EJEAFChe

Electronic Journal of Environmental, Agricultural and Food Chemistry

ISSN: 1579-4377

EFFECTS OF COWPEA LEAF HARVESTING INITIATION TIME ON YIELDS AND PROFITABILITY OF A DUAL–PURPOSE SOLE COWPEA AND COWPEA-MAIZE INTERCROP

Mwanarusi Saidi[1*], Francis M. Itulya[1], Joseph. N. Aguyoh[1], Patience. M. Mshenga[2] and George Owour[2]
[1]Dept. of Crops, Horticulture and Soils, Egerton University, P.O. Box 536 Njoro-Kenya; [2]Dept. of Agricultural Economics and Agribusiness Management, Egerton University, P.O. Box 536 Njoro-Kenya
mwanarusi@yahoo.com

ABSTRACT

Harvesting of cowpea leaves for use as leaf vegetable has gained prominence in many parts of Africa and Asia. Little is known on effects of leaf harvesting on leaf and grain yields and profitability of cowpea-based cropping systems. This study sought to determine yields and profitability sole cowpea or cowpea-maize intercrop under different cowpea leaf harvesting initiation times. The study was conducted at Kenya National Dry land Research Center – Machakos using a Randomized Complete Block Design with cowpea grown as a monocrop or intercropped with maize. Leaf harvesting was initiated at 2, 3 or 4 weeks after cowpea emergence (WAE) and a control where no leaf harvesting was done. Initiating leaf harvesting at 3 and 4 WAE resulted in highest leaf and grain yields, respectively among leaf harvested cowpea. Overall, cowpea grain yields were highest in control treatment. Leaf vegetable and grain yields were lower in intercrop than in monocrop treatments. Maize yields in intercrop treatments were improved following harvesting of leaves of the companion cowpea. Initiating leaf harvesting at 3 and 4 WAE yielded highest returns in cowpea-maize intercrop and sole cowpea, respectively. Intercropping was on overall more profitable than sole cropping.

KEYWORDS

Leaf harvesting, cropping regime, yield, profitability.

INTRODUCTION

Cowpea (*Vigna unguiculata* (L) Walp) is a major grain legume, fodder, green pod and leafy-vegetable crop grown on 12.5 million ha in drought-prone regions of Africa and other tropical and subtropical regions (Ehlers and Hall, 1997; Henriet et al., 1997; Langyintuo et al., 2003; Mortomore et al., 1997). Millions of poor farmers and urban consumers in developing countries rely on cowpea for their livelihood and nutritional well-being.

In most areas, cowpea is mainly grown by small-scale farmers who practice intercropping in their small land holdings (Singh et al., 2003). Growers with such small areas are always looking for maximization of their farm income through vertical expansion, achieved by either cultivating the land more than once per year and/or intercropping (Abou-Hussein et al., 2005). Thus, although monocrop cowpea is said to be profitable, farmers plant cowpea in various types of intercropping systems with maize, millet, sorghum and other cereals (Singh et al., 2003). Intercrops have been shown to be better than monocrop cultures because they yield more, protect against risks of drought and pests, provide a more balanced human diet (Vandermeer, 1990) and offer the potential of greater sources of profits (Reis et al., 1985). The monetary gain advantage of intercropping has also been demonstrated by Banik et al. (2000).

Grown as a monocrop or intercrop, two main systems are commonly used in the production of cowpea. Where the crop is grown purely for vegetable production, the entire plant is uprooted at the 3–5 true leaf stage before the leaves become too mature and fibrous, or in the case of dual-purpose production, sequential leaf harvests are made during the vegetative stage of the crop, followed by seed harvesting at the end of the season. The latter system predominates with most subsistence growers who practice intercropping. There is, however, paucity of information on the effects of timing of leaf harvesting initiation on subsequent leaf vegetable and grain yield, and the profitability of cowpea based cropping systems.

