International Scholars Journals

International Journal of Agricultural Sciences ISSN 2167-0447 Vol. 7 (3), pp. 1271-1281, March, 2017. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Effect of cropping system on soil moisture content, canopy temperature, growth and yield performance of maize and cowpea

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Received 10 October, 2016; Revised 25 October, 2016; Accepted 03 February, 2017 and Published 08 March, 2017

An experiment was carried out at Pwani University and Kenya Agricultural and Livestock Research Organization-Mtwapa to determine the effects of intercropping on soil moisture, canopy temperature and yield performance of maize-cowpea intercrops in the coastal lowland of Kenya in 2011 and 2012. Randomized complete block design with a factorial arrangement of treatments used and replicated thrice. Data collected included: soil moisture content, canopy temperature, weed biomass, chlorophyll content, percent ground cover, leaf number, plant height, grain weight and grain yield for both maize and cowpea. Cowpea root nodule number, number of pods per plant, number of grains per pod and maize ears per plant and stover yield. Data collected were analyzed using the general linear model (GLM) procedure for analysis of variance using SAS statistical package and means separated using least significant difference (LSD) test at p = 0.05. Sole cowpea and maize-cowpea intercrop had higher moisture content than sole maize plots. Intercropping reduced chlorophyll content, weed biomass, growth attributes, yield and yield components of maize and cowpea, but increased canopy temperature and cowpea nodule numbers. Land equivalent ratios for Lamu-cowpea and DH04-cowpea intercrops were 1.23 and 1.49, respectively. Intercropping enhanced moisture retention and was more productive than sole cropping.

Keywords: Cowpeas, growth, maize, intercropping, yield

INTRODUCTION

Maize (*Zea mays* L.), a staple food in Kenya, is produced by mostly small scale farmers who have little capacity to produce it efficiently. The small scale farmers form the largest portion of over 80% of the total Kenyan farmers (Booker, 2010). Cereal-legume intercropping plays an important role in subsistence food production in both developed and developing countries, especially in situations of limited water resources (Dahmardeh *et al*., 2010). It alters the abiotic and biotic features of an agro-ecosystem and could alter the life cycle of pests such as weeds (Banik, *et al.,* 2006). A cropping system that reduces weed population may provide a weed suppressive foundation upon which cultural weed control could be laid (Tsubo *et al*., 2005). Cowpea is frequently intercropped with cereals where it contributes to the maintenance of soil fertility (Carsky, *et al.,* 2001). Over

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90% of small scale farmers in the coastal lowland of Kenya intercrop or relay maize and cowpea during the long rains season (Saha, *et al.,* 1993). The ability of legumes to fix nitrogen through symbiosis with species of rhizobia gives them special value in low input agriculture (Saha *et al.,* 1993; Giller, 2001). By incorporating cowpea into the cropping systems, farmers in the region have for long utilized biologically fixed nitrogen to maintain soil fertility but the yields have not stabilized. The individual crops that constitute an intercrop can differ in their use of resources spatially, temporally, or in form, resulting in overall more complementary and efficient use of resources than when they are grown in sole cropping; thus decreasing the amount available for weeds (Hauggard-Nielson *et al.,* 2001). For example, when growing pea and barley in intercrops, Hauggard-Nielsen *et al.* (2006) found that there was an increased efficiency in utilizing environmental resources for plant growth and a better competitive ability towards weeds as compared to sole crops. Baumann *et al.* (2000) reported that intercropping increases light interception by the weakly competitive component and can, therefore, shorten the critical period for weed control and reduce growth and fecundity of late-emerging weeds. The apparent increased competitiveness of intercropping systems makes them potentially useful for integration into low in-put farming systems in which options for chemical weed control are reduced or non-existent (Szumigalski and Van Acker, 2005). The advantages of intercropping over monocropping include soil conservation, lodging resistance, yield increment (Anil, 1998) and weed control (Banik *et al.,* 2006). Yields of intercropping are often higher than in sole cropping systems (Lithourgidis *et al.,* 2006) mainly due to resources such as water, light and nutrients that can be utilized more effectively than in sole cropping systems (Li *et al.,* 2006). When two crops are planted together, intra and/or inter specific competition or facilitation between plants may occur (Zhang and Li, 2003). Competition among the mixtures is thought to be a major aspect affecting yield as compared with sole cropping of cereals (Ndakidemi, 2006). Land equivalent ratio has been used to determine the intercropping system advantages (Yilmaz *et al.,* 2008). According to Naresh *et al.,* (2014) reported reduced canopy temperature in maize-wheat intercropping system. In the coastal lowland region of Kenya the growth, canopy temperature, chlorophyll content and yield performance of different maize and cowpea varieties under intercrop systems have not been evaluated. Therefore, the objective of this study was to determine the effect of intercropping on soil moisture content, canopy temperature, chlorophyll content and yield performance of maize-cowpea intercrops in the coastal lowland Kenya.

