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EFFECT OF N-FERTILIZER APPLICATION ON SOIL MOISTURE CONTENT, CANOPY TEMPERATURE, GROWTH AND YIELD MAIZE - COWPEA INTERCROPS

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ABSTRACT
Nitrogen is a major yield determining nutrient in maize production. Soils in coastal lowland Kenya are generally low in N and require replenishment using inorganic fertilizers. The objective of the study was to investigate the effect of varying N-fetilizer application on soil moisture content, canopy temperature, growth and yield of maize-cowpea intercrop. An experiment was carried out at Pwani University and Kenya Agricultural Research Institute- Mtwapa in 2011 and 2012. The experiment was laid out in a randomized complete block design with a factorial arrangement of treatments and replicated three times. Treatments consisted of two cropping systems and three N-fertilizer rates. The cropping systems were: Dryland Hybrid 04 and Lamu maize varieties intercropped with cowpea variety Nyeupe. The N-fertilizer rates comprised: control (no N-fertilizer), 30 kg N/ha and 60 kg N/ha. Data collected included: soil moisture content, canopy temperature, weed biomass, chlorophyll content, percent ground cover, leaf number, plant height, grain weight and grain yield of maize and cowpea, cowpea root nodule number, numbers of pods per plant, number of grains per pod, maize ears per plant and stover yield. Data was subjected to analysis of variance using SAS statistical package. Where the F values were significant, means were compared using the least significant difference (LSD) test, at p = 0.05. Application of N-fertilizer significantly increased soil moisture content, maize growth parameters, yield components and grain yield while the converse was true for cowpea. Maize under DH04-cowpea intercrop had higher performance than under Lamu-cowpea intercrop.
Key words: N-fertilizer, moisture, temperature, maize and cowpea

Introduction

Maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.) are important components of traditional mixed cropping systems in many countries of the world (Iderawumi, 2014). Intercropping system has for long been used by traditional farmers as a risk avoidance mechanism against total crop failure and it can be used to increase food supply without decreasing the suitability of the soil (Rehman, 2010). A report by Saha (2007) indicates that over 90% of the smallholder farmers in the coastal lowland Kenya, intercrop or relay maize and cowpea during the long rains season. Adediran and Banjoko (1995) indicated that in crop production nitrogen is an essential macronutrient required by cereals and it is a major yield determining nutrient required for maize production. It is a component of proteins and nucleic acids and also enhances and facilitates the utilization of other nutrients like phosphorus, potassium and other elements (Adediran and Banjoko, 1995). Nitrogen is also the most vulnerable of all the plant nutrients in the soil; as it is highly volatile and can be readily leached. Increasingly high cost of fertilizer has made the knowledge of the effectiveness of its use by

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maize and other plants inevitable (Moll *et al.,* 1982). Usually the crop uses 30 to 50% of the inorganic nitrogen fertilizer applied, the rest is lost by volatilization, denitrification or leaching (Stewart *et al*., 2005).

Amujoyegbe and Elemo (2013) and Thobatsi (2009) reported enhanced early ground cover, canopy formation in maize-cowpea intercrop with increase in fertilizer rates. When nitrogen fertilizer is added to cowpea intercropped with maize the cowpea use the inorganic nitrogen instead of fixing nitrogen from the air and thus competes with maize for nitrogen. However, when nitrogen fertilizer is not applied, the cowpea under intercrop will fix most of their nitrogen and not compete with maize for nitrogen resources (Adu-Gyamfi *et al.,* 2007). Maintenance of the soil fertility status is an important factor in order to obtain stable and sustainable agro-ecosystem (Graham and Vance, 2000). The use of a suitable and balanced use of fertilizers is one of the different factors which influence crop yield and its contributory factors (Rehamn, 2010). Therefore a study was set up to investigate the effect of varying N-fetilizer application on growth and yield of intercropped maize and cowpea in coastal lowland Kenya.

Materials and Methods

Study site

The study was carried out at Pwani University and Kenya Agricultural and Livestock Research Organization (KALRO) Mtwapa, both located at Kilifi County in the coastal region of Kenya. Pwani University is located 60 km north of Mombasa between latitudes 3^{o} S and 4^{o} S and longitudes 39^{o} E and 40^{o} E. Kenya Agricultural and Livestock Research Organization (KALRO) Mtwapa is situated at 30 m ASL, 39.219^{o} E and 4.347^{o} S, 20 km north of Mombasa (Jaetzold et al., 2012). The two sites are situated in coastal lowland zone 4 (CL4). The region receives an average annual rainfall of 600–1100 mm that comes in two seasons (Sombroek et al., 1982). The long rains are received in March/April through August while the short rains are received in October, November and December. The long rains season is the most important cropping season as it receives 75% of the annual rainfall (Saha, 2007). Mean monthly minimum and maximum temperatures of about 22^{0}C and 30^{0}C respectively, and mean relative humidity of 80% (Jaetzold et al., 2012). According to Sombroek et al., (1982) the soils in coastal lowland Kenya are mostly ferralsols. These soils have low organic matter content, are deficient in essential plant nutrients (especially nitrogen), prone to leaching, and have a pH ranging between 5 and 7 (Mureithi et al., 1995).