An earlier study conducted under greenhouse conditions showed that leaf harvesting initiation time and frequency affect leaf vegetable and grain yield of dual-purpose cowpea (Saidi et al., 2007). Wein and Tayo (1978) showed that up to 50% defoliation of cowpea in the vegetative stage had no effect on grain yield. Nielsen et al. (1994), on the other hand, observed that harvesting leaves from cowpea plants at 5 or 7 weeks after planting had detrimental effects on grain yields. According to Barrett (1987) the timing of leaf removal can have great effect on the plants ability to recover from leaf harvesting. Most studies conducted on effects of leaf harvesting on cowpea yield have failed to address this aspect. Moreover, studies on cowpea defoliation have tended to target even leaves that were past the consumable (young/tender) stage in the defoliation intensities, did not use germplasm selected for dual-purpose production or were conducted under protected environment. Results from such studies may, therefore, not be relevant to understanding how removal of young leaves intended for consumption as leaf vegetable would impact leaf vegetable and grain yield of a dual-purpose cowpea grown either in monoculture or intercropped with a cereal.

Defoliation has also been shown to influence profitability of crops. In cowpea, poor performance of the crop was observed for defoliation imposed in the vegetative stage and at 100 % intensity but yield and economic performance of the crop was impressive for defoliation imposed in flowering stage and at 50 % intensity (Rahman et al, 2008). Profitability has been termed as the kingpin of any agricultural practice (Korir et al., 2006).

The kind of decision regarding the cropping and harvesting regime to be used will thus depend on the satisfaction or benefits expected from such activities. There is, however, no information available to us showing the profitability of dual–purpose cowpea based cropping systems and how the monetary gains derived from such production systems would be influenced by leaf harvesting initiation time of cowpea. The objectives of this study were therefore (i) to determine the effects of cowpea leaf harvesting initiation time on yield of a sole dual-purpose cowpea and a dual-purpose cowpea–maize intercrop and (ii) determine the profitability of sole crop dual-purpose cowpea and dual-purpose cowpea–maize intercrop production systems under different leaf harvesting initiation times.

MATERIALS AND METHODS

The study was conducted in a span of two seasons at the National Dry Land Research Center - Katumani, Machakos in Eastern Province of Kenya beginning October 2007 – February 2008, through April 2008 – July 2008. A site in Eastern province was chosen since the province is the major cowpea growing area of Kenya. Katumani lies at an altitude of 1575 m above sea level and latitude of 1^0 35' S and 37^0 14' E in agro-ecological zone 4 with Chromic Luvisols soil types (FAO - UNESCO, 1990). The area receives bimodal rainfall with rainy seasons in October to February (Season 1) and in April to July (Season 2).

One of the most popular dual-purpose cowpea cultivars in the area ('K80') was used in this study, grown either as a monocrop or intercropped with maize. Where intercropping was done, 'Katumani Composite B' maize variety was used. 'K80' is a dual-purpose cultivar with a sprawling growth habit and flowers in about 50 days from emergence. 'Katumani Composite B' is a fast growing open pollinated maize variety, which is fairly short (about 170cm) and produces short cobs. It is a drought escaping variety flowering within 60-65 days, matures within 90-120 days and is well adapted for marginal rainfall areas.

The study was an unbalanced factorial experiment in a Randomized Complete Block Design with three replications. Two factors were studied: (i) leaf harvesting initiation time (CR) and (ii) cropping regime (CR). Leaf harvesting was initiated at three different times: 2, 3 and 4 weeks after emergence (WAE) of cowpea with a control treatment where no leaf harvesting was done. Cropping regime factor comprised of cowpea grown as a monocrop or cowpea intercropped with maize. Individual plots in a block measured 4 m by 6 m separated from each other by a one meter buffer. In each plot, data was collected from the inner 3.4 m by 4.8 m leaving outer rows as guard rows. Treatment application entailed manual picking of all young but fully expanded leaves (usually pale green in colour, smoother and shinier than mature leaves) from each vine. Leaf harvesting was initiated at different times in the different plots based on the treatments. Once initiated, leaf harvesting was continued at a 7 days interval in all non-control plots until the onset of flowering on the plots that flowered earliest.

