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Yield and yield components of local cowpea (Vigna unguiculata L.) landraces grown in mixed culture with maize (Zea mays L.) in vertic cambisols in the Northern part of Tanzania

Abstract

Smallholder farmers in the North eastern Tanzania practice cereal-legume mixed culture to manage risks of crop failure in sole crops. The production and productivity of cereal-legume intercrops may be influenced by the practice of cultivating two or more crops in the same space and time and the status of land races/cultivars involved as intercrops. Data on the effect of intercropping system on cowpea landraces with maize grown on Vertic Cambisols on yield and yield components are inadequate in the North eastern Tanzania although considerable knowledge has been accumulated on mixed culture system. A field experiment involving two cropping systems (sole crop and intercropping) was therefore conducted for two years (2017 and 2018) at Shirimatunda village, Kilimanjaro Region, North East Tanzania, to evaluate three local cowpea (*Vigna unguiculata L.*) landraces (i.e. landrace 1 (L1), landrace 2 (L2) and landrace 3 (L3)) grown in association with maize (*Zea mays L*). Intercropping significantly ($P \leq .05$) decreased cowpea and maize yields. Performance of local cowpea landraces, however, did not show ($P \leq .05$) any variation except for 100–seed weight where cowpea landrace 2 (L2) showed superiority compared with the other cowpea landraces. Although there was no significant variation in maize yield when intercropped with cowpea landraces, maize intercropped with cowpea landrace 1 gave numerically the highest grain yield. Regardless of cropping system and cowpea landraces, combined productivity of cowpea and maize increased in the intercropped plots as indicated by higher total land equivalent ratios (1.64 to 1.94). Highest LER_T value was observed in the 'Cowpea landrace 1'+Maize mixed culture. The observed total Land equivalent ratio (LER) values correspond to 48.25, 38.54 and 43.66 % of lands saved which could be used for other agricultural purposes. In these cropping systems, both cowpea landrace 1 & 3 and maize crop components were significantly complementary and most suitable in mixed culture as shown by competitive ratio (CR) values of 1.85 and 1.45 respectively.

Keywords: mixed culture, Shirimatunda, landrace, cowpea, genotype, yield components

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Abbreviations: LER, land equivalent ratio; DAE, days after emergence; YICc, mass yields per unit area of cowpea; YICm, maize in mixed culture respectively; LERT, total land equivalent ratio; CR, Competitive ratio; LERm, partial ler for maize; LERc partial LER for cowpea; LS, percentage land saved

Introduction

Intercropping, one of the cropping systems in developing countries,[1,2] is a practice by smallholder farmers of cultivating two or more crops in the same space and time,[3] with a view to minimize risks of crop failure due to weather variability. With this type of cropping system all the environmental resources are utilized for the maximization of crop production and productivity.[2,4–10] In Tanzania and elsewhere in the tropics, intercropping is mostly practiced by small scale farmers characterized by subsistence agriculture, low agricultural mechanization, high labour and low - yield farming on small parcels of land.[11] Since intercropping has been reported to increase both the amount of biomass, crop yield per unit area of land harvested and crop failure mitigation,[12,13] farmers in the area practices mixed culture systems with a view that if one crop fails during the cropping season due to unequal distribution of rainfall and variability the other intercrop will be available for the household. According to Rusinamhodzi et al.[14] intercropping can support increased aggregate yields per unit input, and thus ensure improved soil quality, food security and poverty alleviation through increased income. Several other benefits with regards to intercropping has been highlighted as increased land use efficiency; light capture and its use,[15] soil moisture and nutrients; controlling weeds, insects, and diseases,[16] increase in the length of production cycles; improved seed quality and better control of water quality through minimizing the use of inorganic N fertilizers, replacing them by the use of legumes.[17] Typically this cropping system include maize (*Zea mays* L), millet (*Pennisetum glaucum* L) and sorghum (*Sorghum bicolor* L) as cereal crops components and beans (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata* L), groundnut (*Arachis hypogaea*), pigeonpea (*Cajanus cajan*) and soybean (*Glycine max*) as legume crops components. However, in this study maize was intercropped with different types of cowpea local variety as used by local farmers. It has been shown that leguminous plants can benefit the intercrop cereals during the same season through N excretion and nodule decomposition,[18] although according to Senaratne et al.[19] each legume specie has different ability to supply N to its corresponding associated cereal neighbor. It is similarly assumed that intercropping cereals with legume crops, is that the legume, when associated with the specific Rhizobium, may satisfy most of its N requirement derived through N2 - fixation of atmospheric N, leaving the soil available N for the companion cereal. Legumes are therefore the major crop companion in many intercropping systems placed within the top ten (10) most frequently used intercrop species.[20] Therefore; the main target of this research was to study the yield and yield components of cowpea local varieties when intercropped with maize.