Experimental design, treatments and crop husbandry

The study evaluated the effect of intercropping maize with cowpea variety under different N-fetilizer rates. The experiment was laid out in a randomized complete block design with a factorial arrangement of treatments and replicated three times. The experiment consisted of two cropping systems and three N-fertilizer rates. The cropping systems were: maize variety Dryland Hybrid 04 (DH04) intercropped with cowpea variety Nyeupe and Maize variety Lamu intercropped with cowpea variety Nyeupe. The N-fertilizer rates comprised: control (no N-fertilizer), 30 kg N/ha and 60 kg N/ha. A drought/insect pest resistant and farmer preferred cowpea variety Nyeupe was used for intercropping with maize. Plot size and spacing are as directed in previous chapters. Triple superphosphate (46% P_2O_5) was applied at the rate of 20 kg P/ha in all plots. The source of nitrogen was calcium ammonium nitrate (26 % N).

Data collected

Data collected included: soil moisture content, canopy temperature, weed biomass, chlorophyll content, percent ground cover, leaf number, plant height, grain weight and grain yield of maize and cowpea, cowpea root nodule number, numbers of pods per plant, number of grains per pod, maize ears per plant and stover yield.

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Data analysis

Collected data were analyzed by the general linear model (GLM) procedure for analysis of variance using SAS statistical package (SAS Institute, 1993). Where the F values were significant, means were compared using the least significant difference (LSD) tests, at p = 0.05.

Results

Soil moisture content

Cropping systems, N-fertilizer application and their interaction had significant effects on soil moisture content at most sampling depths and growth stages (Table 1 and 2). Application of 30 kg N/ha caused a significant increase in soil moisture content at most growth stages and soil depths. Application of 60 N kg/ha had significantly lower soil moisture content than 30 N kg/ha at most growth stages and soil depths (Table 2). DH04-cowpea intercrop plots had significantly higher soil moisture content than Lamu-cowpea intercrop plots under 0 kg N/ha at most growth stages. In contrast, Lamu-cowpea intercrop generally had higher moisture content than DH04-cowpea intercrop at 30 and 60 kg N/ha at most growth stages.

Table 1: Effects of cropping system and N-fertilizer application at different growth stages on soil moisture (% per volume) at 20 and 40 cm soil depths.

Cropping system (CPS)	20 cm soil depth				40 cm soil depth			
	0 kg/ha	30 kg/ha	60 kg/ha	Mean-CPS	0 kg/ha	30 kg/ha	60 kg/ha	Mean-CPS
	Booting stage							
Lamu-cowpea	9.47	10.20	11.22	10.30	18.59	22.42	19.53	20.18
DH04-cowpea	11.77	10.35	10.55	10.89	18.64	19.59	14.38	17.54
Mean-N-fert	10.62	10.28	10.89		18.62	21.01	16.96	
P-value (CPS)	0.002				0.0008			
P-value (N-fert)	0.019				0.0006			
	0.000							
P-value (CPS x N-fert)	1				0.011			
$LSD_{0.05}$ (CPS)	0.30				1.25			
$LSD_{0.05}$ (N-fert	0.37				1.52			
$LSD_{0.05}$ (CPS x N-fert)	0.47				1.93			
	Silking stage							
Lamu-cowpea	18.59	22.42	19.53	20.18	21.28	26.81	19.45	22.51
DH04-cowpea	18.64	19.59	17.59	18.61	25.42	22.95	17.59	21.99
Mean-N-fert	18.62	21.01	18.56		23.35	24.88	18.52	
P-value (CPS)	0.019				0.347			
P-value (N-fert)	0.01				0.0001			
P-value (CPS x N-fert)	0.145				0.0009			
$LSD_{0.05}$ (CPS)	1.28				NS			
$LSD_{0.05}$ (N-fert	1.55				1.65			
$LSD_{0.05}$ (CPS x N-fert)	NS				2.10			
	Maturity stage							
Lamu-cowpea	8.68	9.87	8.77	9.11	12.48	14.47	11.74	12.90
DH04-cowpea	9.19	9.74	17.59	12.17	13.52	12.45	17.59	14.52
Mean-N-fert	8.94	9.81	13.18		13.00	13.46	14.67	

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P-value (CPS)	0.0001				0.006			
P-value (N-fert)	0.0001				0.031			
P-value (CPS x N-fert)	0.0001				0.0001			
$LSD_{0.05}$ (CPS)	0.59				0.99			
$LSD_{0.05}$ (N-fert	0.72				0.88			
$LSD_{0.05}$ (CPS x N-fert)	0.91				1.53			

Table 2: Effects of cropping system and N-fertilizer application at different growth stages on soil moisture (% per volume) at 60 and 80 cm soil depths.

Cropping system (CPS)	60 cm soil depth				80 cm soil depth			
	0 kg/ha	30 kg/ha	60 kg/ha	Mean-CPS	0 kg/ha	30 kg/ha	60 kg/ha	Mean-CPS
	Booting stage							
Lamu-cowpea	18.59	22.42	19.53	20.18	8.68	9.87	8.77	9.11
DH04-cowpea	18.62	19.59	17.62	18.61	9.19	9.84	24.42	14.48
Mean-N-fert	18.61	21.01	18.58		8.94	9.86	16.60	
P-value (CPS)	0.014				0.0001			
P-value (N-fert)	0.007				0.0001			
P-value (CPS x N-fert)	0.115				0.0001			
$LSD_{0.05}$ (CPS)	1.22				0.54			
$LSD_{0.05}$ (N-fert	1.49				0.65			
$LSD_{0.05}$ (CPS x N-fert)	NS				0.83			
Silking stage								
Lamu-cowpea	25.31	27.43	14.06	22.267	28.73	29.49	27.62	28.61
DH04-cowpea	28.38	27.65	17.59	24.540	29.76	30.23	17.59	25.86
Mean-N-fert	26.85	27.54	15.83		29.25	29.86	22.61	
P-value (CPS)	0.017				0.0001			
P-value (N-fert)	0.0001				0.0001			
P-value (CPS x N-fert)	0.0001				0.0001			
$LSD_{0.05}$ (CPS)	0.73				0.45			
$LSD_{0.05}$ (N-fert	0.89				0.55			
$LSD_{0.05}$ (CPS x N-fert)	1.13				0.70			
Maturity stage								
Lamu-cowpea	15.40	21.25	13.41	16.69	22.54	24.23	18.55	21.77
DH04-cowpea	19.48	15.99	17.59	17.69	23.47	22.45	17.59	21.17
Mean-N-fert	17.44	18.62	15.50		23.01	23.34	18.07	