In all plots, cowpea was planted at a spacing of 60 cm x 20 cm at the onset of the rains. Two seeds were planted in each hill and later thinning was done to leave one seedling per hill. Maize was planted at a spacing of 120 cm x 30 cm with two rows of cowpea between consecutive maize rows. This arrangement allowed an equal population of cowpea in both monocrop and intercrop plots. Once established, all other maintenance activities including weeding and pest and disease management were uniformly applied to all the plots. Data was collected on

Cowpea Leaf Vegetable Yield

Leaf vegetable yield data were collected at a 7 days interval upon initiation of leaf harvesting. The total leaf vegetable weight for each treatment was obtained by summing up the fresh leaf weights obtained for the given treatment at the different leaf harvesting dates and is expressed in kilograms per hectare (kg/ha).

Cowpea Grain Yield

These data were collected at the end of each season by harvesting all the cowpea grain from the data collection area of individual treatments when about 75% of the pods were dry. Harvested grain was sun dried to a moisture content of around 12%, and then weighed. Obtained grain yields were expressed in kg/ha.

Maize Grain Yield

Maize was also harvested from individual treatments when over 75% of the cobs were dry. Harvested grain was sun dried and the weight obtained from individual treatments expressed kg/ha.

Profitability Assessment

To examine the profitability of the different leaf harvesting and cropping regimes, gross margin analysis was done. Costs associated with each activity (land preparation, seed, planting, weeding, spraying, leaf harvesting, and grain harvesting and threshing) were recorded during each season. Currency used is Kenya shillings (Ksh.) where 1 US$ = Ksh. 72. Farm gate prices of cowpea leaves and grain and maize grain in the different seasons were used. Returns per hectare were computed as yield per hectare multiplied by price per unit kilogram less the total costs of production.

Data Analysis

Yield data obtained were subjected to analysis of variance (ANOVA) at $P \leq 0.05$ using Proc Mixed code of SAS (SAS Institute, 2002). Treatment means found to be significantly different were separated using LSMeans statement of Proc Mixed at $P \leq 0.05$. Profitability was determined by comparing gross margins obtained for the different leaf harvesting and cropping regimes.

RESULTS AND DISCUSSION

Leaf Vegetable Yields

Cowpea leaf vegetable yield was influenced by both leaf harvesting initiation time (LHI) and CR. The interaction between LHI x CR was not significant in both seasons (Table 1).

Table 1. Effects of cowpea leaf harvesting initiation time (LHI) on leaf vegetable yield of cowpea (kg/ha) under different cropping regimes (CR).

LHI (Weeks after Emergence)	Cropping Regime (CR) Monocrop	Intercrop	**LHI Means**
Season 1			
No	-	-	-
2 WAE	1822.1*	1733.4	**1777.8 c****
3 WAE	2521.0	2236.2	**2378.6 a**
4 WAE	2270.5	2068.1	**2169.3 b**
CR Means	**2204.6 f****	**2012.6 g**	
Season 2			
No	-	-	-
2 WAE	1204.9*	946.6	**1075.8 a***
3 WAE	1554.3	1312.7	**1433.5 a**
4 WAE	1352.7	1146.2	**1249.5 a**
CR Means	**1370.6 d****	**1135.2 d**	

* Season x leaf harvesting initiation time (LHI) interaction is not significant according to the F Test ($P \leq 0.05$).
** Within season, means followed by the same letter in a letter series are not significantly different ($P \leq 0.05$).