Maize (*Zea mays* L.) in Tanzania is a primary staple crop and it's grown in nearly all agro-ecological zones.[21] Maize production is characterized by smallholders farms with less than 10 hectares (i.e. an average of 2-3 ha each) and contributes about 85 % of total production. However, although around 45 % or over 4.9 million hectares are used for maize production,[22] the national yield is pegged between 1.0 and 1.5 t ha-1, compared with the estimated potential yields of 4 - 5 t ha-1.[23,24] The main constraints of low yield and sporadic production are drought stress (shortage of rainfall), infestation by insects, molds, and other pests. Other factors include weeds and diseases, low agricultural inputs such as fertilizer and crop protection chemicals, low levels of technology and poor infrastructure and storage facilities.[25,26] Tanzania like other developing countries, maize is mainly used for human consumption. It's a single most important staple food both in rural and urban areas.[27] Maize accounts for 31 % of the total food production and constitutes more than 75% of the cereal consumption in the country. It is estimated that the annual per capita consumption of maize is around 128 kg. According to Nyoro et al,[28] and Peter et al.[29] nearly 400 grams of maize are consumed per day per person in Tanzania; average national consumption is estimated to be over three (3) million metric tons per year.[30] Similarly, maize contributes about 34-36 % of the average daily calorie intake,[31–33] about 67 % starch, 10 % protein, 4.8% oil, 8.5% fiber, 3% sugar and 7% ash,[34] to both human (in the developing countries),[35] and it is recently used in production of biofuel. It is equally well accepted for animal feed ingredient with high feeding value and can contribute up to 30 % protein, 60 % energy, and 90 % starch in animal diet.[36]

Cowpea *(Vigna unguiculata* L. Walp.) is a valuable crop in semiarid regions used by the resource poor farmers,[37–40] and is consumed as a source of high - quality plant protein in many parts of the world. Recently, cowpea has gained more attention from different stakeholders worldwide because of its exerted health beneficial properties, including anti-diabetic, anti - cancer, anti - hyperlipidemic, anti - inflammatory and anti - hypertensive properties. Its tolerance to moisture stress,[41] along with numerous other advantages ranging from nutritional, soil fertility improvement, and weed control,[42] make it a useful component of the cropping systems involving cereals.[43] Similarly, high protein and carbohydrate contents with a relatively low fat content and a complementary amino acid pattern to that of cereal grains make cowpea an important nutritional food in the human diet. Although considerable knowledge has been accumulated on intercropping system,[44] data on the effect of intercropping system of cowpea landraces with maize grown on Vertic Cambisols on yield components are inadequate. This study aim to assess the effect of cropping system on yield and yield components of three cowpea landraces grown in mixture with maize on Vertic Cambisols.

Materials and methods

The study was conducted at the backyard garden in Osterbay Shirimatunda in the Northern Tanzania (3º22'S, 37º19E, and altitude 853.7m.a.m.s.l.) during the Masika rains growing seasons of 2017 and 2018. The study area receives mean annual rainfall of about 946mm (Table 1). The average mean annual low temperature is 15.5°C and maximum annual high temperature is about 33.3°C with possibility of rising to 40°C during the dry season. The mean annual potential evapotranspiration (ETo) as measured by Penman Monteith (Monteith, 1965) was 1.390 mm (Table 1). The soil is clay classified as Vertic Cambisol in the FAO soil classification system. Prior to planting each year, soil samples (0 to 20 cm soil depth) were collected from the experimental plots, pooled, and sub - samples taken for chemical analysis. The soil physico-chemical properties are shown in (Table 2).

The experimental variables included three local cowpea landraces ('mixed colour'; 'black'; and 'light brown colour, Figure 1), and two cropping systems (sole cowpea/maize and cowpea+maize intercropping). A two factor completely randomized block design was used with three replicates. Plot size of 3mx2.6m (7.8m^2) was used for maize and cowpea. Maize was sourced from Kibo Seed Company and was grown at a spacing of 75x60cm to maintain a uniform density of 22.222 plants•ha^{-1}. Cowpea seeds were obtained from Moshi Municipality local markets, and were grown at a spacing of 20 x 40cm with a population of 125,000 plants ha^{-1}. All seedlings were later thinned to two per hole. Weeding was done manually to all crops with a hoe four times until harvesting. Fertilizer was applied for both sole and intercropped maize using the recommended rate. DAP was applied at the rate of 100kg ha^{-1} at planting. Urea at the rate of 100kg ha^{-1} was applied as top dressing in two splits one - third at 20 days after emergence (DAE), and two third at 40 DAE. The benefit of intercropping was quantified by LER which is defined as the relative land area in pure stands that is required under monoculture to produce the yields of all products from the mixture.[45–47]

Table 1 Climate data representative of the study area (Moshi Airport, Lat. -3.35, Long. 37.35, Alt. 831 mamsl)