MATERIALS AND METHODS

Study site

The study was carried out at Pwani University (PU) and Kenya Agricultural and Livestock Research Organization (KALRO)-Mtwapa both located in Kilifi County in the coastal region of Kenya. Pwani University is located 60 km north of Mombasa between latitudes 3º S and 4º S and longitudes 39º E and 40º E. Kenya Agricultural and Livestock Research Organization (KALRO)-Mtwapa is situated at 30 m above sea level (a.s.l), 39.219º E and 4.347º 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 and continue up to 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). The sites have 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 experiment was set up in a randomized complete block design with three replications. Treatments consisted of two drought tolerant and insect resistant maize varieties (Lamu and DH04) which were either sole cropped or intercropped with cowpea variety Nyeupe. The experimental plot size was 5 m x 5 m. The spacing for sole maize was 100 cm x 50 cm with two plants per hill, while the spacing for sole cowpea was 60 cm x 30 cm with two plants per hill. For the intercrop, the cowpea was planted in between the maize rows. All the experimental plots were hand weeded at 4 and 8 weeks after planting maize, as recommended in the coastal region (Gacheru *et al*., 1993). Maize stem borer was controlled using Bulldock (0.5 g/kg Beta cyfluthrin) at 2 kg per Ha (or a pinch into the funnel of the plant at knee height stage when there is adequate moisture). Triple superphosphate was applied to sole maize and intercropped maize at planting using the recommended rate of 100 kg ha^{-1} (46 kg P_2O_5 ha^{-1}). The maize was later top-dressed with nitrogen at 30 kg N/ha in form of

Table 1. Effect of cropping systems on soil moisture content (% per volume)at 20, 40, 60 and 80 cm at different growth stages

Cropping system	Boot	Silk	Maturity	Boot	Silk	Maturity
	20 cm Soil depth			40 cm soil depth		
Sole cowpea	16.54	17.11	15.41	18.77	22.88	22.97
Sole Lamu	12.64	11.58	11.34	16.78	17.51	16.53
Sole DH04	15.55	13.41	13.65	15.86	21.49	20.62
Lamu– cowpea	13.28	12.75	12.38	17.46	19.44	18.98
DH04-cowpea	15.55	14.58	14.42	16.41	23.01	21.9
P-value	0.0001	0.0001	0.0001	0.1515	0.0975	0.1199
$LSD_{0.05}$	0.72	0.62	0.53	NS	NS	NS
CV (%)	2.66	2.37	2.08	7.57	11.64	13.57
	60 cm Soil depth			80 cm soil depth		
Sole cowpea	23.55	28.45	25.49	28.6	29.19	25.51
Sole Lamu	19.76	25.52	27.54	25.51	28.61	29.57
Sole DH04	18.48	19.87	23.35	23.38	25.42	24.36
Lamu – cowpea	23.55	28.33	26.64	27.56	29.52	27.59
DH04-cowpea	22.51	24.66	23.49	26.27	27.18	23.64
P-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
$LSD_{0.05}$	0.54	0.5	0.48	0.53	0.49	0.51
CV (%)	1.31	1.04	1.01	1.06	0.92	1.04

calcium ammonium nitrate in two splits: 18 kg N ha^{-1} at first weeding and 12 kg N ha^{-1} at top-dressing during the second weeding according to Saha and Muli (2002).

