three seeds per hill then thinned to two seedlings per hill after 14 days of emergence. Mechanical weed control was done at two, four and six weeks after plant emergence in plots under conventional tillage and conventional tillage +mulch. Cowpea plants were protected against aphid infestation and flower sucking insects through sprays of Duduthrin (Lambda- cyhalotrin 1.75 EC) and Alpha- cypermetrin 10 EC insecticides at the rate of 20 ml / 20L.H_2O and 5 ml / 20 L.H_2O respectively.

2.3 Data Collection

The plant height was measured from the ground level to the highest tip of the stem from one square meter area of plants from the central rows in all the experimental plots. Five plants were tagged and measurements taken using 30 cm rule once every 10 days after 14 days of emergence and continued for five weeks. Nodule count was determined at podding stage. Five plants from one square meter area of the central rows in all the experimental plots were watered to saturation point then uprooted. The root system was washed in a bucket containing water. The nodules were separated and counted. Fresh leaf weight was determined by harvesting fully expanded leaves from one square meter area of the central rows in all the experimental plots at the beginning of the fourth week after emergence and thereafter at 14 days intervals [12]. Fresh weight was obtained for each treatment and the leaves were then dried in the sun for three days to 5% moisture content and the dry weight determined. Harvesting of leaves continued in all treatments until 50% flowering was attained as this gave the highest grain yield [13]. Number of pods per plant was determined at physiological maturity using the method suggested by [14] where total number of pods was divided by total number of plants from one square meter area in all experimental plots.

$$\text{Number of pods per plant} = \frac{\text{Number of pods on selected plants}}{\text{Number of selected plants}}$$

Pod length was taken when pods had matured as indicated by change in pod colour. Five plants from one square meter area of the central rows on each experimental plot were selected and their pod length measured using 30 cm rule and an average taken for each treatment.

The number of seeds per pod was determined by taking five plants from one square meter area of the central rows from each plot. Pods were shelled, seeds counted and an average number of seeds per pod for each plot calculated.

Hundred-seed weight was determined by randomly counting 100 seeds from the threshed and sun dried seeds from each plot. These were weighed to represent the 100-seed weight. Grain yield was determined at physiological maturity when about 85% of the pods had turned brown [14] and more than 75% of the leaves had senesnced. One square meter area of plants from the central rows on each plot was harvested for the grain yield analysis. The harvested pods were sun dried to a constant weight. The grains were removed from the pods and weighed. Finally, the grains were dried to 13% moisture content. The total dry matter weight was evaluated after harvesting all the plants from one square meter area of the central rows in each plot. The plants were uprooted (together with the pods) when over 75% of the pods had dried. To determine the dry weight, plants were sun dried for three days to constant moisture content and reweighed. Harvest index was calculated using the formula suggested by Donald (1963) and expressed as a percentage:

$$\text{Harvest Index} = \frac{\text{Economic yield}}{\text{Total biological yield}} \text{X100}$$

Where economic yield is seed yield whilst the total biological yield is the summation of total biomass and seed yield plus pod chaff.

2.4 Data Analysis

The data collected were subjected to analysis of variance (ANOVA) using the Genstat (2012) software package version 15.1. Where the F values were significant, means were compared using the least significant difference (LSD) test at 5% significance level.

3. RESULTS

3.1 Effects of Tillage Practice on Plant Height

The effects of tillage practice, variety and their interaction were not significant (P=.05) on plant height in both sites.

3.2 Effects of Tillage Practice and Variety on Nodule Count

The effects of tillage practice and variety (Table 1) on nodulation were significant at St Theresa demo farm. However, tillage practice had no influence on nodulation at Nakamane irrigation scheme. Interaction of the treatments under investigation was significant at St Theresa demo farm. Results revealed that conventional tillage + mulch increased the number of nodules per plant by 42.98% while zero tillage reduced it by 27% as compared to conventional tillage. The total number of nodules was significantly influenced by variety in both experimental sites. Kenkunde had higher mean number of nodules per plant than both M66 and K80.