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P-value (CPS)	0.365	0.138
P-value (N-fert)	0.043	0.0001
P-value (CPS x N-fert)	0.002	0.05
$LSD_{0.05}$ (CPS)	NS	NS
$LSD_{0.05}$ (N-fert	2.32	1.13
$LSD_{0.05}$ (CPS x N-fert)	2.95	1.43

Ground cover and canopy temperature

Cropping system, N-fertilizer application and their interactions significantly affected ground cover and canopy temperature at both sites (Table 3). Application of 60 kg/ha increased percent ground cover in both cropping systems and sites, while application of 30 kg N/ha increased percent ground cover in Lamu-cowpea intercrop at Kilifi and DH04-cowpea intercrop at Mtwapa. Increasing N-fetilizer application from 30 kg N/ha to 60 kg N/ha increased percent ground cover in Lamu-cowpea at Kilifi but not at Mtwapa. DHO4-cowpea intercrop had significantly higher percent crop ground cover than Lamu-cowpea intercrop at 0 and 30 kg N/ha at Kilifi and 30 and 60 kg N/ha at Mtwapa. Application of 60 kg N/ha N-fertilizer significantly reduced canopy temperatures in both cropping systems at Kilifi and Lamu-cowpea intercrop at Mtwapa (Table 3). . Application of 30 kg N /ha N-fertilizer level had no significant effect on canopy temperature. The two cropping systems had generally similar canopy temperatures across the different N levels except at 60 Kg N/ha at Mtwapa where Lamu-cowpea intercrop had a significantly lower temperature than DHO4-cowpea intercrop. Crop canopy temperatures were significantly higher at Mtwapa than at Kilifi.

Chlorophyll contents of cowpea and maize

Cropping system, N-Fertilizer application and their interactions significantly affected cowpea chlorophyll content at both sites and maize chlorophyll content at Mtwapa (Table 4). Application of 60 kg N/ha reduced cowpea chlorophyll content relative to 30 kg N/ha and control in both cropping systems at both sites. Application of 30 kg N/ha had no significant effect on cowpea chlorophyll content at Kilifi, but decreased this parameter at Mtwapa. Lamu maize intercropped with cowpea had higher chlorophyll content than DHO4 maize intercropped with cowpea at Kilifi, but the converse was the case at Mtwapa. The average chlorophyll content of cowpea at Kilifi was 10.5% higher than at Mtwapa. N- Application of N-fertilizer significantly increased maize chlorophyll content of both cropping systems at both sites. At Mtwapa however, there was no significant increase in maize chlorophyll content as N rate increased from 30 N kg/ha to 60 N kg/ha. Lamu maize intercropped with cowpea had higher maize chlorophyll content than DH04 maize intercropped with cowpea at 0 kg N/ha in Kilifi and 30 and 60 kg N/ha at Mtwapa. Average maize chlorophyll content at Mtwapa was higher by 20.6% than at Kilifi.

Table 3: Effects of cropping system and N-fertilizer application on percent crop ground cover and canopy temperature (^{O}C) at kilifi and at mtwapa sites during July – October 2011/2012 season

Cropping system (CPS)	Kilifi				Mtwapa			
	N_0	N_1	N_2	CPS-mean	N_0	N_1	N_2	CPS-mean
	Percent ground cover							
Lamu - cowpea	76.77	82.33	86.03	81.71	23.43	28.77	30.60	27.60
DH04 - cowpea	83.77	85.40	86.63	85.27	25.33	46.33	54.57	42.08

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Mean-N-fert	80.27	83.87	86.33		24.38	37.55	42.59	
P-value (CPS)	0.0002				0.0003			
P-value (N-fert)	0.0001				0.006			
P-value (CPS x N-fert)	0.002				0.001			
$LSD_{0.05}$ (CPS)	1.37				5.86			
$LSD_{0.05}$ (N-fert)	1.67				7.17			
$LSD_{0.05}$ (CPS x N-fert)	2.50				10.72			
CV (%)	1.56				16.00			
	Canopy temperature (^{O}C)							
Lamu - cowpea	25.47	24.87	23.27	24.54	27.61	27.28	24.04	26.31
DH04 - cowpea	26.20	25.43	23.33	24.99	26.82	26.80	25.50	26.37
Mean-N-fert	25.84	25.15	23.30		27.22	27.04	24.77	
P-value (CPS)	0.327				0.840			
P-value (N-fert)	0.196				0.067			
P-value (CPS x N-fert)	0.02				0.0004			
$LSD_{0.05}$ (CPS)	Ns				Ns			
$LSD_{0.05}$ (N-fert)	1.21				0.89			
$LSD_{0.05}$ (CPS x N-fert)	2.4				1.33			
CV (%)	3.79				2.63			

