VOL. 5, NO. 5, SEPTEMBER 2010 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

YIELDS AND PROFITABILITY OF A DUAL–PURPOSE SOLE COWPEA AND COWPEA-MAIZE INTERCROP AS INFLUENCED BY COWPEA LEAF HARVESTING FREQUENCY

Mwanarusi Saidi[1], Francis M. Itulya[1], Joseph. N. Aguyoh[1] and Patience. M. Mshenga[2]
[1]Department of Crops, Horticulture and Soils, Egerton University, Njoro, Kenya
[2]Department of Agricultural Economics and Agribusiness Management, Egerton University, Njoro, Kenya
E-Mail: mwanarusi@yahoo.com

ABSTRACT

Dual-purpose cowpea production is a common component of many tropical and sub tropical subsistence farming systems. Under such systems, cowpea leaves are harvested for vegetable use at the vegetative stage of the plants and seeds later at crop maturity. Little information exists on effects of leaf harvesting frequency on subsequent yields and economic returns of the many dual-purpose cowpea based cropping systems. This study investigated the effects of harvesting cowpea leaves at every 7-days or 14-days interval on leaf vegetable and grain yields and profitability of a sole dual-purpose cowpea and a dual-purpose cowpea-maize intercrop. Harvesting cowpea leaves at 7-days interval gave higher leaf vegetable yield with both cropping regimes. Grain yields were higher for 14-days compared to 7-days leaf harvesting frequency. The highest grain yields were obtained in none leaf harvested control cowpea. Maize yields in intercrop treatments were highest when leaves of the companion cowpea were harvested at 7-days interval and lowest when no leaf harvesting was done to the companion cowpea. Harvesting cowpea leaves at 7-days interval resulted in higher gross margins with both cropping regimes. Profitability correlated positively with leaf vegetable and grain yields. Gross margins were also higher for intercropping compared to sole cropping in both seasons.

Keywords: dual-purpose cowpea, leaf harvesting frequency, cropping regime, leaf vegetable yield, grain yield, gross margins.

INTRODUCTION

Cowpea (*Vigna unguiculata* (L) Walp) is one of the highly appreciated species of African leafy vegetables (Keller, 2004). It is an important food legume, and its use as leafy vegetable is essential in many African countries. Its ability to withstand drought, short growing period and multi-purpose use make cowpea a very attractive alternative for farmers in marginal, drought-prone areas with low rainfall and less developed irrigation systems (Hallensleben *et al*., 2009).

Dual-purpose cowpea production offers versatility by utilization of both foliage and seeds from the same crop (Bubenheim *et al*., 1990). Growing of dual-purpose cowpea can contribute greatly towards meeting food requirement of many people especially in areas where food security and malnutrition are a major challenge. Under such scenario, both cowpea leaves and grain can play an important role towards meeting the nutritional requirements of especially the resource poor families.

In many areas, cowpea has been produced mainly for its protein-rich grains, popularly consumed with cereal foods. The production of cowpea as a leafy vegetable, however, appears to have increased markedly in many areas in recent years as farmers shift to more drought-tolerant vegetable crops in light of repeated droughts facing many parts of Africa (Saidi *et al*., 2007). Two main systems are commonly used in the production of cowpea as a leafy vegetable; uprooting the entire plant at the 3-5 true leaf stage before the leaves become too mature and fibrous or dual-purpose production where sequential leaf harvests are made during the vegetative phase of plant growth, followed by seed production at the end of the season. The latter system predominates with most subsistence growers in the tropics and subtropics as a means of maximizing productivity and diversification on their small land holdings

Despite its increasing importance, cowpea's use as leafy vegetable in many African countries has been widely neglected in research (Barret, 1990). Although lately some research has been widely carried out on African leafy vegetables, cowpea research continued to focus on grain and/or the entire herbage for animal feed (Singh *et al*., 2003). There is paucity of information on factors that affect leaf vegetable yields, more so, on how leaf vegetable harvesting practices impact on grain yields and profitability of the different dual-purpose cowpea-based production systems.