Climate variable	J	F	M	A	M	J	J	A	S	O	N	D	Mean annual
Max (°C)	33.0	33.3	32.3	29.6	26.8	26.0	25.6	26.6	28.7	30.8	31.9	32.0	29.7
Min (°C)	17.6	17.8	18.6	19.1	18.4	16.7	15.7	15.5	15.7	16.8	17.6	17.6	17.3
Mean (°C)	25.3	25.6	25.5	24.4	22.6	21.4	20.7	21.1	22.2	23.8	24.8	24.8	23.5
RH (%)	68.4	64.5	51.6	81.2	85.5	81.6	75.2	71.4	65.6	61.1	61.7	68.7	69.7
WS (km.d^{-1})	198.7	198.7	178	156.5	110.6	110.6	133.1	155.5	199.6	244.5	288.6	222.1	183.0
WS (m.s^{-1})	2.3	2.3	2.1	1.8	1.3	1.3	1.5	1.8	2.3	2.8	3.3	2.6	2.1
SH (hrs.d^{-1})	5.3	6.0	5.0	4.8	3.6	4.3	3.8	4.7	5.2	5.8	5.1	4.4	4.8
SR (MJ.m^{-2})	17.5	19.0	17.4	16.3	13.5	13.9	13.4	15.6	17.2	18.5	17.2	16	16.3
ETo (mm.d^{-1})	4.3	4.7	4.8	3.5	2.7	2.7	2.8	3.3	4.0	4.7	4.8	4.1	3.9
ETo (mm.m^{-1})	128.1	140.1	144.6	104.4	81.9	81.3	83.7	98.4	118.8	141.0	145.2	122.4	1389.9
Rainfall (mm.m^{-1})	42	46	113	318	141	29	22	14	15	37	81	88	946.0

Table 2 Soil physical chemical properties of the study area

BD	Texture (%)	pH 1:2.5 (H_2O)	Ca	Mg	K	Na	C	N	Av P	CEC	BS	ESP	C/N
			cmol (+) kg^{-1}				g kg^{-1}		mg kg^{-1}	cmol (+) kg^{-1}	%		
1.5	SCL	7.0	16.6	0.2	85.0	0.6	21.0	1.0	85.0	12.0	149	5.0	29.8

BD, bulk density; pH, soil reaction; Ca, Calcium; Mg, magnesium; K, potassium; Na, sodium; C, carbon; N, nitrogen; P, phosphorus; CEC, cation exchange capacity; BS, base saturation; ESP, exchangeable sodium percentage; C/N, carbon nitrogen Ratio

Figure 1 Traditional landraces used in the experiment (C-TRAD1=Landrace 1, C-TRAD2= andrace 2, C-TRAD3=Landrace 3).

Intercropping efficiency

Intercropping efficiency was evaluated by using land equivalent ratio,[46] as given below:

$$LER_C = \frac{YIC_C}{YMC_C};\ LER_M = \frac{YIC_M}{YMC_M};\ LER_T = LER_C + LER_M$$

Where LERc and LERm=Partial land equivalent ratio for cowpea and maize respectively; YICc and YICm=Mass yields per unit area of cowpea and maize in mixed culture respectively; YMCc and YMCm=Mass yields per unit area of cowpea and maize in monoculture respectively; LER_T=Total Land Equivalent Ratio. If LER_T is greater than one (LER_T>1), intercropping has a yield advantage while there is a yield disadvantage from intercropping if LER_T is less than one (LER_T<1).[48,49]

Competition ratio and percentage land saved

Percentage (%) land saved was calculated as described in Ijoyah et al.[50] and Workayehu,[51] and competitive ratio was calculated as described in Willey and Rao,[52] as:

$$CR = \frac{LER_m}{LER_c} \times 100$$

Where: CR = Competitive ratio, LERm: Partial LER for maize; LERc: Partial LER for cowpea, and

$$LS\ (\%) = 100 - \left(\frac{1}{LER_T} \times 100 \right)$$

Where: LS=Percentage land saved, LER_T=Total Land Equivalent ratio

At physiological maturity, the plants were counted and harvested. Yield assessment was carried from the middle rows of each plot excluding the border rows. Sixteen (16) plants of cowpea were sampled from each plot to determine the numbers of pods plant–1 and seeds pod–1. From the maize plots, eight plants were sampled for determination of the weights of head plant–1 and seed plant–1. Both cowpea pods and maize heads were manually threshed and allowed to air dry (~ 13 % moisture content). Grain yields of cowpea and maize were determined from each plot and 100 - seed weight and shelling percentage recorded. Mean values of yield components were analyzed statistically using a factorial analysis of variance (ANOVA) using the software, STATISTICA 2007 (StatSoft Inc., Tulsa, OK, USA). Fisher's least significant difference was used to compare treatment means at P<.05.[53]

Results and discussion

Intercropping cowpea (*Vigna unguiculata* L) with maize (*Zea mays* L) decreased (P≤.05) the weight of seeds plus pods plot-1, weight of seeds plot-1, weight of 100–seeds, grain yield and shelling per cent (Table 3). The decreased attributes as a result of mixed culture system is ascribed to the inter - and intra - specific competition for site resources typical of intercropping system treatments.[54] The observed cowpea seed yield was on the average of 2.7 t ha^{-1} in the monoculture and 1.9 t ha^{-1} in the mixed culture plots (Table 3). Previous studies by Alom et al.[55] showed that cowpea grain yield was (P≤.05) minimum when grown in mixed culture with maize compared with other treatment combinations. Intercropping cowpea with maize is characterized by a very low cowpea grain yields.[56–58] Studies have also indicated that intercropping cowpea with maize (P≤.05) reduced cowpea yield by 43 %.[54,59,60] The low productivity of cowpea in intercropping systems is due to among other reasons, to shading by cereals. Other studies by Nambiar et al.[61] also reported similar negative effects for cowpea when intercropped with sorghum (*Sorghum bicolor* L).