N_0 = No N-fertilizer; N_1 = 30 kg/ha N-fertilizer and N_2 = 60 kg/ha N-fertilizer

Leaf numbers of cowpea and maize

Cropping system, N-Fertilizer application and their interactions significantly affected cowpea and maize leaf numbers at both sites (Table 5). Application of N-fetilizer significantly reduced cowpea leaf numbers in both cropping systems at Kilifi and in DH04-cowpea intercrop system at Mtwapa. At Mtwapa, there were no significant differences in cowpea leaf number among all fertilizer rates in Lamu-cowpea intercrop and between 30 kg N/ha and 60 kg N/ha. The average ccowpea leaf number at Mtwapa was 24.9% higher than at Kilifi. Application of N-fertilizer significantly increased maize leaf number of cropping systems at Mtwapa but not at Kilifi (Table 5). There was no significant difference between 30 kg/ha and 60 kg/ha of N-fertilizer applications at Mtwapa. DHO4 maize intercropped with cowpea had significantly higher maize leaf number than Lamu maize intercropped with cowpea at Kilifi while, the converse was the case at Mtwapa.

Table 4: Effects of cropping system and N-fertilizer application on chlorophyll content (index) of cowpea and maize at kilifi and at mtwapa sites during July – October 2011/2012 season

Cropping system (CPS)	Kilifi				Mtwapa			
	N_0	N_1	N_2	CPS-mean	N_0	N_1	N_2	CPS-mean
	Cowpea chlorophyll index							
Lamu - cowpea	59.56	59.24	53.40	57.40	49.63	47.73	45.17	47.51
DH04 - cowpea	55.96	54.58	50.83	53.79	52.93	52.60	48.03	51.19

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Mean-N-fert	57.76	56.91	52.12		51.28	50.17	46.60	
P-value (CPS)	0.0001				0.0001			
P-value (N-fert)	0.005				0.012			
P-value (CPS x N-fert)	0.002				0.0001			
$LSD_{0.05}$ CPS	1.38				1.15			
$LSD_{0.05}$ N-fert	1.69				1.38			
$LSD_{0.05}$ CPS x N-fert	2.53				2.06			
CV (%)	2.66				1.93			
	Maize chlorophyll index							
Lamu - cowpea	36.87	37.30	41.57	38.58	43.43	49.67	50.40	47.83
DH04 - cowpea	33.30	42.20	42.23	39.24	43.37	46.97	47.67	46.00
Mean-N-fert	35.09	39.75	41.90		43.40	48.32	49.04	
P-value (CPS)	0.27				0.001			
P-value (N-fert)	0.001				0.001			
P-value (CPS x N-fert)	0.001				0.001			
$LSD_{0.05}$ CPS	Ns				0.71			
$LSD_{0.05}$ N-fert	1.54				0.91			
$LSD_{0.05}$ CPS x N-fert	2.30				1.36			
CV (%)	3.08				1.51			

N_0 = No N-fertilizer; N_1 = 30 kg/ha N-fertilizer and N_2 = 60 kg/ha N-fertilizer

Table 5: Effects of cropping system and N-fetilizer application on cowpea leaf number at kilifi and at mtwapa sites during July – October 2011/2012 seasonn

Cropping system (CPS)	Kilifi				Mtwapa			
	N_0	N_1	N_2	CPS-mean	N_0	N_1	N_2	CPS-mean
	Cowpea leaf number							
Lamu - cowpea	22.17	19.70	19.53	20.47	30.83	27.70	26.50	28.34
DH04 - cowpea	31.50	23.23	21.27	25.33	36.40	25.27	24.80	28.82
Mean-N-fert	26.84	21.47	20.40		33.62	26.49	25.65	
P-value (CPS)	0.014				0.008			
P-value (N-fert)	0.0001				0.057			
P-value (CPS x N-fert)	0.0001				0.022			
$LSD_{0.05}$ CPS	0.36				3.30			
$LSD_{0.05}$ N-fert	0.43				4.04			
$LSD_{0.05}$ CPS x N-fert	0.65				6.04			
CV (%)	1.19				13.72			
	Maize leaf number							
Lamu - cowpea	16.20	16.17	15.90	16.09	10.20	10.87	10.67	10.58

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DH04 - cowpea	17.50	16.37	17.37	17.08	7.13	8.47	8.67	8.09
Mean-N-fert	16.85	16.27	16.64		8.67	9.67	9.67	
P-value (CPS)	0.008				0.0001			
P-value (N-fert)	0.314				0.001			
P-value (CPS x N-fert)	0.219				0.095			
$LSD_{0.05}$ CPS	0.66				0.40			
$LSD_{0.05}$ N-fert	Ns				0.40			
$LSD_{0.05}$ CPS x N-fert	Ns				Ns			
CV (%)	0.82				4.08			

N_0 = No N-fertilizer application; N_1 = 30 kg/ha N-fertilizer application and N_2 = 60 kg/ha N-fertilizer application

Plant heights of cowpea and maize

Cropping system, N-Fertilizer application and their interactions significantly affected plant height of both cropping systems at both sites (Table 6). Application of N-fetilizer application significantly reduced cowpea plant height in both intercrop systems in both sites. Cowpea plant height was significantly lower in 60 kg N/ha plots than in 30 kg N/ha plots. Cowpea intercropped with Lamu maize variety had significantly lower plant height than cowpea intercropped with DH04 maize variety. The average cowpea plant height was 166.5% higher at Mtwapa than at Kilifi.