Few studies have been conducted on the effect of leaf harvesting on grain and biomass yields. Most of these studies, however, tended to focus on intensity of defoliation, hence targeting even leaves that were past the consumable (young/tender) stage as leafy vegetables in the defoliation intensities (Wien and Tayo, 1978; Nielson *et al*., 1994), did not use germplasm selected for dual-purpose production (Karikari and Molatakgosi, 1999) or were conducted under protected environment Saidi *et al*. (2007). Results from such studies may thus not be relevant to understanding how frequency of harvesting young leaves intended for consumption as leaf vegetable would impact leaf vegetable and grain yield and the profitability of dual-purpose cowpea based production systems under field conditions.

Profitability has been termed as the kingpin of any agricultural practice (Korir *et al*., 2006). The kind of decision regarding any practice to be used in the production of a given crop will thus depend on the yield and economic benefits expected from such activities. This study therefore sought to determine the (i) effects of cowpea leaf harvesting frequency on yield of a sole dual-purpose cowpea and a dual-purpose cowpea–maize intercrop and (ii) economic benefits of sole crop dual-purpose cowpea and dual-purpose cowpea-maize intercrop production systems as influenced by different cowpea leaf harvesting frequencies.

MATERIALS AND METHODS

Experimental site

The study was conducted at the National Dry Land Research Center - Katumani, Machakos in Eastern Province of Kenya in a span of two seasons, 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. Area rainfall amount ranges from 500 - 700 mm per year with mean maximum and minimum temperatures of 24.7^0C and 13.9^0C, respectively. Rainfall is bimodal with rains between March and July and October and February. The area's soil types are Chromic Luvisols (FAO - UNESCO, 1990).

Plant material

One dual-purpose cowpea cultivar ('K80') was used, 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.

Experimental design and treatment application

The study was a balanced factorial experiment in a Randomized Complete Block Design with three replications. Two factors were studied: (i) leaf harvesting frequency (LHF) and (ii) cropping regime (CR). Cowpea leaves were harvested at 7 days or 14 days interval with a control treatment where no leaf harvesting was done. The CR 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 in non-control treatments, beginning 3 weeks after crop emergence to the onset of flowering. Leaves at this stage are what growers harvest for vegetable use.

Crop establishment and maintenance

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 collection

Leaf vegetable and grain yield

Leaf vegetable yield data were collected at a 7-days or 14-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 expressed in kilograms per hectare (kg/ha). Cowpea grain yield 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%, weighed and yields expressed in kg/ha. Maize was also harvested from individual treatments when over 75% of the cobs were dry. Harvested grain was sun dried and individual treatment grain weight expressed in kg/ha.

Profitability

Since there was no debt on the land, profitability of the different leaf harvesting and cropping regime were analyzed by gross margins as in Tekele (2001). 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 $P \leq 0.05$. For profitability assessment, gross margins obtained for the different leaf harvesting and cropping regimes were compared. The relationship between profitability and leaf vegetable and grain yields was also studied by correlation analysis and

VOL. 5, NO. 5, SEPTEMBER 2010 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

multiple regression with profitability as the response variable and leaf vegetable and grain yields as the independent variables. Stepwise selection multiple regression method was employed to select the variables that best described the relationship between profitability and leaf vegetable and grain yields in this study. Prior to stepwise regression, the models were examined for multicollinearity using Condition Index and variables that appeared to be involved in multicollinearity and provided least contribution to the model were excluded from further analysis. Proc Reg code of SAS (SAS, 2002) was used.