Grain weight ear-1, number of grains•row-1 and 100-seed weight of maize were significantly (P≤.05) lower at intercropping compared with monocropping (Table 4). Likewise, intercropping maize with cowpea landraces reduced (P≤.05) the ear length, grains row-1, ear diameter, total ear weight and shelling per cent of maize similar to results observed in Egbe et al.[62] Maize seed yield was on the average of 3.5±0.2 t ha-1 in the sole crop and 3.1±0.1 t ha^{-1} in the intercropped plots. These results are similar to those reported by Randhawa et al,[63] and Alom et al.[55] that sole maize was significantly superior to maize + cowpea intercropping treatments. Likewise, according to Yilmaz et al.[64] the highest yield was achieved from sole maize compared with its combination with groundnut and soybean. Crop competition for site resources has been cited as probably the main reason for reduction in yields typical of mixed culture treatments.[54]

Performance of cowpea landraces when intercropped with maize showed significant (P≤.05) difference between them only on the weight of 100 - seeds parameter (Table 3). The data showed that Landrace 2 (Black colour, Figure 1) was superior (P≤.05) compared with the other landraces. In maize however, with the exception of grain weight ear-1 and grain yield ha-1 which were not significantly (P≤.05) different, the other attributes of maize showed significant (P≤.05) differences when intercropped with cowpea landraces compared with sole maize (Table 4). The observed differences among maize grown in mixed culture with cowpea landraces is ascribed to crop competition and intrinsic differences in the ability of different cultivars to access growth resources and compete with associated crops. Similar cowpea landrace differences in yield have previously been reported in Krasilnikoff et al.[65] in cowpea – maize mixed cultures, and crop competition was reported as possibly the main reason for reduction in crop yields. In line with this finding, Kheroar and Patra,[66] reported that yield of cowpea during intercropping with maize was reduced due to lower amount of solar radiation received. This is because crops with C4 photosynthetic pathways such as maize have been known to be dominant when intercropped with C3 crops like cowpea. The reduction in seed yield by intercropping could be due to interspecific competition and depressive effect of maize, as C4 species on cowpea as C3 crop.

The results showed that there was significant (P≤.05) difference in the effect of intercropping system on land productivity potential or land equivalent ratio (LER) as indicated in Table 5. On the one hand, partial land equivalent ratio (LER_M) of maize ranged from 0.87 in maize grown in mixture with cowpea landrace 2 (L2) to 1.25 in maize grown with cowpea landrace 1 (L1). Maize LER_M was greater than cowpea LER_C, indicating that maize is the dominant species. This result is in line with most other field studies reported in Mukhala,[67]; Tsubo,[68] and Ogindo.[69] On the other hand, partial land equivalent ratio (LER_C) of cowpea ranged from 0.69 in L1 to 0.77 in L2. Additionally, total land equivalent ratio (LER_T) ranged from 1.64 in L2 to 1.94 in L1. These findings are similar to those of Ijoyah et al,[50] and Workayehu.[51] Regardless of cowpea landraces, LER_T values were all greater than 1 (i.e. 1.64 to 1.94), implying a significant yield advantage for the intercropping system. In other words, 64 to 94 % more land would have been required if the component crops were planted as sole crops to obtain the same yield as obtained in the intercropped plots. This corresponds to 48.3 as percent land saved with 1.85 competitive ratio. In this study, LER_T>1, an indication that intercropping is advantageous in terms of the improved use of available resources for plant growth and development.[70–74]

Table 3 Effect of cropping systems and cowpea landraces on yield and yield components of cowpea (*Vigna unguiculata L.*) landraces in Shirimatunda, Northern Tanzania

	Wt. of Seeds	Wt. of 100 seeds	Yield		Shelling
Cropping systems	**(g)**		**(g.plant^{-1})**	**(t.ha^{-1})**	**(%)**
Sole Crop	250.4a	10.9a	13.5a	2.7a	77.7a
Intercropping	180.9b	8.0b	9.5b	1.9b	64.4b
Landraces					
L1 (Grey)	213.0a	9.9b	11.1a	2.2a	68.5a
L2 (Black)	228.4a	10.3a	11.2a	2.2a	68.1a
L3 (Light yellowish brown)	205.6a	8.2c	12.2a	2.4a	76.6a
2 - Way ANOVA F - Statistics					
Cropping System	15.8**	23.5***	21.8***	21.8***	11.9**
Landraces	0.6ns	4.8*	0.7 ns	0.7 ns	2.1 ns
CV (%)	17.2	13.3	15.8	15.8	11.5