Table 6: Effects of cropping system and N-fetilizer application on plant plant heights (cm) of cowpea and maize at kilifi and at mtwapa sites during July – October 2011/2012 season

Cropping system (CPS)	Kilifi				Mtwapa			
	N_0	N_1	N_2	CPS-mean	N_0	N_1	N_2	CPS-mean
	Cowpea plant height (cm)							
Lamu - cowpea	9.40	6.13	4.77	6.77	24.80	16.63	13.83	18.42
DH04 - cowpea	12.67	6.87	2.80	7.45	33.17	17.87	7.53	19.52
Mean-N-fert	11.04	6.50	3.79		28.99	17.25	10.68	
P-value (CPS)	0.0001				0.0001			
P-value (N-fert)	0.0001				0.0001			
P-value (CPS x N-fert)	0.0001				0.0001			
$LSD_{0.05}$ CPS	0.02				0.01			
$LSD_{0.05}$ N-fert	0.02				0.01			
$LSD_{0.05}$ CPS x N-fert	0.03				0.02			
CV (%)	4.12				3.13			
	Maize plant height (cm)							
Lamu - cowpea	154.03	150.63	145.40	150.02	146.17	161.27	166.13	157.86
DH04 - cowpea	129.17	128.93	140.80	132.97	99.40	133.23	156.00	129.54
Mean-N-fert	141.60	139.78	143.10		122.79	147.25	161.07	

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P-value (CPS)	0.036	0.0001
P-value (N-fert)	0.661	0.017
P-value (CPS x N-fert)	0.073	0.288
$LSD_{0.05}$ CPS	0.07	6.58
$LSD_{0.05}$ N-fert	Ns	8.05
$LSD_{0.05}$ CPS x N-fert	Ns	Ns
CV (%)	8.44	4.36

N_0 = No N-fertilizer application; N_1 = 30 kg/ha N-fertilizer application and N_2 = 60 kg/ha N-fertilizer application

N-Fertilizer application and cropping system significantly affected maize plant height in Mtwapa while in Kilifi only cropping system had significant effect (Table 6). Application of N-fetilizer application significantly increased maize plant height at Mtwapa. The plant height for Lamu maize intercropped with cowpea was taller than DHO4 maize intercropped with cowpea. The average maize plant height at Mtwapa was 1.6% higher than at Kilifi.

Cowpea root nodule number

Cropping system, N-Fertilizer application and their interaction significantly affected the number of cowpea root nodules at Kilifi but not at Mtwapa (Table 7). At Kilifi application of N-fertilizer resulted in significant reduction in the number of cowpea root nodules per plant in both cropping systems. Cowpea intercropped with Lamu maize had higher number of root nodules than cowpea intercropped with DHO4 maize at all N levels. Kilifi site had 68.3% higher number of nodules than Mtwapa.

Table 7: Effects of cropping system and N-fertilizer application on number of cowpea root nodules per plant at kilifi and at mtwapa sites during July – October 2011/2012 season

Cropping system (CPS)	Kilifi				Mtwapa			
	N_0	N_1	N_2	CPS-mean	N_0	N_1	N_2	CPS-mean
Lamu - cowpea	39.13	33.40	33.07	35.20	20.90	19.70	18.57	19.72
DH04 - cowpea	36.63	30.93	30.41	32.66	19.70	19.50	22.57	20.59
P-value (CPS)	0.008				0.565			
P-value (N-fert)	0.034				0.453			
P-value (CPS x N-fert)	0.0001				0.997			
$LSD_{0.05}$ CPS	0.58				Ns			
$LSD_{0.05}$ N-fert	0.71				Ns			
$LSD_{0.05}$ CPS x N-fert	1.07				Ns			
CV (%)	2.75				26.67			

N_0 = No N-fertilizer application; N_1 = 30 kg/ha N-fertilizer application and N_2 = 60 kg/ha N-fertilizer application

Pods per plant and grains per pod of cowpea

Cropping system, N-Fertilizer application and their interactions had significant effect on the number of cowpea pods per plant at both sites (Table 9.8). Application of 60 kg/ha N-fertilizer significantly reduced the number of cowpea pods per plant in both cropping systems at both sites. N-fertilizer application of 30 kg/ha had no significant effect on pods per plant at both sites. DH04 maize intercropped with cowpea had a higher

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number of pods per plant than Lamu maize intercropped with cowpea at 0 kg N/ha and 30 kg N/ha N-fetilizer application in both sites, Mtwapa had 189.2% higher number of pods per plant than at Kilifi. Application of 60 kg N/ha N-fertilizer significantly reduced the number of cowpea grains per pod of cropping systems at Mtwapa. In most cases, there were no differences in number of grains per pod between Lamu-cowpea and DH04-cowpea intercrop.