Data collection

Data collected included: soil moisture content, canopy temperature, weed biomass, chlorophyll content, percent ground cover, leaf number, plant height, grain weight and grain yield for both maize and cowpea. Cowpea root nodule number, numbers of pods per plant, number of grains per pod and grain yield was determined. The methods of data collection for all the aforementioned parameters were as indicated in chapter four. For maize ears per plant and maize stover yield were also determined. To determine the number of nodules per plant, five cowpea plants were dug out with all the roots, dipped in water to remove the soil and root nodules counted. Land equivalent ratios were calculated.

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) test, at p = 0.05.

RESULTS

Effects of cropping system on soil moisture content

The cropping system had significant effect on soil moisture content at 20, 60 and 80 cm soil depths, but not at 40 cm soil depth. At 20 cm, sole cowpea plots had higher moisture content than sole maize crop plots and maize-cowpea intercrop plots at maize booting, silking and maturity. Lamu-cowpea intercrop plots had significantly lower moisture content than DH04-cowpea and sole DH04 plots. Sole crops maize had lower moisture content than maize-cowpea intercrops. Sole Lamu maize variety plots had the lowest moisture content compared to other cropping systems.

In most stages, sole crop of maize had higher moisture content than maize cowpea intercrop. At 60 and 80 cm depths, sole cowpea had similar moisture content as Lamu-cowpea intercrop at most growth stages. Lamu-cowpea intercrop plots and sole Lamu plots had higher moisture content than DH04-cowpea intercrop and sole DHO4 plots respectively. Sole cowpea plots had higher moisture than sole maize and DH04-cowpea plots. (Table 1).

Ground cover, weed biomass and canopy temperature

The cropping system had significant effects on crop ground cover, weed biomass and canopy temperature (Table 2). Sole cowpea had higher percent ground cover

Table 2. Effects of cropping systems on ground cover, canopy temperature and weed biomass at Kilifi and at Mtwapa sites during July – October 2011/2012 season.

Cropping system	Ground cover (%)		Weed biomass (t/ha)		Canopy temp (o C)	
	Kilifi	Mtwapa	Kilifi	Mtwapa	Kilifi	Mtwapa
Sole cowpea	86	61.03	0.05	0.03	29.67	26.27
Maize var. Lamu-cowpea	77.87	32.87	0.06	0.05	26.5	27.82
Maize var. DH04-cowpea	84.93	34.43	0.08	0.04	28.87	26.44
Sole maize var. Lamu	67.07	46.37	0.15	0.07	24.3	24.33
Sole maize var. DH 04	74.43	58.47	0.13	0.07	26.4	24.31
P-value	0.0001	0.0001	0.0001	0.0001	0.002	0.0001
$LSD_{0.05}$	3.27	0.55	0.02	0.009	1.89	0.58
CV (%)	2.22	0.63	10.91	9.41	3.7	1.2

* DH04 = Dryland Hybrid 04; temp = temperature.

Table 3. Effects of cropping systems on cowpea chlorophyll content and leaf number at Kilifi and at Mtwapa sites during July – October 2011/2012 season

Cropping system	Chlorophyll content (Index)		Cowpea leaf number/plant	
	Kilifi	Mtwapa	Kilifi	Mtwapa
Sole cowpea	51.60	45.87	65.70	31.47
Maize var. Lamu-cowpea	46.37	46.60	18.90	26.50
Maize var. DH04-cowpea	50.90	48.60	23.60	22.57
P-value	0.01	0.12	0.0001	0.0002
$LSD_{0.05}$	2.63	2.87	2.83	1.47
CV (%)	2.34	2.69	3.46	2.41

* DH04 = Dryland Hybrid 04

than sole maize crops and Lamu-cowpea intercrop in both sites. In Kilifi, intercrops had higher percent ground cover than sole maize crops while in Mtwapa the converse was the case. Lamu-cowpea intercrop had significantly lower ground cover than DH04-cowpea intercrop in Mtwapa. Ground cover in Kilifi was 40.3% higher than in Mtwapa. Maize–cowpea intercrops and sole cowpea had significantly lower weed biomass than sole maize in both sites. No differences in weed biomass were noted between DHO4-cowpea and Lamu-cowpea intercrops and between DHO4 and Lamu sole crops.