Initiating leaf harvesting at 3 WAE produced higher leaf vegetable yields than 2 or 4 WAE in both seasons. The yield difference between 3 WAE and other LHI treatments was, however, significant in season 1 but not in season 2 (Table 1). Among CR treatments, monocrop cowpea gave higher leaf vegetable yields in both seasons. Although intercropping cowpea with maize reduced cowpea leaf vegetable yields, the reduction was significant only in season 1 (Table1). From the results of this study, it can be deduced that delaying LHI from 2 WAE to 3 WAE increases leaf vegetable yields of cowpea while a further delay in initiation of leaf harvesting to 4 WAE results in a decline in leaf vegetable yields. Initiating cowpea leaf harvesting at 2 WAE does not allow the plants ample time to develop adequate vegetative growth to favour photosynthesis and subsequent recovery and growth of the plants (Saidi et al, 2007). At 2 WAE, most of the plants are at the second true leaf stage with either of the leaves too young or at the right stage of harvesting for consumption as leaf vegetable. Thus, when leaf harvesting is initiated at this time, it leaves the plants with insufficient foliage to support subsequent leaf production. However, at 3 WAE and beyond, the plants have formed lateral shoots and at least 3 fully expanded true leaves with some of these leaves past the consumable stage as leaf vegetable. This leaves the plants with adequate foliage to support subsequent recovery upon harvesting of leaves. A further delay in initiating leaf harvesting beyond 3 WAE, on the other hand, reduces the time period between leaf harvesting initiation and flowering, hence reducing on the number of leaf harvests that can be made. The reduced number of leaf harvests could account for the low leaf vegetable yields obtained when leaf harvesting was initiated at 4 WAE in the current study. Findings of this study are also in agreement with those of Le et al. (2003) who recorded a decline in leaf yields of sweet potato as leaf harvesting was delayed from 25 to 120 days after planting.

COWPEA GRAIN YIELD

Cowpea grain yield was significantly affected by LHI and CR. Leaf harvesting initiation time x CR interaction was not significant in both seasons (Table 2).

Table 2. Effects of cowpea leaf harvesting initiation time (LHI) on grain yield of cowpea (kg/ha) under different cropping regimes (CR).

LHI (Weeks after Emergence)	Cropping Regime (CR) Monocrop	Intercrop	**LHI Means**
Season 1			
No	2804.6*	1560.0	**2182.3 a****
2 WAE	1313.1	831.6	**1097.4 c**
3 WAE	1535.3	1451.8	**1518.6 b**
4 WAE	2133.4	1508.3	**1820.9 b**
CR Means	**1959.1 f****	**2012.6 g**	
Season 2			
No	1302.8*	855.4	**1079.1 a****
2 WAE	734.0	423.6	**577.8 c**
3 WAE	833.8	478.4	**656.1 c**
4 WAE	1112.1	559.4	**835.7 b**
CR Means	**995.2 f****	**579.2 g**	

*Season x leaf harvesting initiation time (LHI) interaction is not significant according to the F Test ($P \leq 0.05$).
**Within season, means followed by the same letter in a letter series are not significantly different ($P \leq 0.05$).

Harvesting cowpea leaves at the vegetative stage of the plants significantly lowered cowpea grain yields compared to control treatment in both seasons. Among leaf harvested cowpea, initiating leaf harvesting at 4 WAE of cowpea resulted in higher cowpea grain yield, with the lowest grain yield obtained when leaf harvesting was initiated at 2 WAE in both seasons. Since during sequential harvests, only fully expanded tender leaves are harvested for consumption as leaf vegetable, delaying first leaf harvest to 4 WAE left more leaves on the plants offering a higher photosynthetic surface which could have favoured better accumulation of carbon reserves leading to higher grain yields. Several other studies have also shown leaf removal during the growing season to have detrimental effects on subsequent crop yields (Nielson et al., 1994; Karikari and Molatakgosi, 1999; Zewdu and Asregid, 2001; Muir et al., 2005). Among CR treatments, monocrop cowpea gave significantly higher grain yield than intercrop cowpea in both seasons (Tables 2). Maize in a cowpea- maize intercrop has been shown to be more competitive than cowpea in terms of use of resources, mainly soil water (Filho, 2000). When intercropped with maize, the radiation intercepted by maize leaves reduces considerably the energy input at the cowpea canopy level that is necessary for good photosynthesis (Natarajan and Willey, 1981), possibly accounting for the low cowpea leaf vegetable and grain yields obtained in cowpea-maize intercrop treatments.

MAIZE GRAIN YIELD

Intercropping maize with cowpea affected maize grain yield. In both seasons, growing maize as a monocrop resulted in the highest grain yields (Tables 3). Maize yields in cowpea– maize intercrop were, however, improved by sequential harvesting of leaves of the companion cowpea at the vegetative stage of the crop. Higher maize grain yields were obtained from intercropped treatments in which, cowpea leaves were harvested compared to those where no leaf harvesting was done on the cowpea intercrop.