RESULTS AND DISCUSSION

Leaf vegetable and grain yields

Cowpea leaf vegetable yields were significantly influenced by leaf harvesting frequency in both sole and intercropped cowpea (Figure-1). Within the individual seasons, the interaction between CR and LHF was not significant. Harvesting cowpea leaves more frequently at 7-days interval resulted in significantly higher leaf vegetable yields compared to harvesting leaves at 14-days interval in both sole and intercropped cowpea in both seasons. Defoliation has been shown to stimulate leaf production in cowpea (Bubenheim *et al*., 1990). Higher leaf yields obtained under more frequent harvesting could have been a result of stimulation of leaf production. Low leaf yield from the 14 day harvest interval is also attributed to the fact that some of the leaves produced between harvest intervals would surpass the consumable stage before the next harvest. Only young and tender leaves are consumed as vegetable. Averaged across LHFs, higher leaf vegetable yields were obtained from sole cowpea compared to leaf vegetable yields from intercropped cowpea, although the difference was not significant. Similarly, Saidi and Itulya (2003) recorded higher yields in monocrop collards than in collards intercropped with beans or onions.

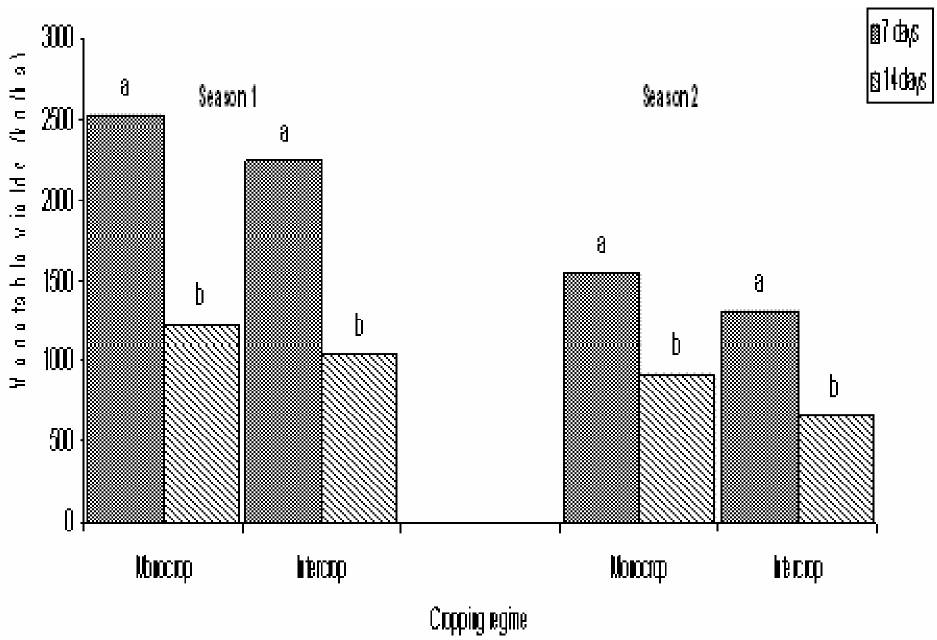

Fig -1. Leaf vegetable yields of dual-purpose cowpea as influenced by cropping regime and cowpea leaf harvesting frequency. Within a season, bars with the same letter are not significantly different ($P \leq 0.05$)

VOL. 5, NO. 5, SEPTEMBER 2010 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