3.3 Effects of Tillage Practice and Variety on Fresh Leaf Weight

Tillage practice (P=.05) significantly affected cowpea fresh leaf weight (Table 2). Conventional tillage + mulch had 29.1% and 38.9% higher fresh leaf weight than conventional tillage at St. Theresa and Nakamane sites respectively. Zero tillage increased fresh leaf weight by 7.9% and 16.2% at St. Theresa demo farm and Nakamane irrigation scheme sites respectively as compared to conventional tillage. Variety effect on fresh leaf weight was significant (P=.05) at Nakamane irrigation scheme only. Kenkunde had higher mean fresh leaf weight as compared to both K80 and M66.The interaction of tillage practice and variety was significant in the two experimental sites.

3.4 Effects of Tillage Practice and Variety on Pod Length

Tillage practice had a significant effect on pod length at St Theresa. However, tillage practice had no effect on pod length at Nakamane irrigation scheme. Variety had significant influence on pod length (P=.05). Kenkunde had higher mean pod length than both K80 and M66. While the interaction of tillage method and variety was not significant at St Theresa demo farm, results showed that there was a significant interaction of the two factors at Nakamane irrigation scheme.

3.5 Effects of Tillage Practice and Variety on Number of Pods per Plant

Tillage practice had significant effect (P=.05) on number of pods per plant at St Theresa demo farm (Table 4). Conventional tillage + mulch recorded the highest mean (15.11) number of pods per plant followed by zero tillage at 13.22 and conventional tillage was the lowest at 13.00. Tillage practice had no significant effect on the number of pods per plant at Nakamane irrigation scheme (P=.05). Variety had no significant effect on the number of pods in both experimental sites.

Table 1. Effects of tillage practice and variety on nodule count per plant

	Theresa				Nakamane			
Variety (V)	**M66**	**K 80**	**Ken**	**Mean**	**M 66**	**K 80**	**Kenkunde**	**Mean**
Tillage(T)								
Conventional tillage	10.33	9.00	16.33	11.89	11.00	7.67	11.67	10.11
Conventional tillage + mulch	10.67	20.33	20.00	17.00	12.00	7.33	16.00	11.78
Zero tillage	10.00	6.33	9.67	8.67	11.00	7.67	8.00	8.89
Mean	10.33	11.89	15.33		11.33	7.56	11.89	
LSD $_{(p<0.05)}$T	2.910**				3.407^{ns}			
LSD$_{(p<0.05)}$V	2.910*				3.407*			
LSD$_{(p<0.05)}$TXV	5.041*				5.900^{ns}			
CV%	23.3				33.2			

*Lsd =least significance difference, * =significant * * = highly significant and ns=non significance*

Table 2. Effects of tillage practice and variety on fresh leaf weight per plant (g)

	Theresa				Nakamane			
Variety (V)	**M66**	**K 80**	**Ken**	**Mean**	**M 66**	**K 80**	**Kenkunde**	**Mean**
Tillage(T)								
Conventional tillage	1.97	2.48	3.12	2.53	1.54	2.14	3.17	2.28
Conventional tillage + mulch	3.39	3.21	3.18	3.26	3.27	3.16	3.07	3.17
Zero tillage	2.77	2.40	2.99	2.73	2.57	2.53	2.83	2.65
Mean	2.71	2.70	3.09		2.46	2.61	3.02	
$LSD_{(p\leq0.05)}$(T)	0.3579^{*}				0.4376^{*}			
$LSD_{(p\leq0.05)}$V	0.3579^{ns}				0.4376^{*}			
$LSD_{(p\leq0.05)}$T*V	0.6199^{*}				0.7580^{*}			
CV%	12.6				16.2			

*Lsd =least significance difference, * =significant and ns=non significance*

Table 3. Effects of tillage practice and variety on pods length (cm)