Table 3. Effects of cowpea leaf harvesting initiation time (LHI) on grain yield of maize (kg/ha) of a cowpea–maize intercrop.

Cropping Regime	Season 1	Season 2
Monocrop	3230.1 a**	2025.6 a
Intercrop No	1380.5 d	727.1 c
Intercrop 2 WAE	1599.4 cd	1232.7 b
Intercrop 3 WAE	1879.5 b	1209.8 b
Intercrop 4 WAE	1684.9 bc	1106.8 b

** Within a column, values followed by the same letter column are not significantly different ($P \leq 0.05$).

Among the treatments where leaf harvesting was done to the companion cowpea crop, initiating cowpea leaf harvesting at 3 WAE of cowpea resulted in higher maize grain yield than 2 WAE in season 1, with no significant differences noted in maize yields among the different cowpea LHI treatments in season 2 (Table 3). High yields in maize grown in association with leaf harvested cowpea may have been as a result of reduced competition for other growth resources, especially light and water. Removing some cowpea leaves reduces competition through reduction in shading of maize crop by cowpea early in the season, in seasons with high rainfall or reduction of water requirement by the crops in relatively dry seasons. Similarly, Nyeko et al., (2004) recorded an increase in total biomass of maize by up to 209% with defoliation of a companion alder (*Alnus acuminate*) crop compared to maize grown in association with non-defoliated alder, with highest shoot nitrogen content recorded in more intense defoliation treatments.

PROFITABILITY ASSESSMENT

Table 4 presents costs, revenue and profits by CR and LHI. Labour costs included the Table 4. Gross margin analysis for dual-purpose sole cowpea and cowpea-maize intercrop as influenced by cowpea leaf harvesting initiation time. costs for planting, weeding, spraying, leaf harvesting and grain harvesting and threshing. Other costs comprised of cost of land preparation (done by tractor), seeds, and chemicals. The cost of land preparation was the same for all treatments. Seed costs differed for monocrop and intercrop treatments due to additional costs of seed in intercropping regime. Labour costs varied by CR and LHI due to differences in the cost of planting, cowpea leaf harvesting and cowpea and maize grain harvesting and threshing.

The profitability varied with treatment in both seasons supporting Rahman et al. (2008). In both sole and intercropping regimes, profitability was influenced by cowpea leaf harvesting initiation time. Harvesting of cowpea leaves for use as leaf vegetable improved profitability of both cropping regimes except when leaf harvesting was initiated at 2 WAE in sole crop cowpea. In both seasons, economic gains in cowpea-maize intercrop regime were higher when the cowpea component was leaf harvested compared to control treatments. Improved profitability following cowpea leaf harvesting may be attributed to diversification in produce obtained from the piece of land (leaves and grain), with this diversification being higher under intercropping than sole cropping. Initiating leaf harvesting at 4 WAE gave highest economic returns in sole cowpea while highest returns for cowpea-maize intercrop were obtained when leaf harvesting was initiated at 3 WAE. The better economic gains obtained for 3 WAE leaf harvesting initiation time for the intercrop treatments may be attributed to improved performance of the maize crop in these treatments compared to maize yield in 4 WAE intercrop treatments, probably due to better resource use efficiency (Pathick and Malla, 1979; Moniruzzaman et al., 2007). Although individual crop yields were lower in intercrop than monocrop treatments, intercrop treatments on average gave higher returns in both seasons which could be due to greater yield stability (Wiley and Reddy, 1981).

Based on the findings of this study, cowpea leaf harvesting initiation time affects yields and profitability of sole dual-purpose cowpea as well as of a dual-purpose cowpea-maize intercrop. We anticipate that testing of more leaf harvesting and cropping regimes would reveal even greater range in yields and profitability. While we feel this study provide a good foundation in describing the effects of leaf harvesting initiation time on yield and profitability of cowpea-based cropping regimes, additional studies with more dual-purpose cowpea-based cropping systems would be useful.