Values (Mean±SE, n=3) followed by dissimilar letters in a column, are significantly different. Data for 2017 and 2018 have been pooled together since they were similar

Table 4 Effect of cropping systems and cowpea landraces on yield and yield components of Maize (*Zea mays* L.) in Shirimatunda, Northern Tanzania

	Ear length (cm)	Rows ear^{-1}	Grains row^{-1}	Ear diameter (cm)	Total ear weight (g)	Grain weight Ear^{-1} (g)	Shelling (%)	100 seed weight (g)	Yield (t ha^{-1})
Cropping Systems									
Sole Crop	16.9±0.4a	12.1±0.3a	33.2±1.0a	14.5±0.4a	194.4±7.1a	158.0±7.3a	78.9±2.4a	42.5±1.3a	3.5±0.2a
Intercropping	14.9±0.4b	10.7±0.4b	29.3±0.9b	12.8±0.4b	170.9±4.5b	138.8±5.4b	69.9±2.4b	37.5±1.1b	3.1±0.1b
Landraces (L)									
Sole Maize	17.7±0.5a	12.7±0.5a	34.8±1.3a	15.2±0.5a	203.7±9.7a	165.8±11.0a	82.9±3.7a	44.6±1.8a	3.7±0.2a
Maize+L1	16.5±0.4b	11.8±0.4ab	32.4±1.1ab	14.1±0.5ab	189.4±7.7ab	154.0±9.2a	77.2±3.3ab	41.5±1.4ab	3.4±0.2a

Table Continues...

	Ear length (cm)	Rows ear^{-1}	Grains row^{-1}	Ear diameter (cm)	Total ear weight (g)	Grain weight Ear^{-1} (g)	Shelling (%)	100 seed weight (g)	Yield (t ha^{-1})
Maize+L2	15.3±0.4c	10.9±0.5bc	30.0±1.0bc	13.1±0.5bc	175.1±5.9bc	142.2±7.6a	71.5±3.0bc	38.4±1.1bc	3.2±0.2a
Maize+L3	14.2±0.6d	10.2±0.6c	27.9±1.4c	12.2±0.6c	162.4±7.8c	131.5±7.2a	66.0±2.5c	35.6±1.6c	2.9±0.2a
2-Way ANOVA F-Statistics									
Cropping System	35.7***	9.3**	13.7**	12.6**	11.2**	4.9*	10.1**	15.7***	4.9*
Landraces	21.6***	5.8**	8.3***	7.8***	6.5**	2.9ns	6.5**	9.5***	2.9ns

Values (Mean±SE, *n*=3) followed by dissimilar letters in a column, are significantly different. Data for 2017 and 2018 have been pooled together since they were similar. CS, cropping system; L, landrace/Variety; ns, not significant; L1, cowpea landrace 1; L2, cowpea landrace 2; L3, cowpea landrace 3

Table 5 Effect of cropping systems and cowpea landraces on the total land equivalent ratio (LER_T) in Shirimatunda, Northern Tanzania

	LER_C	LER_M	LER_T (Cowpea+Maize)	%LS	CR
L1	0.69a	1.25a	1.94a	48.25a	1.85a
L2	0.77a	0.87c	1.64a	38.54a	1.15b
L3	0.73a	1.05b	1.78a	43.66a	1.45ab
One - Way ANOVA F-Statistics					
F-Value	0.4 ns	38.0***	3.6 ns	3.1 ns	7.4*
CV (%)	13.2	5.2	10.3	72.3	18.3

LS (%, 100−(1/LER_T×100); where LS, percentage land saved; LER_T, total land equivalent ratio; Competitive ratio as described by Willey and Rao,[52] as LER_M/LER_C, where: CR, competitive ratio; LER_M, partial LER for maize; LER_C, partial LER for cowpea; CV, coefficient of variation; L1, cowpea landrace 1; L2, cowpea landrace 2; L3, cowpea landrace 3. Values (Mean±SE, n=3) followed by dissimilar letters in a column, are significantly different. Data for 2005 and 2006 have been pooled together since they were similar

Conclusion

In conclusion, intercropping system in the study area improved the overall profitability compared with monocropping even though the yield of the component crops was reduced when considered separately. Generally, although yields of the component crops were lower than yield from monocropping, the crop components taken together were more productive as shown by the total land equivalent ratio (LER_T), percentage land saved (% LS) and the competitive ratio (CR). It was also evident that although there was no significant difference between the cowpea landraces, yield of maize grown in mixed culture with cowpea landrace 1 was higher compared with maize grown with other cowpea landraces.

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Conflicts of interest

Author declares that there is no conflict of interest.