Table 8: Effects of cropping system, N-fetilizer application on number of pods per plant and grains per pod in cowpea at kilifi and at mtwapa sites during July – October 2011/2012 season

Cropping system (CPS)	Kilifi				Mtwapa			
	N_0	N_1	N_2	CPS-mean	N_0	N_1	N_2	CPS-mean
	Number of pods per plant							
Lamu - cowpea	2.87	2.86	2.16	2.63	8.87	8.43	6.83	8.04
DH04 - cowpea	3.69	3.52	2.08	3.10	9.70	9.57	6.20	8.49
Mean-N-fert	3.28	3.19	2.12		9.29	9.00	6.52	
P-value (CPS)	0.02				0.002			
P-value (N-fert)	0.0001				0.0005			
P-value (CPS x N-fert)	0.0001				0.0001			
$LSD_{0.05}$ CPS	0.39				0.25			
$LSD_{0.05}$ N-fert	0.44				0.30			
$LSD_{0.05}$ CPS x N-fert	0.66				0.45			
CV (%)	4.13				8.17			
	Number of grains per pod							
Lamu - cowpea	8.54	12.83	8.58	9.98	15.97	15.83	14.37	15.39
DH04 - cowpea	7.62	11.97	12.72	10.77	16.63	15.00	15.00	15.54
Mean-N-fert	8.08	12.40	10.65		16.30	15.42	14.69	
P-value (CPS)	0.50				0.012			
P-value (N-fert)	0.949				0.0001			
P-value (CPS x N-fert)	0.002				0.0001			
$LSD_{0.05}$ CPS	Ns				0.58			
$LSD_{0.05}$ N-fert	Ns				0.71			
$LSD_{0.05}$ CPS x N-fert	0.91				1.05			
CV (%)	0.05				5.28			

N_0 = No N-fertilizer application; N_1 = 30 kg/ha N-fertilizer application and N_2 = 60 kg/ha N-fertilizer application

Ears per plant and 100-grain weight of maize

Cropping system, N-fertilizer and their interaction had significant effects on the number of ears per plant of maize of both cropping systems at sites (Table 9).

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Table 9: Effects of cropping system and N-fetilizer application on number of ears per plant and 100-grain weight in maize

Cropping system (CPS)	Kilifi				Mtwapa			
	N_0	N_1	N_2	CPS-mean	N_0	N_1	N_2	CPS-mean
	Number of maize ears per plant							
Lamu - cowpea	0.56	0.58	0.65	0.60	0.17	0.21	0.25	0.22
DH04 - cowpea	0.56	0.61	0.72	0.63	0.21	0.23	0.28	0.23
Mean-N-fert	0.56	0.60	0.69		0.19	0.22	0.27	
P-value (CPS)	0.007				0.0004			
P-value (N-fert)	0.005				0.0001			
P-value (CPS x N-fert)	0.032				0.0001			
$LSD_{0.05}$ CPS	0.08				0.01			
$LSD_{0.05}$ N-fert	0.10				0.01			
$LSD_{0.05}$ CPS x N-fert	1.33				0.02			
CV (%)	12.14				3.35			
	Maize 100-grain weight (g)							
Lamu - cowpea	27.37	28.7	26.63	27.57	10.08	10.46	9.97	10.17
DH04 - cowpea	33.43	31.27	31.33	32.01	12.59	11.05	11.81	11.82
Mean-N-fert	30.4	29.99	28.98		11.34	10.76	10.89	
P-value (CPS)	0.0001				0.0002			
P-value (N-fert)	0.229				0.27			
P-value (CPS x N-fert)	0.13				0.059			
$LSD_{0.05}$ CPS	1.43				0.64			
$LSD_{0.05}$ N-fert	Ns				Ns			
$LSD_{0.05}$ CPS x N-fert	Ns				Ns			
CV (%)	4.57				5.55			

N_0 = No N-fertilizer application; N_1 = 30 kg/ha N-fertilizer application and N_2 = 60 kg/ha N-fertilizer application

Application of N-fertilizer significantly increased the number of ears per plant in both cropping systems and at both sites. Cropping system had significant effect on maize 100-grain weight in both sites. However, N-fetilizer application and the interaction between cropping system and N-fetilizer application had no significant effect on maize 100-grain weight in both sites. DH04 maize variety intercropped with cowpea had higher 100-grain weight than Lamu maize variety intercropped with cowpea.

Cowpea 100-grain weight and grain yield

Cropping system, N-Fertilizer application and their interactions had significant effects on cowpea 100-grain weight at Mtwapa and grain yield at Kilifi (Table 10).

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Table 10: Effects of cropping system and N-fetilizer application on 100-grain weight (g) and grain yield (t/ha) of cowpea in Kilifi and Mtwapa sites during July – October 2011/2012 season

Cropping system (CPS)	Kilifi				Mtwapa			
	N_0	N_1	N_2	CPS-mean	N_0	N_1	N_2	CPS-mean
	Cowpea 100-grain weight (g)							
Lamu - cowpea	5.33	4.41	5.25	5.00	14.66	14.60	13.75	14.34
DH04 - cowpea	5.55	5.47	5.55	5.52	16.51	15.65	15.53	15.90
Mean-N-fert	5.44	4.94	5.40		15.59	15.13	14.64	
P-value (CPS)	0.0002				0.0001			
P-value (N-fert)	0.962				0.0001			
P-value (CPS x N-fert)	0.033				0.0001			
$LSD_{0.05}$ CPS	0.68				0.01			
$LSD_{0.05}$ N-fert	Ns				0.10			
$LSD_{0.05}$ CPS x N-fert	0.55				0.19			
CV (%)	3.83				0.14			
	Cowpea grain yield (t/ha)							
Lamu - cowpea	0.23	0.50	0.40	0.38	0.07	0.04	0.06	0.06
DH04 - cowpea	0.57	0.50	0.37	0.48	0.04	0.03	0.02	0.03
Mean-N-fert	0.40	0.50	0.39		0.06	0.04	0.04	
P-value (CPS)	0.018				0.002			
P-value (N-fert)	0.036				0.030			
P-value (CPS x N-fert)	0.002				0.112			
$LSD_{0.05}$ CPS	0.09				0.01			
$LSD_{0.05}$ N-fert	0.09				0.01			
$LSD_{0.05}$ CPS x N-fert	0.12				Ns			
CV (%)	17.06				21.06			