	Theresa				Nakamane			
Variety (V)	**M66**	**K 80**	**Ken**	**Mean**	**M 66**	**K 80**	**Kenkunde**	**Mean**
Tillage(T)								
Conventional tillage	11.5	13.7	14.5	13.3	10.8	11.03	16.4	12.7
Conventional tillage + mulch	12.4	11.4	12.2	12.0	11.0	11.0	12.6	11.8
Zero tillage	12.4	12.9	13.4	12.9	12.0	11.9	13.5	12.9
Mean	12.1	12.7	13.4		11.2	11.3	14.2	
LSD $_{(p<0.05)}$T	0.973^{*}				1.115^{ns}			
$LSD_{(p<0.05)}$V	0.973^{*}				1.115^{**}			
$LSD_{(p<0.05)}$TXV	1.686^{ns}				1.932^{*}			
CV%	7.7				8.9			

*Lsd =least significance difference, * =significant * * = highly significant and ns=non significance*

Table 4. Effects of tillage practice and variety on number of pods per plant

	St Theresa				Nakamane			
Variety (V)	**M 66**	**K 80**	**Ken**	**Mean**	**M 66**	**K 80**	**Kenkunde**	**Mean**
Tillage(T)								
Conventional tillage	13.67	12.33	13.00	13.00	14.00	13.33	14.33	13.89
Conventional tillage + mulch	14.67	15.67	15.00	15.11	15.67	12.67	14.00	14.11
Zero tillage	14.00	11.67	14.00	13.22	12.67	11.33	12.67	12.22
Mean	14.11	13.22	14.00		14.11	12.44	13.67	
LSD $_{(p<0.05)}$T	1.384*				1.938^{ns}			
$LSD_{(p<0.05)}$V	1.384^{ns}				1.938^{ns}			
$LSD_{(p<0.05)}$TXV	2.396^{ns}				3.356^{ns}			
%CV	10.0				14.5			

*Lsd =least significance difference, * =significant and ns=non significance*

3.6 Effects of Tillage Practice and Variety on Number of Seeds per Pod

Tillage practice had a significant effect on number of seeds per pod (Table 5). Conventional tillage + mulch increased seeds per pod by 35.4% and 38.5% at St Theresa demo farm and Nakamane irrigation scheme respectively as compared to conventional tillage only. It was followed by zero tillage which increased number of seeds per pod by 9.7% and 27.9% at St Theresa and Nakamane irrigation scheme respectively as compared to conventional tillage. Variety had significant effect on the number of seeds per pod at St Theresa demo farm only. Kenkunde had the highest mean number of pods per plant of 14.0 followed by M66 at 13.3 then K80 at 11.4. However, the effect of variety on number of seeds per pod was not significant (P=.05) at Nakamane irrigation scheme. The interaction of tillage practice and variety was not significant (P=.05) in the two experimental sites.

3.7 Effects of Tillage Practice and Variety on Total Grain Yield

The effect of tillage practice on total grain yield was significant (Table 6). At St Theresa demo farm, conventional tillage + mulch and zero tillage significantly out-yielded conventional tillage by 27.6% and 13.0% respectively. Zero tillage and conventional tillage + mulch out-yielded conventional tillage by 52% and 60.57% respectively at Nakamane irrigation scheme. Variety had a significant effect on total grain yield at St Theresa demo farm only. Kenkunde out-yielded K80 and M66 by 10.1% and 16.9% respectfully. No significant difference was noted between K80 and M66 varieties.

3.8 Effects of Tillage Practice and Variety on 100 Seed Weight

The effects of both tillage practice and variety on 100 seed weight were significant only at Nakamane irrigation scheme (Table 7). The interaction of the effects of both tillage practice and variety were significant in both experimental sites.

3.9 Effects of Tillage Practice and Variety on Total Biomass

Tillage practice had a significant effect on total biomass in the two experimental sites (Table 8). Zero tillage had significantly lower total biomass than conventional tillage which, in turn, had significantly lower total biomass than conventional tillage + mulch at Nakamane irrigation scheme. However, at St Theresa demo farm tillage +mulch had more biomass followed by zero tillage and conventional tillage was the lowest. Variety had no significant influence on total biomass (P=.05). The interaction of tillage practice and variety (P=.05) on total biomass was not significant.