Weed biomass in Kilifi was 50% higher than in Mtwapa. Intercropping systems had significantly higher canopy temperatures than sole maize cropping systems in both sites. Canopy temperature of sole cowpea was not significantly different from canopy temperature of DH04-cowpea intercrop in both sites. In Kilifi, DH04-cowpea intercrop and sole cowpea had higher canopy temperature, than sole maize crops and Lamu–cowpea intercrop. In contrast, Lamu-cowpea intercrop had the highest canopy temperature in Mtwapa. Canopy temperatures in Mtwapa were 4.9% lower than in Kilifi.

Cowpea chlorophyll content and leaf number

Chlorophyll content and leaf number of cowpea were significantly affected by cropping systems (Table 3). Cowpea chlorophyll content in Lamu-cowpea intercrop was significantly lower than for sole cowpea and DH04-cowpea intercrop. Cowpea chlorophyll content in Kilifi was 4.8% higher than in Mtwapa. Intercropped cowpea had significantly lower leaf number per plant than sole cowpea in both sites. In Kilifi, DH04-cowpea intercrop system had a higher cowpea leaf number per plant than Lamu-cowpea intercrop system, while the converse was the case for Mtwapa. Cropping systems in Kilifi had 25.6% higher cowpea leaf numbers than in Mtwapa.

Maize chlorophyll content and leaf number

The cropping system significantly affected maize chlorophyll content (Table 4). In Kilifi, intercropped maize had significantly higher chlorophyll content than sole maize. However, in Mtwapa intercropped Lamu maize was not significantly different from sole maize. DH04-

Table 4. Effect of cropping system on maize chlorophyll content and leaf number at Kilifi and at Mtwapa sites during July – October 2011/2012 season.

Cropping system	Chlorophyll content (Index)		Maize leaf number/plant	
	Kilifi	Mtwapa	Kilifi	Mtwapa
Maize var. Lamu-cowpea	43.50	42.50	12.17	11.73
Maize var. DH04-cowpea	49.30	45.47	11.47	8.63
Sole maize var. Lamu	38.57	43.53	11.07	11.63
Sole maize var. DH 04	42.23	42.03	12.47	8.47
P-value (CPS)	0.0002	0.0721	0.2039	0.0001
$LSD_{0.05}$	2.28	2.66	Ns	0.60
CV (%)	2.63	3.06	6.51	2.95

* DH04 = Dryland Hybrid 04.

Table 5. Effect of cropping system on plant height of cowpea and maize at Kilifi and at Mtwapa sites during July – October 2011/2012 season.

Cropping system	Plant height (cm)		Maize plant height (cm)	
	Kilifi	Mtwapa	Kilifi	Mtwapa
Sole cowpea	40.63	28.60	-	-
Maize var. Lamu-cowpea	24.60	29.93	160.23	157.87
Maize var. DH04-cowpea	29.53	29.43	164.57	107.50
Sole maize var. Lamu	-	-	188.83	199.20
Sole maize var. DH04	-	-	178.77	122.40
P-value	0.0003	0.052	0.001	0.0001
$LSD_{0.05}$	3.05	1.02	9.38	0.85
CV (%)	4.26	1.53	2.71	0.29

* DH04 = Dryland Hybrid 04.

cowpea intercrop system had higher maize chlorophyll than Lamu-cowpea intercrop system in both sites. Mean maize chlorophyll contents in Kilifi and Mtwapa were similar. The cropping systems had no significant effect on the maize leaf number in Kilifi.

In contrast, in Mtwapa sole cropped and intercropped maize variety Lamu had higher maize leaf numbers than sole cropped and intercropped maize variety DH04. Kilifi had 14.2% higher maize leaf numbers than Mtwapa.