N_0 = No N-fertilizer application; N_1 = 30 kg/ha N-fertilizer application and N_2 = 60 kg/ha N-fertilizer application

Application of 60 kg N/ha, significantly reduced cowpea 100-grain weight at Mtwapa but not at Kilifi. DH04 maize variety intercropped with cowpea had higher 100-grain weight than Lamu maize variety intercropped with cowpea at all N-fertilizer levels. At Kilifi, application of 60 kg/ha N-fetilizer application significantly reduced cowpea grain yield in both cropping systems. However, no differences were noted between the cropping systems at all N-fertilizer levels. At Mtwapa, cowpea intercropped with DH04 maize variety had higher grain yield than cowpea intercropped with Lamu maize variety. Average cowpea grain yield was at Kilifi was 855.6 % higher than at Mtwapa.

Stover yield and grain yield of maize

Cropping system, N-fertilizer application and their interaction significantly affected maize stover yield and grain yield in both sites (Table 9.11). Application of 30 and 60 kg N/ha increased maize stover yields and grain yield in both cropping systems at both sites. Application of 60 kg/ha had higher maize stover yield and grain yield than 30 kg N/ha in both cropping systems at both sites. Lamu maize variety intercropped with cowpea had higher maize stover yield at 60 kg N/ha. The mean maize stover yield at Kilifi was 160.0 % higher

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than at Mtwapa. Application of 30 and 60 kg N/ha significantly increased maize grain yield in both cropping systems at both sites. DH04 maize variety intercropped with cowpea had higher grain yield than Lamu maize variety intercropped with cowpea at all N-levels at all N levels. On average, application of 30 and 60 kg N/ha increased maize grain yield by 20.7% and 51.0 %, respectively, at Kilifi and 78.6 % and 114.3 %, respectively, at Mtwapa. Average maize grain yield at Kilifi was 536.7 % higher than at Mtwapa.

Table 11: Effects of cropping system and N-fetilizer application maize stover yield (t/ha) and grain yield (t/ha) of maize at kilifi and at mtwapa sites during July – October 2011/2012 seasonn

Cropping system (CPS)	Kilifi				Mtwapa			
	N_0	N_1	N_2	CPS-mean	N_0	N_1	N_2	CPS-mean
	Maize stover yield (t/ha)							
Lamu – cowpea	2.34	2.77	4.26	3.12	1.02	1.07	1.52	1.20
DH04 – cowpea	2.06	2.55	3.25	2.62	0.75	0.89	1.20	0.95
Mean-N-fert	2.20	2.66	3.76		0.89	0.98	1.36	
P-value (CPS)	0.0001				0.0001			
P-value (N-fert)	0.0001				0.0001			
P-value (CPS x N-fert)	0.0001				0.0001			
$LSD_{0.05}$ CPS	0.07				0.02			
$LSD_{0.05}$ N-fert	0.08				0.02			
$LSD_{0.05}$ CPS x N-fert	0.12				0.03			
CV (%)	2.28				1.36			
	Maize grain yield (t/ha)							
Lamu – cowpea	1.50	1.77	2.17	1.81	0.13	0.15	0.23	0.28
DH04 – cowpea	1.60	1.97	2.50	2.02	0.15	0.13	0.26	0.32
Mean-N-fert	1.55	1.87	2.34		0.14	0.14	0.25	
P-value (CPS)	0.008				0.0003			
P-value (N-fert)	0.025				0.0001			
P-value (CPS x N-fert)	0.0001				0.0001			
$LSD_{0.05}$ CPS	0.13				0.01			
$LSD_{0.05}$ N-fert	0.16				0.01			
$LSD_{0.05}$ CPS x N-fert	0.20				0.01			
CV (%)	6.39				3.53			

N_0 = No N-fertilizer application; N_1 = 30 kg/ha N-fertilizer application and N_2 = 60 kg/ha N-fertilizer application

DISCUSSION

Soil moisture content

Nitrogen fertilizer application significantly increased soil moisture content at all growth stages at 20 cm soil depth. Application of 30 N kg/ha had significantly higher soil moisture content than 60 N kg/ha at all growth stages. This could be attributed to an increase in soil water uptake at 60 kg N/kg due to high N levels

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from the inorganic fertilizer (Ofori et al., 2014). The high biomass production under 60 N kg/ha application associated with more soil moisture utilization (Gaiser et al., 2004).

Ground cover and growth parameters of cowpea and maize

The study has shown that application of N-fertilizer increased cowpea and maize percent ground cover and maize growth parameters but the converse was true for cowpea growth parameters in both sites. Thobatsi (2009) reported that N-fertilizer application enhanced early ground cover of a maize-cowpea intercropping system. Amujoyegbe and Elemo (2013) reported that canopy formation in a maize-cowpea intercrop increased slightly with increase in N-fertilizer rate. This could be attributed to the fact that nitrogen is a constituent of chlorophyll, protein, amino acids and photosynthetic activity (Sumeet et al., 2009). Nitrogen also enhances and facilitates the utilization of other nutrients like phosphorus, potassium and other elements (Adediran and Banjoko, 1995). Generally, ground cover intercepts both PAR, raindrops and retards runoff therefore promoting infiltration. Soil moisture availability is subsequently prolonged by reduced surface evaporation due to insulation and shading off of radiation transmittance by the main crop canopy (Odhiambo and Bomke, 2001).