3.10 Effects of Tillage Practice and Variety on Harvest Indices

Analysis of variance showed that the effect of tillage practice on harvest indices (P=.05) was significant in the two experimental sites (Table 9). Conventional tillage + mulch and zero tillage increased harvest indices by 25.4% and 8.5% respectively at St Theresa demo farm and by 38.6% and 14.39% respectively at Nakamane irrigation scheme as compared to conventional tillage. Variety effect on cowpea harvest indices (P=.05) was not significant. The interaction of tillage practice and variety (P=.05) on harvest indices was not significant.

Table 5. Effects of tillage practice and variety on number of seeds per pod

	St Theresa				Nakamane			
Variety (V)	**M 66**	**K 80**	**Ken**	**Mean**	**M 66**	**K 80**	**Kenkunde**	**Mean**
Tillage(T)								
Conventional tillage	11.7	9.67	12.7	11.3	10.3	9.00	12.0	10.4
Conventional tillage + mulch	15.3	14.3	15.3	15.0	14.0	13.3	16.0	14.4
Zero tillage	13.0	10.3	14.0	12.4	10.0	12.3	11.7	13.3
Mean	13.3	11.4	14.0		11.4	11.6	13.2	
LSD (p<0.05)T	1.465**				2.193*			
LSD(p<0.05)V	1.465*				2.193^{ns}			
LSD(p<0.05)TXV	2.537ns				3.798^{ns}			
%CV	11.3				18.2			

*Lsd =least significance difference, * =significant * * = highly significant and ns=non significance*

Table 6. Effects of tillage practice and variety on total grain yield (t/ha)

	St Theresa				Nakamane			
Variety (V)	**M66**	**K 80**	**Ken**	**Mean**	**M 66**	**K 80**	**Kenkunde**	**Mean**
Tillage(T)								
Conventional tillage	1.12	1.10	1.48	1.23	0.97	0.89	1.26	1.04
Conventional tillage + mulch	1.49	1.58	1.64	1.57	1.56	1.55	1.64	1.58
Zero tillage	1.22	1.38	1.58	1.39	1.67	1.72	1.70	1.67
Mean	1.27	1.35	1.57		1.40	1.39	1.53	
$LSD_{(p<0.05)}T$	0.24^{*}				0.30^{*}			
$LSD_{(p<0.05)}V$	0.24^{*}				Ns			
$LSD_{(p<0.05)}TXV$	Ns				Ns			
%CV	17.2				21.0			

*Lsd =least significance difference, * =significant and ns=non significance*

Table 7. Effects of tillage practice and variety on 100 seed weight (g)

	Theresa				Nakamane			
Variety (V)	**M66**	**K 80**	**Ken**	**Mean**	**M 66**	**K 80**	**Kenkunde**	**Mean**
Tillage(T)								
Conventional tillage	7.02	10.06	7.72	8.27	9.43	8.60	7.53	8.52
Conventional tillage + mulch	7.96	6.16	9.34	7.82	6.42	11.86	10.55	9.61
Zero tillage	7.11	7.24	8.23	7.53	7.28	6.73	9.69	7.90
Mean	7.36	7.82	8.43		7.71	9.06	9.06	
LSD $_{(p<0.05)}$T	1.282^{ns}				0.877*			
LSD$_{(p<0.05)}$V	1.282^{ns}				0.877*			
LSD$_{(p<0.05)}$TXV	2.221*				1.519*			
%CV	16.3				10.1			

*Lsd =least significance difference, * =significant and ns=non significance*

Table 8. Effects of tillage practice and variety on total biomass (g)

	Theresa				Nakamane			
Variety (V)	**M66**	**K 80**	**Ken**	**Mean**	**M 66**	**K 80**	**Kenkunde**	**Mean**
Tillage(T)								
Conventional tillage	6.18	5.55	6.15	5.96	5.39	6.00	5.71	5.70
Conventional tillage + mulch	5.76	6.73	6.39	6.30	6.58	6.45	6.39	6.47
Zero tillage	6.66	7.12	6.66	6.81	4.03	5.10	4.32	4.48
Mean	6.20	6.47	6.40		5.33	5.85	5.47	
LSD $_{(p<0.05)}$T	0.634^{*}				0.953^{*}			
LSD$_{(p<0.05)}$V	0.634^{ns}				0.953^{ns}			
LSD$_{(p<0.05)}$TXV	1.098^{ns}				1.651^{ns}			
%CV	10.0				17.2			