Table 4

Treatment	Production Variables (Kshs.)			Revenues (Kshs)				
				Cowpea				Gross
	Labour Costs	Other Costs	Total Costs	Leaf	Grain	Maize Grain	Total Revenue	Margins (Kshs)
Season 1								
Sole crop								
Control	32976	15747	48723	0	168276	0	168276	119553
2 WAE	37649	15747	53396	72884	78786	0	151670	98274
3 WAE	38644	15747	54390	100840	92118	0	192958	138567
4 WAE	37052	15747	52799	90820	128004	0	218824	166025
Sole crop Means		**52327**					**182932**	**130605**
Intercrop								
Control	34617	19302	53919	0	93600	55220	148820	94901
2 WAE	40119	19302	59521	69336	49896	63596	182828	123407
3 WAE	41500	19302	60802	89448	87108	84576	261132	200330
4 WAE	39353	19302	58655	82724	90498	71880	245102	186447
Intercrop Mean		**58200**					**209471**	**151271**
Season 2								
Sole crop								
Control	31016	15747	46762	0	104224	0	104224	57462
2 WAE	34650	15747	50397	60245	58720	0	118965	68568
3 WAE	34922	15747	50668	77715	66704	0	144419	93751
4 WAE	33718	15747	49465	67635	88968	0	156603	107138
Sole crop Means			**49323**				**131053**	**81730**
Intercrop								
Control	33230	19302	52532	0	68432	39985	108417	55885
2 WAE	36430	19302	55732	47330	34608	65175	147113	91380
3 WAE	37013	19302	56315	65600	38272	74976	178848	122533
4 WAE	35702	19302	55004	57310	44752	67584	169646	114642
Intercrop Mean			**54896**				**151006**	**96110**

ACKNOWLEDGEMENTS

This study was hosted by The Kenya National Dry Land Research Center – Katumani and was funded by Egerton University – Kenya. We also wish to acknowledge the technical help of Samson G. Omolo who served as the main field assistant for the study.

REFERENCES

1. A.S. Langyintuo, J. Lowenberg-DeBoer, M. Faye, D. Lambert, G. Ibro, B. Moussa, A. Kergna, S. Kushwaha, S. Musa, and G. Ntoukam (2003) Cowpea supply and demand in West Africa. Field Crops Res. 82: 215-231.
2. B.B. Singh, H.A. Ajeigbe, S.A. Tarawali, S. Fernandez-Rivera and M. Abubakar (2003) Improving the production and utilization of cowpea as food and fodder. Field Crops Research 84:169-177.
3. D. Pathick and M.L. Malla (1979) Study on performance of crop legume under monoculture and intercrop combination. Sixth Annual Maize Development Workshop. Nepal. 23rd May 1979.