Plant height of cowpea and maize

Cropping systems significantly reduced plant height of cowpea and maize (Table 5). In Kilifi, sole cowpea had significantly higher plant height than intercropped cowpea while Lamu-cowpea intercrop system had the least cowpea plant height. In Mtwapa there was no significant difference between plant height of sole crop cowpea and intercropped cowpea in the DH04-cowpea intercrop system. Plant height in Kilifi was 7.2% higher than in Mtwapa. Plant height in sole crops was significantly higher than in intercrops in both sites. Maize plant height in Lamu-cowpea and DH04-cowpea intercrops was not significantly different in Kilifi. However, in Mtwapa maize variety Lamu intercropped with cowpea was 31.9% taller than maize variety DH04 intercropped with cowpea. Maize plant height in Kilifi was 15.2% higher than in Mtwapa.

Cowpea root nodules number, pods per plant and grains per pod

Intercropping significantly increased the number of cowpea root nodules, number of pods per plant and number of grains per pod in both sites (Table 6). Cowpea intercropped with Lamu and DH04 had the highest number of root nodules in Kilifi and Mtwapa respectively. Kilifi had 95% higher number of root nodules than Mtwapa. Cowpea intercropped with DH04 had a higher number of pods per plant than cowpea intercropped with Lamu. The number of pods per plant in Kilifi was 68.9% higher than in Mtwapa. Intercropping significantly increased the number of grains per pod in both sites for Lamu-cowpea but not for DH04-cowpea in Mtwapa

Table 6. Effect of cropping system on number of cowpea root nodules, pods per plant and grains per pod at Kilifi and at Mtwapa sites during July – October 2011/2012 season.

Cropping system	Root nodules (number)		Pods per plant (number		Grains per pod (number)	
	Kilifi	Mtwapa	Kilifi	Mtwapa	Kilifi	Mtwapa
Sole cowpea	7.67	15.33	7.83	2.9	10.7	3.67
Maize var. Lamu-cowpea	12.03	20.33	8.93	3.4	13.73	5.2
Maize var. DH04-cowpea	10.9	24	14.43	3.4	12.27	3.17
P-value	0.0003	0.0002	0.0001	0.009	0.019	0.0004
$LSD_{0.05}$	0.86	1.51	0.41	0.26	1.69	0.42
CV (%)	3.71	3.35	1.76	3.57	6.11	4.63

* DH04 = Dryland Hybrid 04.

Table 7. Effect of cropping system on number of ears per plant and 100-grain weight of maize at Kilifi and at Mtwapa sites during July – October 2011/2012 season

Cropping system	Maize ears per plant (number)		Maize 100-grain wt (g)	
	Kilifi	Mtwapa	Kilifi	Mtwapa
Maize var. Lamu-cowpea	0.56	0.24	36.53	11.63
Maize var. DH04-cowpea	0.47	0.19	31.43	12.35
Sole maize var. Lamu	0.66	0.22	37.60	13.73
Sole maize var. DH 04	0.67	0.22	37.67	12.94
P-value (CPS)	0.008	0.789	0.046	0.002
$LSD_{0.05}$	0.1	Ns	2.81	0.58
CV (%)	8.59	24.03	3.92	2.28

* DH04 = Dryland Hybrid 04

(Table 6). Cowpea intercropped with Lamu had a higher number of grains per pod than sole cowpea in both sites. In Mtwapa, sole cowpea had higher number of grains per pod than cowpea intercropped with DH04. The number of grains per pod in Kilifi was 67.2% higher than in Mtwapa.

Number of ears per plant and 100-grain weight of maize

Numbers of ears per plant and grain weight of maize were significantly affected by cropping system (Table 7). Sole crops had a significantly higher number of maize ears per plant (EPP) than intercrops in Kilifi. Cropping systems had no significant effect on EPP in Mtwapa. The number of EPP in Kilifi was 62.7% higher than in Mtwapa. Maize grain weight was significantly affected by the cropping system (Table 7). Weight of 100-grains of intercropped DH04 maize was lower than for sole DH04 and Lamu crop maize at Kilifi. Maize variety Lamu intercropped with cowpea had the lowest maize 100-grain weight. At Mtwapa, intercropped maize had lower 100-grain weight than sole maize. The weight of maize 100-grains in Kilifi was 64.7% higher than in Mtwapa.