*Lsd =least significance difference, * =significant and ns=non significance*

Table 9. Effects of tillage practice and variety on harvest indices (%)

	Theresa				Nakamane			
Variety (V)	**M66**	**K 80**	**Ken**	**Mean**	**M 66**	**K 80**	**Kenkunde**	**Mean**
Tillage (T)								
Conventional tillage	19.9	17.6	19.64	19.02	19.86	20.06	17.79	19.24
Conventional tillage + mulch	26.6	22.49	24.48	24.52	25.97	28.24	25.79	26.67
Zero tillage	20.40	20.14	21.38	20.64	23.50	19.46	23.43	22.01
Mean	22.28	20.07	21.84		23.11	22.59	22.34	
LSD $_{(p<0.05)}$T	2.55^{**}				4.261^{*}			
LSD$_{(p<0.05)}$V	2.55^{ns}				4.261^{ns}			
LSD$_{(p<0.05)}$TXV	4.424^{ns}				7.380^{ns}			
%CV	11.9				5.8			

*Lsd =least significance difference, * =significant * * = highly significant and ns=non significance*

4. DISCUSSION

Cowpea plants were virtually of the same height with respect to the means for both tillage and variety treatments. Narrow genetic variability among the varieties could be attributed to the lack of significant differences in plant height. Conventional tillage + mulch increased the number of nodules per plant by 42.98% compared to conventional tillage at St Theresa demo possibly due to more moisture retention which enhanced rhizobia activity. Zero tillage reduced nodulation by 27%. This was not supported by [15,16] who confirmed that rhizobia isolates, due to zero tillage conditions, fixed more atmospheric nitrogen as a result of minimal disturbance on the soil and high rhizobia population. Variety had positive influence on cowpea nodulation. Kenkunde had higher nodule count than M66 and K80 in both experimental sites. As reported by [17,18], cowpea nodule count is dependent on host legume, cultivar and availability of essential nutrients and moisture. This observation was also congruent with an earlier report by [19], who concluded that varieties respond differently to various environmental factors, and this differential response is primarily driven by their genetic make-up and their adaptive capacities. The difference in nodule count among cowpea varieties could have been due to differences in their genetic composition.

Significant increase in fresh leaf weight was recorded for both tillage practice and variety at Nakamane. However only tillage practice increased fresh leaf weight at St Theresa demo farm. The positive influence of tillage practice as found out by [20,21,23] was possibly due to high water infiltration through tillage and low soil temperature due to mulching.

Tillage practice increased pod length at St Theresa demo farm. However, tillage practice had no significant effect on pod length at Nakamane irrigation scheme. This was in agreement with [24] who reported that although pod length was under genetic control, environmental conditions had little or no effect on it. Variety factor had significant effect on pod length. The same was observed by [25] who said differences in pod length could not be attributed to environmental fluctuations but genetic constitution. Kenkunde had higher mean pod length in both sites than both K80 and M66. High performance by Kenkunde was attributed to genetic constitution. The results showed that although tillage practice was important, variety selection is key to obtaining longer pods.

Tillage practice increased number of pods per plant at St Theresa demo farm. This was attributed to more moisture retention due to mulch and zero tillage. This finding was consistent with the report of [26] who observed that cowpea plants under high moisture regimes produced more pods per plant than those under deficient moisture. It was also in agreement with [27] who showed that limited moisture supply reduced number of pods per plant. Reduction of the number of pods per plant in control was attributed to the abscission of the reproductive structures [28].

Tillage practice had no significant effect on the number of pods per plant in Nakamane irrigation scheme. Similar result was found by [29]. This showed that moisture retention differences due tillage practice had no influence on the number of pods per plant at Nakamane possibly due soil physical conditions.