4. E. Le van An, E. Bodil, E. Frankow- Lindberg and E.L. Jan (2003) Effects of harvesting interval and defoliation on yield and chemical composition of leaves, stems and tubers of sweet potato (*Ipomea batatas* L. (Lam.) plant parts. Field Crops Research 82:49-58.
5. FAO – UNESCO. 1990. Soil map of the world. Revised legend. World Resources. Report 60. FAO, Rome.
6. H.C. Wein and T.O. Tayo (1978) The effect of defoliation and removal of reproductive structure on growth and yield of tropical grain legumes. In: Pests of Grain Legumes: Ecology and Control. Eds. Singh, S.R.,Van Emden, H.F. and Taylor, T.A., pp. 241-252. Academic Press. London and New York.
7. J.D. Ehlers and A.E. Hall (1997) Cowpea (*Vigna unguiculata* L. Walp). Field Crops Res. 53:187-204.
8. J. Henriet, G.A. van Ek, S.F. Blade, and B.B. Singh (1997) Quantitative assessment of traditional cropping systems in Sudan savanna of northern Nigeria. I. Rapid survey of prevalent cropping systems. Samaru J. Agric. Res. 14:37-45.
9. J.H. Vandermeer (1990) Intercropping. In Carroli., C.R, Vandermeer, J.H and Rosset., P.M. (eds). Agroecology. New York. McGraw-Hill. p.481-516.
10. J.M.L. Filho (2000) Physiological responses of maize and cowpea to intercropping. Pesq. Agropec. Bras. Brasillia. 35(5):915-921.
11. J.P. Muir, L.R. Reed, and D.P. Malinowski (2005) Impact of defoliation on herbage and seed production of *Strophostyles helvula* and *S. leiosperma*. Native plants/Summer 2005 pp. 123-130.
12. M.J. Mortimore, B.B. Singh, F. Harris and S.B. Blade (1997) Cowpea in traditional cropping systems. In Singh B.B., Mohan Raj D.R., Dashiell, K., Jackai, L.E.N. (Eds). Advances in cowpea Research. Co-publication of International Institute of Tropical agriculture (IITA) and Japan International Center for Agricultural Sciences (JIRCAS), IITA, Ibadan, Nigeria, pp. 99-113.
13. M. Moniruzzaman, m.R.. Islam, S.N. Mozumder, S.M.M. Rahman and N.C. Das (2007) Productivity and profitability of bilatidhonia intercropped with cucurbit vegetables. Bangladesh Journal of Agricultural Research 32 (3): 349-357.
14. M. Natarajan and R.W. Willey (1981). Growth studies in sorghum- pigeon pea intercropping with particular emphasis on canopy development and light interception. In International workshop on intercropping, 1979, Patancheru. Proceedings. Patancheru: ICRISAT p.180-187.
15. M. Saidi, M. Ngouajio, F.M. Itulya and J. Ehler (2007). Leaf harvesting initiation time and frequency affect biomass partitioning and yield of cowpea (*Vigna unguculata* (L) Walp. Crop Science 47:1159-1166.
16. N.K. Korir, J.N. Aguyoh and L. Gaoquiong (2006) Economics of using different nitrogen sources and mulching materials for producing fresh market greenhouse cucumbers in Kenya. Agricultura Tropica ET subtropica 39(3): 152-157.
17. P. Banik, T. Sasmal, P.K. Ghosal and D.K. Bagchi (2000) Evaluation of Mustard (*Brassica compestris* var. *toria*) and Legume intercropping under 1:1 and 2:1 row-replacement series systems. Journal of Agronomy & Crop Science. 185:9-14.
18. P. Nyeko, G. Edwards-Jones, R.K. Day and I. Ap-dewi (2004) Effects of defoliation on growth characteristics and N, P, K content in an alder/maize agroforestry system. African Crop Science Journ. 12(4): 369-381.
19. Barrett, R.P. 1987. Integrating leaf and seed production strategies for cowpea (*Vigna unguiculata* (L) Walp. MS. Thesis. Michigan State Univ., East Lansing.
20. R.W. Wiley and S. Reddy (1981) Afield technique for separating above and below ground interaction for intercropping experiments with pearl millet/groundnut. Experimental Agriculture. 17: 257-264.
21. S.A Rahman, U. Ibrahim and F.A. Ajaya (2008) Effect of defoliation at different growth stages on yield and profitability of cowpea (*Vigna unguiculata* (L.) Walp.). EJEAFche 7 (9) :3248-3254).
22. SAS Institute. 2002. SAS Release 9.1. SAS Institute, Cary.

23. S.D. Abou-Hussein, S.R. Salman, A.M.R. Abdel-Mawgoud and A.A. Ghoname (2005) Productivity, Quality and profitability of sole or intercropped green bean (*Phaseolus vulgaris* L.) crop. Journal of Agronomy 4(2): 151-155.
24. S.K. Karikari and G. Molatakgosi (1999) Response of cowpea (*Vigna unguiculata* (L) Walp) varieties to leaf harvesting in Botswana. UNISWA Journ. of Agric. 8:5=11
25. S.S. Nielsen, C.I. Osuala and W.E. Brandt (1994) Early leaf harvest reduces yield but not protein concentration of cowpea seeds. HortScience 29(6): 631-632
26. T. Zewdu and D. Asregid (2001) The effect of growing annual forage legumes with maize and maize leaf defoliation on grain and stover yield components and undersown forage production. Seventh Eastern and Southern African Regional maize Conference 11th-15th Februarypp.487-490.
27. W.P. Reis, M.A.P. Ramalho and J.C. Cruz (1985). Corn and common bean intercropping-system with double and simple corn rows. Pesquisa Agropecuria Brasileira, Brasilia 20: 575-584.