Contrary to leaf vegetables being higher under more frequent leaf harvesting, cowpea grain yields were lower for these treatments. Cowpea grain yields tended to increase with decrease in leaf harvesting frequency from 7-days leaf harvesting interval to no leaf harvesting in both sole and intercropped cowpea (Figure-2). LHF x CR interaction was significant in season 1 but not in season 2 (Figure-2). In both seasons, highest grain yields were obtained in non-leaf harvested monocrop cowpea. While harvesting leaves at 14-days interval resulted in significantly higher grain yields compared to harvesting leaves at 7-days interval in monocrop cowpea, no significant differences were detected in yields of cowpea subjected to the different leaf harvesting frequencies in intercropped cowpea in season 1. In season 2, grain yields decreased with increase in leaf harvesting frequency in both sole and intercropped cowpea. The highest grain yields were obtained when no leaf harvesting was done to the crop at its vegetative phase with the lowest grain yields recorded when leaf harvesting was done at a 7-days interval in both sole and intercropped cowpea (Figure-2). Since during sequential harvests only young tender leaves are harvested for consumption as leaf vegetables, harvesting cowpea leaves less often or not harvesting leaves at all left the plants with more foliage offering a greater photosynthetic surface which could have favoured grain formation. In an earlier study under greenhouse conditions, Saidi *et al.* (2007) similarly recorded an increase in grain yields of two cowpea varieties as leaf harvesting frequency was decreased for 7-days interval to no leaf harvesting. At any given leaf harvesting frequency, intercropped cowpea generally yielded less grain than sole crop cowpea in both seasons (Figure-2). Maize 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 which is necessary for photosynthesis (Natarajan and Wiley, 1981), possibly accounting for the low leaf vegetable and grain yields obtained in intercropped compared to sole crop regime Several other studies (Midya *et al*., 2005; Rusinamhodzu *et al*., 2006; Hauggaard-Neilsen, 2008) have shown reduced individual crop yields under intercropping compared to sole cropping regimes.

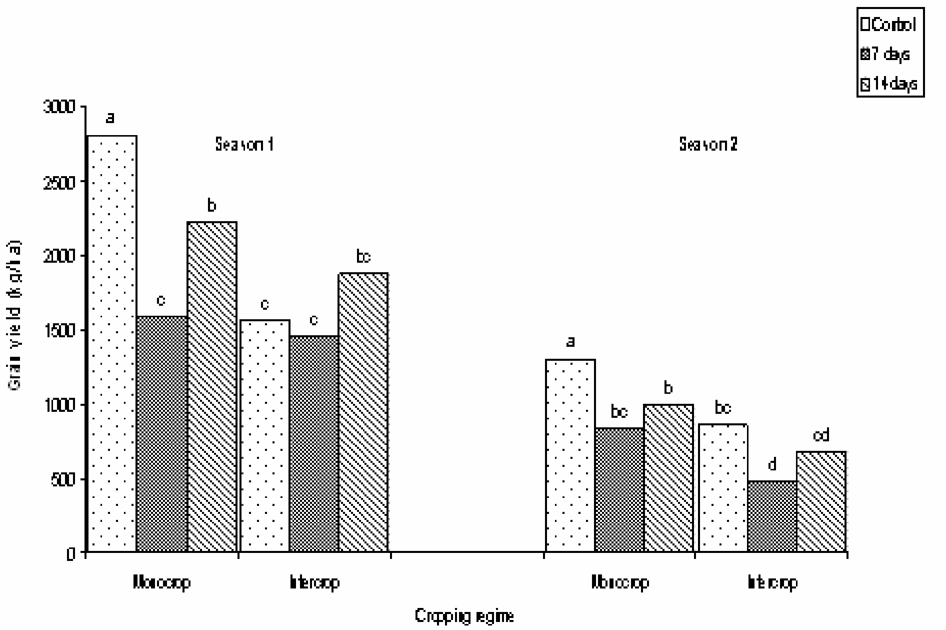

Fig-2. Dual-purpose cowpea grain yield as influenced by cropping regime and cowpea leaf harvesting frequency. Within a season, bars with the same letter are not significantly different ($P \leq 0.05$).

Intercropping similarly reduced maize grain yields (Figure-3). Grain yields were highest in monocropped maize in both seasons. In the intercropped treatments, maize grain yields were, however, significantly improved following harvesting of leaves of the companion cowpea at the vegetative stage of the crop. Maize grain yields tended to increase with increase in cowpea leaf harvesting frequency. Harvesting leaves of the companion cowpea every 7-days resulted in highest improvement in maize grain yields with lowest maize grain yields obtained where maize was intercropped with non-leaf harvested cowpea in both seasons (Figure-3). Harvesting leaves from cowpea plants reduces on cowpea canopy which could have minimized between-species competition for growth resources in favour of maize. Coupled with this, leaf harvesting also minimized shading effects of cowpea on maize early in the season, favouring early maize growth and subsequent grain formation. Similarly, Nyeko *et al.* (2004) recorded an increase in total biomass of maize with defoliation of a companion alder (*Alnus acuminate*) crop compared to maize grown in association with non-defoliated alder.