Cowpea 100-grain weight and grain yield

Intercropping significantly reduced cowpea 100-grain weight when cowpea was intercropped with maize variety Lamu (Table 8). There was no significant difference between sole crop cowpea and cowpea intercropped with DH04 in Kilifi. In Mtwapa, cowpea intercropped with DH04 had the highest 100-grain weight. In Kilifi, cowpea grain weight was 63.1% higher than in Mtwapa. Intercropping system significantly reduced cowpea grain yield by 44 – 46% in Kilifi and 50% in Mtwapa (Table 8). Cowpea grain yield for intercrops was not significantly different in both sites. Kilifi had 69% higher cowpea grain yields than in Mtwapa.

Maize stover yield and grain yield

The cropping system significantly reduced maize grain yield and stover yield in both sites (Table 9). Intercropped Lamu maize variety had 24 – 31% lower maize grain yield than when sole cropped in both sites. In Kilifi, grain yields of sole DH04, sole Lamu and intercropped DH04 were not significantly different. In Mtwapa sole maize

Table 8. Effect of cropping system on cowpea 100-grain weight and grain yield at Kilifi and at Mtwapa sites during July – October 2011/2012 season.

Cropping system	Cowpea 100-grain wt (g)		Cowpea grain yield (t/ha)	
	Kilifi	Mtwapa	Kilifi	Mtwapa
Sole cowpea	13.80	5.02	0.41	0.14
Maize var. Lamu-cowpea	12.71	4.64	0.22	0.07
Maize var. DH04-cowpea	13.74	5.20	0.23	0.07
P-value (CPS)	0.012	0.0001	0.002	0.011
$LSD_{0.05}$	0.60	0.08	0.06	0.04
CV (%)	1.97	0.71	9.01	18.68

* DH04 = Dryland Hybrid 04.

Table 9. Effect of cropping system on maize stover yield and grain yield at Kilifi and at Mtwapa sites during July – October 2011/2012 season.

Cropping system	Maize grain yield		Maize stover yield	
	Kilifi	Mtwapa	Kilifi	Mtwapa
	-----------------(t/ha)----------------			
Maize var. Lamu-cowpea	1.68	0.63	4.82	1.77
Maize var. DH04-cowpea	2.24	0.86	2.73	1.35
Sole maize var. Lamu	2.45	0.83	4.39	2.05
Sole maize var. DH 04	2.41	0.89	5.04	2.33
P-value	0.001	0.0001	0.017	0.0001
$LSD_{0.05}$	0.26	0.03	0.82	0.03
CV (%)	5.99	2.00	9.66	0.74

* DH04 = Dryland Hybrid 04.

variety DH04 had the highest maize grain yield of 0.89 t/ha. Maize grain yield in Kilifi was 61.4% higher than in Mtwapa. Maize variety DH04 intercropped with cowpea had the lowest maize stover yield in both sites. In Kilifi, maize variety Lamu intercropped with cowpea, sole cropped Lamu and sole cropped DH04 were not significantly different. Intercropping reduced maize stover by 42 – 46% in DH04 and 14% in Lamu.

In Mtwapa, the cropping system with the highest maize stover yield was sole maize variety DH04 with 2.33 t/ha. Maize stover yield in Kilifi was 59.7% higher than in Mtwapa.

Land equivalent ratio

Land equivalent ratio was not significantly affected by cropping systems at both sites. Land equivalent ratios for Lamu-cowpea intercrop ranged from 1.23 (Mtwapa) to 1.24 (Kilifi) while that for DHO4-cowpea intecrop ranged from 1.47 (Mtwapa) to 1.33 (Kilifi) (Table 10).

DISCUSSION

Effect of intercropping on soil moisture content

The study has shown that at 20 cm depth, sole cowpea plots had higher moisture content than sole maize crop plots and maize-cowpea intercrop plots at maize booting, silking and maturity stages. Maize-cowpea intercrop plots had higher soil moisture content than sole maize crop plots. Ghanbari *et al.,* (2010) reported higher soil moisture content in sole cowpea and maize-cowpea intercrop plots than in sole maize plots. This was attributed to the fact that sole cowpea and maize-cowpea intercrops, which had higher groundcover and shading effect than sole maize, reduced water evaporation thereby enhancing moisture conservation. The current results could also be attributed to the fact that maize has higher water requirements than cowpea which is adapted to drought stress (Filho, 2000). A study by Gao *et al*., (2010) indicated that lateral growth of maize and legume

Table 10. Land equivalent ratios of cropping systems in Kilifi and Mtwapa at Kilifi and at Mtwapa sites during July – October 2011/2012 season.