N-fertilizer application resulted in significant increase in maize leaf number, plant height and maize stover yield at both sites. Amanullah et al., (2013) reported that nitrogen fertilizer significantly increased maize leaf number, plant height and biomass yield. Increase in maize growth parameters due to nitrogen fertilizer application was also reported by Onasanya et al., (2009). Several reports have attributed significant increase in the development of vegetative plant parts and dry matter accumulation to nitrogen which is an important constituent of chlorophyll, amino acid and nucleic acid (Adediran and Banjoko, 1995). Application of N-fertilizer significantly reduced cowpea leaf number and plant height in both sites. This finding is in agreement with the studies by Abayomi and Jatto, (1998) and Amujoyegbe and Elemo, (2013), who reported significant reduction in cowpea leaf number and plant height due to increase in N-fetilizer application in maize-cowpea intercrops. Cowpea growth parameters were significantly higher when intercropped with DH04 maize variety than when intercropped with Lamu maize variety. This could be because Lamu maize variety was taller than DH04 maize variety; hence the shading and competition for resources could have impacted negatively on the cowpea (Dahmardeh et al., 2010).

Chlorophyll content of cowpea and maize

Application of N-fertilizer significantly reduced cowpea chlorophyll content at both sites. Prasanthi and Venkateswaralu (2014) reported reduction in cowpea chlorophyll content in maize-cowpea intercropping system. They attributed this to shading effect under intercropped situations. The fast and vigorous maize growth might have dominated and utilized the resources more efficiently and suppressed the cowpea. N-fertilizer application significantly increased maize chlorophyll content at both sites. Prasanthi and Venkateswaralu (2014) reported an increase in maize chlorophyll content due to N-fertilization in a maize-cowpea intercropping system.

Canopy temperature

Application of N-fertilizer significantly reduced canopy temperature of cropping systems. Elbashier et al., (2012) reported reduction in canopy temperature of maize-wheat intercrop due to N-fertilizer application. This was attributed to promotion of photosynthesis by N- fertilizer application, which involves stomatal opening, leading to water loss and cooling of the canopy. In this study the increase in soil moisture content due to application of 30 kg N/ha suggests the observed improved moisture retention by the increase in ground cover.

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Cowpea root nodule number

In this study application of 60 kg/ha N-fertilizer significantly reduced the number of root nodules. The findings of these studies are in agreement with study by Otieno et al., (2007) who reported that the application of nitrogen fertilizer depressed nodulation in legumes. Fukai et al. (1980) reported that addition of nitrogen to a cereal/cowpea system is generally favoring the cereal at the expense of cowpea. If the intercropped non-legume is taller than the legume, shading will occur and photosynthesis and subsequently N-fixation will be reduced (Van Kessel and Hartley, (2000). Lamu maize variety had taller average height than DH04 maize variety, hence the number of root nodules in cowpea intercropped with DH04 maize variety were higher than in cowpea intercropped with Lamu maize variety. Also, moisture availability under DH04-cowpea intercrop was higher than under Lamu-cowpea intercrop. Root nodules at Kilifi were 68.3% higher than at Mtwapa. This could be because Kilifi received a higher amount of rainfall than Mtwapa because moisture enhances nodulation (Ofori et al., 2014).

Yield and yield components of cowpea and maize

The study indicates that application of nitrogen fertilizer significantly reduced the number of pods per plant, number of grains per pod, 100-grain weight and grain yield of cowpea at both sites but the converse was true for maize number of ears per plant and grain yield. The reduction in cowpea yield and yield components and grain yield is in agreement with previous studies (Amujoyegbe and Elemo, 2013). In a system where cowpea was intercropped with maize shading had significant effects on cowpea yield and yield components because it is the shorter component, and could not compete effectively for resources (Eskandari, 2012). Cowpea grain yield and yield components were higher in cowpea intercropped with DH04 maize variety than cowpea intercropped with Lamu maize variety. This could be attributed to interspecies competition because Lamu maize variety was taller than DH04 maize variety. Cowpea yield and yield components were significantly higher at Kilifi than at Mtwapa possibly the former received a higher amount of rainfall than the latter. Grain yield of maize with N application at both sites is in agreement with the studies by Akmal et al., (2010) and Karasu (2012) who observed that nitrogen fertilizer exerts strong influence on maize growth, development and yield. According to Purcell et al., (2002) nitrogen availability increases maize general growth which leads to increased grain yiewld. Application of 60 kg/ha N-fertilizer had higher grain yield than 30 kg N-fertilizeer in all cropping system at both sites. Therefore, farmers intercropping maize-cowpea in the region can use 60 kg/ha N-fertilizer because it gives higher yields than 30 kg/ha N-fertilizer under normal rainfall conditions.

Conclusion

Application of N-fertilizer significantly reduced cowpea growth parameters, yield and yield components while the converse was true for maize under maize-cowpea intercropping system. Application of 60 N kg/ha had significantly higher performance than 30 N kg/ha while the converse was true for soil moisture content at all growth stages in all soil depths. The performance of maize under DH04-cowpea intercrop was significantly higher than Lamu-cowpea intercrop.

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