References

1. Hirpa T. Response of maize crop to spatial arrangement and staggered inter-seeding of haricot bean. *Journal of Agricultural and Crop Research*. 2014;2(7):143−151.
2. Brooker RW, Bennett AE, Cong WF, et al. Improving intercropping: a synthesis of research in agronomy, plant physiology and ecology. *New Phyt.* 2015;206:107–117.
3. Ijoyah MO, Jimba J. Evaluation of yield and yield components of maize (*Zea mays* L.) and okra (*Abelmoschus esculentus* L. Moench) intercropping System. *J Biodiver Environ Sci.* 2012;2(2):38−44.
4. Muoneke CO, Asiegbu JE. Effect of okra planting density and spatial arrangement in intercrop with maize on the growth and yield of the component species. *J Agron Crop Sci.* 1997;179:201−207.
5. Okpara DA, Awurum AN, Okeke AI. Effect of planting schedule and density on cowpea/maize intercropping in south eastern Nigeria. *J Tropical Agric Res.* 2004;11:59−67.
6. Akande MO, Oluwatoyinbo FI, Kayode CO, et al. Response of maize (*Zea mays*) and okra (*Abelmoschus esculentus*) intercrop relayed with cowpea (*Vigna unguiculata*) to different levels of cow dung amended phosphate rock. *World J Agric Sci*. 2006;2(1):119−122.
7. Sanginga N, Woomer PL. Integrated soil fertility management in Africa: Principles, Practices and Development Process. *Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture*. Nairobi; 2009. 263. p.
8. Addo-Quaye AA, Darkwa AA, Ocloo GK. Yield and productivity of component crops in a maize-soybean intercropping system as affected by time of planting and spatial arrangement. *J Agric Biol Sci.* 2011;6(9):50−57.
9. Bhatti IH, Ahmad R, Jabbar A, et al. Agronomic performance of mash bean as an intercrop in sesame under different planting patterns. *Emirates J Food Agric.* 2013;25(1):52−57.
10. Bedoussac L, Journet EP, Hauggaard-Nielsen H, et al. Ecological principles underlying the increase of productivity achieved by cereal-grain legume intercrops in organic farming. *Rev Agron Sust Dev.* 2015;35:911–935.
11. Ngwira AR, Aune JB, Mkwinda S. On-farm evaluation of yield and economic benefit of short term maize legume intercropping systems under conservation agriculture in Malawi. *Field Crops Res.* 2012;132:149–157.
12. Willey RW. Intercropping: its importance and research needs. Part II. Agronomy and research approaches. *Field Crops Res*. 1979;32:1–10.
13. Lithourgidis AS, Dordas CA, Damalas CA, et al. Annual intercrops: an alternative pathway for sustainable agriculture. *Australian J Crop Sci.* 2011;5(4):396−410.
14. Rusinamhodzi L, Corbeels M, Nyamangara J, et al. Maize–grain legume intercropping is an attractive option for ecological intensification that

reduces climatic risk for smallholder farmers in central Mozambique. *Field Crops Res.* 2012;136(20):12–22.

15. Hinsinger P, Betencourt E, Bernard L, et al. P for two, sharing a Scarce Resource: Soil Phosphorus Acquisition in the Rhizosphere of Intercropped Species. *Plant Physiol.* 2011;156:1078–1086.

16. Zhu J, Zhang C, Lynch JP. The utility of phenotypic plasticity for root hair length for phosphorus acquisition. *Functional Plant Biol*. 2010; 37(4):313–322.

17. Dhimaa KV, LithourgidisbI AS, Vasilakoglouc B, et al. Competition indices of common vetch and cereal intercrops in two seeding ratio. *Field Crop Res.* 2007;100(2–3):249−256.

18. Eaglesham ARJ, Ayanaba A, Rao VR, et al. Improving the nitrogen nutrition of maize by intercropping with cowpea. *Soil Biol Biochem Oxford.* 1981;13(2):169−171.

19. Senaratne R, Liyanage NDL, Soper RJ. Nitrogen fixation and N transfer from cowpea, mungbean and groundnut when intercropped with maize. *Fertilizer Res.* 1995;40:41-48.

20. Hauggaard-Nieson H, Ambus P, Jensen ES. Temporal and spatial distribution of roots and competition for nitrogen in pea-barley intercrops. A field studies employing 23 P techniques. *Plant and Soil*. 2001;236:63−74.

21. USAID. Staple foods value chain analysis: Country report Tanzania. 2010.

22. Pauw K, Thurlow J. Agricultural growth, poverty and nutrition in Tanzania. *Food Policy.* 2011;36(6):795–804.

23. Mbwaga AM, Massawe C. Evaluation of maize cultivars for Striga resistance in the Eastern zone of Tanzania. Integrated Approaches to Higher Maize Productivity in the New Millennium. *7 Proceedings of the Eastern and Southern Africa Regional Maize Conference.* Kenya: Nairobi; 2002. p. 174−178.

24. Barreiro-Hurle J. *Analysis of incentives and disincentives for maize in the United Republic of Tanzania.* Technical notes series, Rome: MAFAP, FAO; 2012.