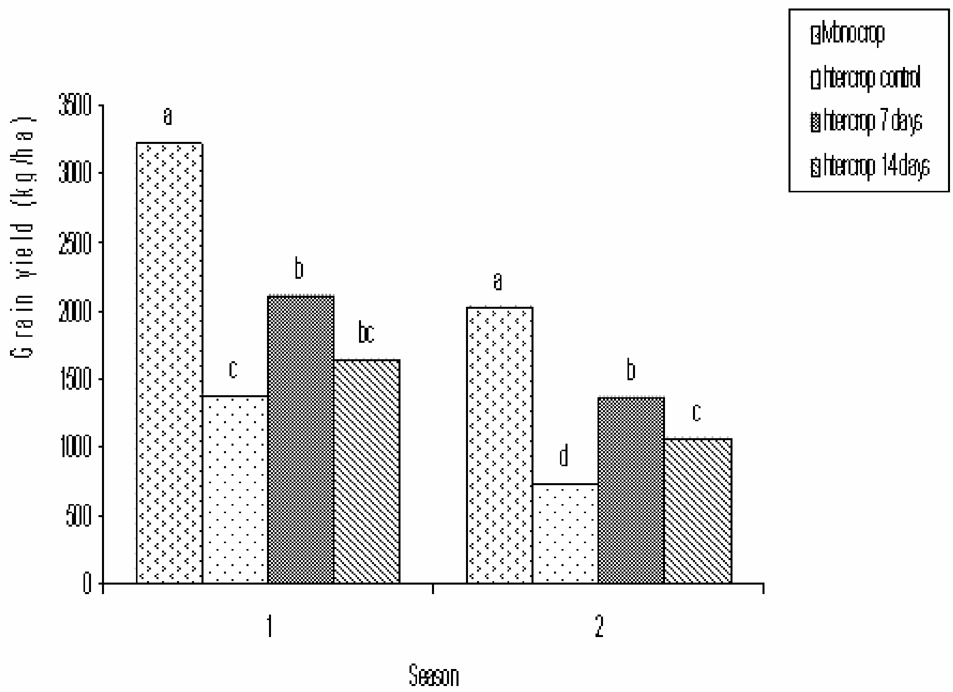

Fig-3. Effects of cowpea leaf harvesting frequency on grain yield of a companion maize crop in a dual-purpose cowpea-maize intercrop. Within a season, bars with the same letter are not significantly different ($P \leq 0.05$)

Profitability

The costs, revenue and profits by LHF and CR are presented in Table-1. Labour costs included the 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 LHF due to differences in the cost of planting, cowpea leaf harvesting and cowpea and maize grain harvesting and threshing. Profitability was influenced by LHF and CR in both seasons. In both sole and intercropping regimes, profitability was influenced by the frequency with which cowpea leaves were harvested. Generally, profitability tended to increase with LHF. Gross margins were highest when cowpea leaves were harvested at 7-days interval and lowest in control treatments where no leaf harvesting was done in both cropping regimes. In this study, harvesting leaves for use as leaf vegetables not only increased yields per unit area of land but also created diversification in produce and increased economic returns. At any given LHF, gross margins were higher under intercropping than sole cropping in both seasons, probably due to greater yield stability (Wiley and Reddy, 1981).