Cropping system	Kilifi	Mtwapa
	LER	LER
Lamu - cowpea	1.24	1.23
DH04 - cowpea	1.33	1.47
P-value	0.628	0.198
$LSD_{0.05}$	Ns	Ns
CV (%)	15.18	11.79

LER = Land equivalent ratio.

roots in the intercropped plots occurred mainly in the top 16–22 cm layer, or just above the plough pan. The soil moisture content below the root levels was not perhaps being transpired hence the increase in soil moisture with increase in soil depth. Lamu-cowpea intercrop and sole Lamu maize plots had lower moisture content than DH04-cowpea intercrop and sole DH04 maize variety plots at 20 cm depth; suggesting that Lamu variety exploited moisture in the top 20 cm better than DHO4 variety. At lower depths (60 and 80 cm), sole DHO4 and DH04-cowpea intercrop crops depleted moisture more than sole cowpea, lamu-cowpea intercrop and sole Lamu crops. This suggests that DH04 maize variety roots exploited moisture in the lower layers of the soil more than Lamu maize variety roots. Rooting depth is positively related to soil exploration and greater acquisition of water from deep strata (Lynch and Wojciechowsk, (2015). Genotypes with greater rooting depth are better able to exploit moisture stored from previous season (Wasson *et al*., 2012). In most case, sole maize crop plots had lower moisture content than maize-cowpea intercops. This could be attributed to the higher ground cover observed under the maize-cowpea intercrop system than in the maize monocrop system. High ground cover reduces water evaporation thereby improving soil moisture retention Ghanbari *et al.,* (2010).

Canopy temperatures

The study demonstrated that maize-cowpea intercrop and sole cowpea canopies had raised temperatures relative to maize sole crop canopies. Choudhary *et al.,* (2012) reported higher canopy temperatures in intercrops and sole cowpea than in sole maize. In this study sole cowpea and intercrops had higher canopy temperatures and also higher soil moisture content. The higher canopy temperature in sole cowpea than sole maize could be attributed to the fact that maize transpires much more than cowpea hence maize canopies become cooler than cowpea-maize canopies (Belel *et al.,* 2014).

Chlorophyll contents of cowpea and maize

Intercropping significantly reduced cowpea chlorophyll contents in both sites. The findings of this study agreed with the report by Prasanthi and Venkateswaralu (2014) which indicated that sole cropped legumes recorded higher total chlorophyll than intercropped legumes. Under intercropped situation, maize by virtue of its faster and vigorous growth might have dominated and utilized soil resources more efficiently, thereby suppressing cowpea plants. This could be the reason why cowpea chlorophyll content reduced under intercropping. In this study intercropping increased maize chlorophyll content. The finding is in agreement with the studies by Amini *et al*., (2013) and Prasanthi and Venkateswaralu (2014) who reported that intercropped maize had higher maize chlorophyll content than pure stands. Similarly a report by Dahmardeh *et al.,* (2010) indicated that maize intercropped with cowpea showed increases in the amount of nitrogen, phosphorus and potassium content as compared to sole maize. Increases in N could be attributed to biological nitrogen fixation by the cowpea and potential transfer of nitrogen to the associated maize intercrop (Matusso *et al.,* 2014). In this study, there was an increase in nodulation due to intercropping suggesting increased N-fixation and available N for intercropped maize (Chemining'wa and Nyabundi, 1994).