25. Cairns JE, Hellin J, Sonder K, et al. Adapting maize production to climate change in sub-Saharan Africa. *Food Security.* 2013;5(3):345−360.

26. Homann-Kee Tui S, Bluemmel M, Valbuena D, et al. Assessing the potential of dual-purpose maize in southern Africa: A multi-level approach. *Field Crops Res.* 2013;153:37−51.

27. Oladejo JA, Adetunji MO. Economic analysis of maize (*zea mays* l.) production in Oyo state of Nigeria. *Agric Sci Res J.* 2012;2(2):77−83.

28. Nyoro J, Kirimi L, Jayne TS. *Competitiveness of Kenyan and Ugandan maize production: Challenges for the future.* Nairobi: International Development Collaborative Working Papers KE-TEGEMEO-WP-10, Department of Agricultural Economics, Michigan State University. 2004.

29. Ranum P, Peña-Rosas JP, Garcia-Casal MN. Global maize production, utilization, and consumption. *Ann N Y Acad Sci.* 2013;1312:105−112.

30. FAOSTAT. *Africa maize production.* 2012/13.

31. Amani HKR. Agricultural Development and Food Security in Sub-Saharan Africa Tanzania. *Country Report, Economic and Social Research Foundation (ESRF) Dar es Salaam,* Tanzania; 2006.

32. Zorya S, Morgan N, Rios LD. Missing food: The Case of Postharvest Grain Losses in Sub-Saharan Africa. The International Bank for Reconstruction and Development/The World Bank. Report No. 60371-AFR. The World Bank, Washington, DC. 2011;1:2–45.

33. BEFS. *Bioenergy and Food Security Projects.* Tanzania; 2014.

34. Chaudhary AH. Effect of population and control of weeds with herbicides in maize. *Field Crop Abst.* 1983;35(5):403.

35. Undie UL, Uwah DF, Attoe EE. Effect of intercropping and crop arrangement on yield and productivity of late season Maize/soybean mixtures in the humid environment of South Southern Nigeria. *Journal of Agricultural Science*.2012;4(4):37–50.

36. Dado RG. Nutritional benefit of specialty Maize grain Hybrid in Dairy diets. *J Animal Sci.* 1999;77 Suppl 2:197−207.

37. Ayisi KK, Nkgapele RJ, Dakora FD. Nodule formation and function in six varieties of cowpea (*Vigna unguiculata* L. Walp.) grown in nitrogen rich soil in South Africa. *Symbiosis.* 2000;28:17–31.

38. Phillips RD, McWatters KH, Chinnan MS, et al. Utilization of cowpeas for human food. *Field Crop Res.* 2003;82(2−3):193–213.

39. Hall AE. Phenotyping cowpeas for adaptation to drought. *Front Physiol.* 2012;3:1–8.

40. Singh BB. Cowpea: The Food Legume of the 21st Century. *Crop Sci Soc Am Madison.* 2014.

41. Nkongolo KK. Genetic characterization of Malawian cowpea (*Vigna unguiculata* L. Walp) landraces: diversity and gene flow among accessions. *Euphytica.* 2003;129(2):219−228.

42. Aliyu BS, Emechebe AM. Effect of Intra row and Inter row mixing of Sorghum with two Varieties of Cowpea on Host Crop Yield in a Striga hermonthica Infested field. *Afr J Agric Res.* 2006;1(2):24−26.

43. Blade SF, Mather DE, Singh BB, et al. Evaluation of yield stability of cowpea under sole and intercrop management in Nigeria. *Euphatica.* 1992;61:193−201.

44. Reddy KC, Visser BP. Pearl millet and cowpea yields in sole and intercrop systems, and their after-effects on soil and crop productivity. *Field crops Res.* 1992;28(4):315−326.

45. Mead R, Willey RW. The concept of land equivalent ratio and advantages in yields from intercropping. *Exp Agric*. 1980;16:217−228.

46. Ofori F, Stern WR. Cereal-legume intercropping systems. *Adv Agron.* 1987;41:41−90.

47. Vandermeer J. *The Ecology of Intercropping*. Cambridge University Press, Cambridge: UK; 1989. p. 237.

48. Beets WC. *Multiple Cropping and Tropical Farming Systems.* Colorado: West View Press Inc, Baulder; 1982.

49. Willey RW. Evaluation and presentation of intercropping advantages. *Experimental Agriculture*. 1985;21(2):119–133.

50. Ijoyah MO, Ogar AO, Ojo GOS. Soybean-maize intercropping on yield and system productivity in Makurdi, Central Nigeria. *Scientific J Crop Sci.* 2013;2(4):49−55.

51. Workayehu T. Legume-based cropping for sustainable production, economic benefit and reducing climate change impacts in southern Ethiopia. *Journal of Agricultural and Crop Research*. 2014;2(1):11–21.

52. Willey RW, Rao MR. A competitive Ratio for qualifying competition between intercrops. *Experimental Agriculture*. 1980;16(2):117–125.