In both sole and intercrop regimes, profitability showed positive correlation with leaf vegetable and grain yields. Correlation coefficients for profitability and yields were 0.44 and 0.64 for leaf vegetable and grain yields, respectively in sole cowpea. Cowpea leaf vegetable and grain yields showed a weak negative correlation; correlation coefficient of -0.32 ($P = 0.34$). No multicollinearity was detected between leaf vegetable and cowpea grain yields. The model with only cowpea grain yield as the independent variable could explain only 41 % of variability in profitability ($R^2 = 0.41$). Including both leaf vegetable and grain yields in the model explained 87 % of variability in profitability ($R^2 = 0.87$). The fitted multiple regression equation for profitability in Ksh. cowpea leaf vegetable and grain yields in kg was;

Profitability = $44248 + 18.5_{\text{leaf vegetable yields}} + 28.7_{\text{grain yields}}$

VOL. 5, NO. 5, SEPTEMBER 2010 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

Table-1. Gross margin analysis for dual-purpose sole cowpea and cowpea-maize intercrop as influenced by cowpea leaf harvesting frequency.

Treatment	**Production variables** (Kshs.)			**Revenues** (Kshs)				Gross Margins (Kshs)
	Labour Costs	Other Cost	Total Cost	Cowpea Leaf	Cowpea Grain	Maize Grain	Total Revenue	
				Season 1				
Sole crop								
Control	32976	15747	48723	0	168276	0	168276	119553
7 days	38711	15747	54458	100840	95118	0	195958	141500
14 days	33923	15747	59671	49040	132990	0	182030	132359
Sole crop means			**50950**				**182088**	**131138**
Intercrop								
Control	34617	19302	53919	0	93600	55220	148820	94901
7 days	41497	19302	60800	89448	87108	84576	261132	200332
14 days	36745	19302	56048	41760	112332	65788	219880	163832
Intercrop Mean			**56923**				**209944**	**153021**
				Season 2				
Sole crop								
Control	31016	15747	46762	0	104224	0	104224	57462
7 days	33966	15747	49713	77700	66704	0	144404	94691
14 days	31932	15747	47680	45600	79248	0	124848	77169
Sole crop means			**48052**				**124492**	**76440**
Intercrop								
Control	33230	19302	52532	0	68432	39985	108417	55885
7 days	37009	19302	56312	65630	38272	74921	178823	122512
14days	34193	19302	53496	32960	54184	58097	145241	91744
Intercrop mean			**54115**				**144160**	**90045**

In cowpea-maize intercrop, correlation coefficients for profitability and cowpea leaf vegetable, cowpea grain and maize grain yields were 0.90, 0.52 and 0.96, respectively. Maize grain yield, however, strongly positively correlated with cowpea leaf vegetable yields with a correlation coefficient of 0.83 ($P = 0.039$). Including both maize grain yield and cowpea leaf vegetable yield in the multiple regression model caused multicollinearity as indicated by high a Condition Index value (27.3). The regression model with cowpea grain and maize grain yield as independent variables had R^2 of 0.93 and RMSE of 17540. The model with cowpea leaf vegetable and cowpea grain yields had much higher R^2 of 0.98 and lower RMSE of 7423.6 and was selected as final recommended model for predicting the relationship between profitability and leaf vegetable and grain yields. The fitted multiple regression equation for profitability as the response variable and cowpea leaf vegetable and grain yields as the independent variables was;

Profitability = $31057 + 52.3_{\text{leaf vegetable yields}} + 39.7_{\text{cowpea grain yields}}$

These findings indicate the possible contribution that the leaf vegetable component of yields of a dual-purpose cowpea can make in boosting the economic returns of cowpea-based production system if cowpea in such systems is given a dual-purpose status.

Based on the findings of this study, it can be concluded that harvesting cowpea at 7-days interval give higher leaf vegetable yields but higher grain yields are obtained when no leaf harvesting is done to the crop at its vegetative phase. Harvesting of leaves of a companion cowpea crop improves on maize yields of a cowpea-maize intercrop. Profitability of a sole dual-purpose cowpea or a dual-purpose cowpea-maize intercrop is increased by harvesting of cowpea leaves for use as vegetables, with the increment being highest when leaf harvesting is done at 7-days interval. Although our study provides a good foundation to understanding the effects of cowpea leaf harvesting frequency on yields and profitability of dual-purpose cowpea-based cropping systems, additional studies using different varieties/cultivars, leaf harvesting frequencies, cowpea-based cropping systems and in different agro-ecological zones would also be useful.