Ground cover and growth parameters of cowpea and maize

Intercropping maize with cowpea significantly increased percent ground cover relative to sole cropping. Previous studies showed that maize intercropped with cowpea had higher ground cover than sole maize crops (Kariaga, 2004). Intercropping significantly reduced cowpea leaf number and plant height. The reduction in growth parameters is in agreement with the study by Lemlem (2013) who reported that intercropping legumes with maize significantly reduced cowpea growth. This could be attributed to shading of cowpea by the taller maize crop (Iderawumi, 2014). Cowpea was introduced 28 days after planting maize hence it could have faced shading and increased competition from already established maize (Iderawumi, 2014). The study has shown intercropping reduced maize leaf number, plant height and stover yield. Undie *et al.,* (2012) reported that intercropping maize with soybean reduced maize plant height, number of leaves per plant and stover yield were below their sole crop values. This was attributed to competition for resources by component crops. The intercrops had higher percent ground cover at Kilifi than at Mtwapa possibly because there was less competition for moisture (Lemlem, 2013) in Kilifi than in Mtwapa since the former received higher amounts of rainfall than the latter (Appendix 1).

Weed biomass

The study indicates that intercropping resulted in significant percent reduction in weed biomass compared to sole maize crop system in both sites. Eskandari and Kazemi (2011) reported that intercrops were more effective in weed control than sole crops. This could be attributed to weed suppression in intercropping systems through more efficient use of environmental resources by component crops (Poggio, 2005). Under intercropping system light interception and shading due to increased ground cover could be the main reason for reduction of weed biomass (Ghanbari-Bonjar, 2000). The finding that intercropping suppressed weed biomass in this study underscores the importance of intercropping maize and cowpea as one of the weed management strategies in the coastal lowland Kenya. Katsaraware and Manyanhaire (2009) reported reduction in weed biomass under maize-cowpea intercropping system in Zimbabwe. In this study the increase in ground cover could have resulted in weed suppression.

Cowpea root nodule number

The study has shown that intercrops had higher number of root nodules than sole crops in both sites. This finding is in agreement with the findings of Cardoso *et al.,* (2007) and Lemlem (2013) who reported increases in the number of root nodules and nodule weight of legumes under intercrops compared to sole crops. This may be associated with depletion of nitrogen by the more competitive maize since nodulation and nitrogen fixation are enhanced under low N conditions (Chemining'wa and Nyabundi, 1994). Root nodules in Mtwapa were higher than in Kilifi. This could be because Kilifi received a higher amount of rainfall than Mtwapa (Appendix 1) which may have enhanced maize growth causing increased shading of cowpea (Kombiok *et al.,* 2005). Lamu maize variety was taller than DH04 maize variety. This could explain why DH04 -cowpea intercrop had higher number of root nodules than Lamu-cowpea intercrop in Mtwapa. Shading has been known to reduce nodule number (Egbe *et al.,* 2013).

Grain yield and yield components of cowpea and maize

Intercropping significantly reduced cowpea and maize grain yield and yield components. The findings of this study are in agreement with the studies by Takim (2012) and Lemlem (2013) who reported that intercropping legumes with maize significantly reduced cowpea and maize grain yield and yield components. The reduction in cowpea grain weight and grain yield in this study could be attributed to the reduction in cowpea leaf number and plant height under intercropping system. Maize grain yield was higher when DH04 maize variety was intercropped with cowpea than when Lamu maize variety was intercropped with cowpea. This could be attributed to the fact that DH04 maize variety was an improved maize variety, hence may be more efficient in utilization of soil resources. In the current study, DH04 maize appeared to exploit water at lower soil depths better than Lamu maize variety.

Land equivalent rations (LER) for Lamu-cowpea and DH04-cowpea intercrops were 1.24 and 1.33, respectively, in Kilifi and 1.23 and 1.47, respectively, in Mtwapa. This suggests that intercropping maize and cowpea is more efficient and productive in the use of environmental resources for plant growth than growing sole crops of maize and cowpea (Ghanbari *et al.,* 2010; Mead and Willey, 1980). Therefore the two maize-cowpea intercrops are both beneficial and could be used to enhance land productivity in the region. However, DHO4-cowpea intercrop appears more productive than Lamu-cowpea intercrop.

CONCLUSION

Intecropping increased soil moisture content at all growth stages in 20, 60 and 80 cm soil depths. Although intercropping significantly reduced yield and yield components of cowpea and maize, intercropped maize-cowpea had higher land productivity than monocropped cowpea and maize respectively. Land productivity of DH04-cowpea intercrop was higher than for Lamu-cowpea intercrop in both sites.

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