The response of variety to number of pods per plant was not significant. This finding was not in agreement with [24,30] who reported that the number of pods per plant were under genetic control and varied among cowpea varieties. The lack of significance as found out in this study indicated that all varieties studied had equal efficiency in partitioning photo assimilates into pods.

Tillage + mulch application and zero tillage significantly increased number of seeds per pod. This was due to favorable soil moisture regime which enhanced production of large number of seeds possibly by reducing floral abortion, maintenance of a steady flux of assimilates during grain filling and reduction of the rate of leaf senescence. The effect of variety on the number of seeds per pod was significant in both experimental plots. Kenkunde had more seed per pod as compared to both M66 and K80. This is in line with an earlier finding by [31] who reported that seeds per pod were genetically controlled and environmental conditions may have little or no effect. The same was confirmed by [24] who pointed out that seeds per pod were moderately heritable under most environmental conditions. Kenkunde had higher number of seeds per pod than both M66 and K80 due to its longer pods.

Conventional tillage + mulch increased total grain weight by 27.6% and 52% at St Theresa demo farm and Nakamane irrigation scheme respectively. Similar results were observed by [32,33,34] who reported that conventional tillage + mulch increased moisture retention which enhanced grain filling. Zero tillage increased grain yield by 13% and 60.57% in St Theresa demo farm and Nakamane irrigation scheme respectively. The favorable effect of zero tillage was perhaps due to breakdown of capillaries in the soil which minimized evaporation losses and depletion of nutrients. Variety showed significant effect on grain yield at St Theresa demo farm only. The results are in line with the observation of [34] who reported that cowpea grain yield varied across genotypes. Kenkunde had higher mean grain yields than both K80 and M66, this was attributable to both its pod length and more seed per pod thus suggesting that it was the most efficient variety in partitioning much of the assimilates into economic yield.

The effects of tillage practice and variety were significant on 100 seed weight at Nakamane irrigation scheme only. While tillage+mulch increased 100 seed weight by 12.6%, zero tillage reduced it by 7.2%. This was in agreement with the earlier works by [24,30]. The significant effect in 100 seed weight at Nakamane irrigation scheme could be due significant moisture retention due tillage practice as compared to St Theresa demo farm. The significant effect of variety on 100 seed weight at Nakamane was due to genetic make-up. Similar variations were reported by [35]. The results were also supported by [36] who found highly significant variation for 100 seed weight in six cowpea cultivars. The effects of tillage practice and variety had no significant effect on 100 seed weight at St Theresa demo farm. This showed that although performance of 100 seed weight was heritable, variability in moisture retention due to tillage practice was not significant in influencing this yield attribute.

Tillage + mulch and zero tillage increased cowpea biomass in both experimental sites. Similar results were observed by [37] who reported that drought stress can significantly affect the total biomass produced by a crop through reducing CO_2 assimilation area, leaf number and total leaf area. Conventional tillage + mulch and zero tillage enhanced cowpea biomass by extending the period of moisture retention which resulted in a higher dry matter accumulation. Variety had no effect on total biomass, suggesting a narrow range of variability among the varieties that were tested. Conventional tillage + mulch and zero tillage increased harvest indices in both experimental sites. A similar observation was made by [38] who reported that harvest indices were lower under conventional tillage due to water stress conditions which resulted in reduction of assimilates. High harvest indices in plots under conventional tillage + mulch and zero tillage implied that more moisture was available which went into increasing economic yields. In both experimental sites variety had no influence on harvest indices meaning that there was little variability among varieties on this yield attribute.

5. CONCLUSION

In most cases, conventional tillage + mulch significantly outperformed conventional tillage and zero tillage in growth, nodule number, total biomass, grain yield and yield components. Zero tillage produced higher grain yield and harvest index than conventional tillage. Generally, Kenkunde variety was superior to the other two varieties in nodulation, leaf fresh weight and grain yield. Further work is required on the effect of tillage practice on moisture retention. Also, a similar study using a broader range of cowpea varieties may be advisable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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