ARPN Journal of Agricultural and Biological Science

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

Barrett R.P. 1990. Legume species as leaf vegetables. In: J. Janick and J.E. Simon (Ed.). Advances in new crops. Portland, OR; Timber Press. pp. 391-396.

Bubenheim D.L, C.A. Mitchell and S.S. Nielsen. 1990. Utility of cowpea foliage in crop production for space. In: J. Janick and J.E. Simon (Ed.). Advances in new crops. Timber Press. pp. 535-538.

FAO - UNESCO. 1990. Soil map of the world. Revised legend. World Resources. Report 60. FAO, Rome, Italy.

Filho J.M.L. 2000. Physiological responses of maize and cowpea to intercropping. Pesq. Agropec. Bras. Brasillia. 35(5): 915-921.

Hallensleben M, S. Polreich, J. Heller, B.L. Maass. 2009. Assessment of the importance and utilization of cowpea (Vigna unguiculata L. Walp.) as leafy vegetable in small-scale farm households in Tanzania-East Africa. Paper presented at the Conference on international research on food security, natural resource management and rural development. University of Hamburg, Tropentag. October 6-8th.

Hauggaard-Nielsen H, B. Jørnsgaard, J. Kinane and E. S. Jensen. 2008. Grain legume-cereal intercropping: The practical application of diversity, competition and facilitation in arable and organic cropping systems. Renewable Agriculture and Food Systems: 23(1): 3-12.

Karikari S.K and G. Molatakgosi. 1999. Response of cowpea (*Vigna unguiculata* (L) Walp) varieties to leaf harvesting in Botswana. UNISWA Journal of Agric. 8: 5-11.

Keller G.B. 2004. Afrian Nightshade, eggplant, spider flower *et al*., - production and consumption aspects of traditionl vegetables in Tanzania from the farmers' point of view. Goettingen: Georg-August Universitat, Germany. MSc. Thesis.

Korir N.K, 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.

Midya A, K. Bhattacharjee, S. S. Ghose, and P. Banik. 2005. Deferred Seeding of Blackgram (*Phaseolus mungo* L.) in Rice (*Oryza sativa* L.) Field on Yield Advantages and Smothering of Weeds. Journal of Agronomy and Crop Science. 191: 195-201.

Natarajan M. 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. pp.180-187.

Nielsen S.S, 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

Nyeko P. 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 Journal. 12(4): 369-381.

Rusinamhodzi L.I, H.K. Murwira and J. Nyamangara. 2006. Cotton-cowpea intercropping and its N_2 fixation capacity improves yield of a subsequent maize crop under Zimbabwean rain-fed conditions. Plant and Soil. 287(1-2): 327-336.

Said M and F.M. Itulya. 2003. Intercropping and nitrogen management effects on diamondback moth damage and yields of collards in the highlands of Kenya. African Crop Science.11(1): 35-42.

Saidi M, 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.

SAS Institute. 2002. SAS Release 9.1. SAS Institute, Cary.

Singh B.B, H.A. Ajeigbe, S.A. Tarawali, S. Fernandez-Rivera and M. Abubaka. 2003. Improving the production and utilization of cowpea as food and fodder. Field Crops Research. 84: 169-177.

Tekele E. 2001. Loose-leaf lettuce production sample cost and profitability analysis. University of California Agricultural and Natural Resource Publication No. 8031.

Wein H.C. and T.O. Tayo. 1978. The effect of defoliation and removal of reproductive structure on growth and yield of tropical grain legumes. P. 241-252 In: S.R. Singh, H.F. Van Emden and T.A Taylor (Eds), Pests of Grain Legumes: Ecology and Control. Academic Press. London and New York.

Wiley R.W 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.