53. Steel RGD, Torrie JH. *Principles and Procedures of Statistics: A Biometrical Approach, 2nd ed.* New York: McGraw Hill; 1980. p.633

54. Kimou SH, Coulibaly LF, Koffi BY, et al. Effect of row spatial arrangements on agromorphological responses of maize (*Zea mays* L.) and cowpea [*Vigna unguiculata* (L.) Walp] in an intercropping system in Southern Cote d'Ivoire. *Afr J Agric Res.* 2017;12(34):2633−2641.

55. Alom MS, Paul NK, Quayyum MA. Performances of different hybrid maize (*Zea mays* L.) varieties under intercropping systems with groundnut (*Arachis hypogaea* L.). *Bangladesh J Agric Res.* 2009;34(4):585−595.

56. Mortimore MJ, Singh BB, Harris F, et al. *Cowpea in traditional cropping systems.* In: Singh BB, Mohan Raj DR, Dashiel KE, Jackai LEN, editors. Co-publication of International Institute of Tropical Agriculture (IITA) and

Japan International Research Center for Agricultural Sciences (JIRCAS). Nigeria: IITA, Ibadan; 1997. p. 99−113.

57. Terao T, Watanabe I, Matsunaga R, et al. *Agro-physiological constraints in intercropped cowpea: an analysis*. In: Singh BB, Mohan Raj DR, Dashiel KE, editor. Adv. *Cowpea Res.* Co-publication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). Nigeria: IITA, Ibadan; 1997. p. 129−140.
58. Olufajo OO, Singh BB. Advances in cowpea cropping research, In: Fatokun, CA, Tarawali SA, Singh BB, Kormawa PM, Tamo M, editors. *Challenges and opportunities for enhancing sustainable cowpea production. Proceedings of the World Cowpea Conference 111*. 2002;267−277.
59. Okpara DA. Growth and yield of maize and vegetable cowpea as influenced by intercropping and Nitrogen fertilizer in the low land humid tropics. *J Sustainable Agric Environ.* 2000;2:188−194.
60. Polthanee A, Surachet B. Comparizon of single cropping, intercropping and relay cropping of corn and cowpea under rained condition in an upland area of north eastern Thailand. *JISSAAS.* 2000;6:1−12.
61. Nambiar PTC, Rao MR, Reddy MS, et al. Effect of intercropping on nodulation and N2 fixation by groundnut. *Exp Agric.* 1983;19:1979–1986.
62. Egbe OM, Alibo SE, Nwueze I. Evaluation of some extra-early-and early-maturing cowpea varieties for intercropping with maize in southern guinea savannah of Nigeria. *Agric Biol J North Amer.* 2010;1(5):845−858.
63. Randhawa MA, Mahmood N, Javed MA, et al. Studies into legumes as intercrop on the growth and yield of maize grown in different geometrical patterns. *J Animal Plant Sci.* 2005;15(1−2):33−34.
64. Yilmaz S, Atak M, Erayman M. Identification of advantages of maize-legume intercropping over solitary cropping through competition indices in the East Mediterranean Region. *Turkish Journal of Agriculture and Forestry*. 2008;32(2):111–119.
65. Krasilnikoff G, Gahoonia T, Nielsen NE. Variation in phosphorus uptake efficiency by genotypes of cowpea (*Vigna unguiculata*) due to differences in root and root hair length and induced rhizosphere processes. *Plant Soil.* 2003; 251(1):83−91.
66. Kheroar S, Patra BC. Productivity of maize-legume intercropping systems under rainfed situation. *Afr J Agric Res.* 2014; 9(20):1610−1617.
67. Mukhala E. *Radiation and water utilization efficiency by mono-culture and inter-crop to suit small-scale irrigation farming.* Ph.D. thesis, Bloemfontein: University of the Orange Free State; 1998.
68. Tsubo M. *Radiation interception and use in a maize and bean intercropping system.* University of the Orange Free State. 2000.
69. Ogindo HO. *Comparing the precipitation use efficiency of maize–bean intercropping with sole cropping in a semi-arid ecotope.* Ph.D. thesis, Bloemfontein: University of the Free State; 2003.
70. Mariotti Ariotti M, Masoni A, Ercoli L, et al. Forage potential of winter cereal/legume intercrops in organic farming. *Italian J Agron.* 2006;3:403−412.
71. Kitonyo OM, Chemining'wa GN, Muthomi JW. Productivity of farmer-preferred maize varieties intercropped with beans in semi-arid Kenya. *Inter J Agron Agric Res.* 2013;3(1):6−16.
72. BEFS. *Bioenergy and Food Security Projects.* Tanzania; 2014.
73. Monteith JL. Evaporation and environment. *Symposium Soc Exp Biol.* 1965;19:205–234.
74. Li L, Tilman D, Lambers H, et al. Plant diversity and over yielding: insights from belowground facilitation of intercropping in agriculture. *New Phytol.* 2014;203:63–69.