ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Journal of Agronomy 10 (4): 112-117, 2011
ISSN 1812-5379 / DOI: 10.3923/ja.2011.112.117

Physiological and Economic Implications of Leaf Harvesting on Vegetative Growth and Cormel Yield of Cocoyam (*Xanthosoma sagittifolium*)

[1]H. Asumadu, [1]E.L. Omenyo and [2]F. Tetteh
[1]CSIR-Crops Research Institute, P.O. Box 3785, Kumasi, Ghana
[2]CSIR-Soils Research Institute, Academy Post Office, Kwadaso, Kumasi, Ghana

Abstract: Cocoyam leaves contain a lot of minerals, vitamins, thiamine and proteins and are used as nutritious spinach in Ghana. The underground cormels which are the major economic part provide easily digestible starch and are often used as substitute for yams and plantains when these become scarce in the dry season. The objectives of the investigation was to determine the effect of leaf harvest on plant growth and cormel yield of cocoyam and also to determine the appropriate age or stage of crop development to start leaf harvest and frequency of harvesting that will result in optimum cormel yield. The stages or times harvesting of leaves began were 12, 16 and 20 Weeks After Planting (WAP) and the frequency of harvesting were 2, 3 and 4 weekly intervals. Delayed harvesting at 20 WAP produced significantly ($p<0.05$) more fresh cormels than 12 WAP. Leaf harvest beginning from 20 WAP produced higher cormel yield than early harvesting at 12 and 16 WAP by 39 and 11%, respectively. Corm yield differences between the three harvesting times were not significant. Cormel and corm yield differences between frequencies of leaf harvest were also not significant. There were significant positive correlation between plant height, leaf area, number of leaves and cormel yield. The Marginal Rate of Return (MRR) of changing from harvesting at 20 WAP at 4 weekly intervals to 3 weekly intervals and subsequently to 16 WAP at 2 weekly intervals were 424 and 521%, respectively. These MRR are above the minimum acceptable rate of return and therefore the two options are more likely to be accepted by farmers.

Key words: Cocoyam leaf, cormel, partial budget, net benefits, marginal rate of return

INTRODUCTION

Cocoyams are plants of the tropical rain forest and although in their natural habitat they grow under the forest canopy, under cultivation they are usually sown with full exposure to sunlight (Giacometti and Leon, 1994). Since cocoyam tolerates shade, the crop is frequently grown in intercropping systems together with perennial crops such as banana, coffee, coconut, rubber, oil palm and cocoa (Wilson, 1984a). The corm and cormels of cocoyam which are the major economic part contains about 15 to 39% carbohydrates, 2 to 3% protein and 70 to 77% water. The young leaves contain 2% protein and are also rich in vitamin C, thiamine, riboflavin, niacin, calcium, phosphorus and iron (Ndon *et al.*, 2003). It has a nutritional value comparable to potato but easier to digest (Sefa-Dedeh and Sackey, 2002).

In Ghana the cormel is used as substitute for yams and plantain for the preparation of various dishes especially in the dry season. The young leaves are also widely used as spinach in the preparation of stews or sauces. In a socioeconomic survey conducted by Quaye *et al.* (2010), they found out that majority of the farmers in Ghana cultivated cocoyam for both the cormel and leaf, but very few of them cultivated it purposely for the cormels. The crop which is mainly grown in the forest areas of Ghana is threatened with environmental problems such as deforestation. Decreasing rainfall and poor soils have also been identified as some of the causes of the decline in cocoyam production in the country (Sagoe, 2006). The crop is generally grown by small-scale farmers with no intensive management such as fertilization and the use of improved varieties for commercial cormel and cocoyam leaf production. Production and the area planted to the cocoyam are on the decline since 2001 to 2006. The mean annual growth rates for area planted and production during the period were 0.2 and 0.3%, respectively (Ministry of Food and Agriculture, 2010).

Cocoyam plant development consists of three major stages namely plant establishment (from planting to about 2 months after planting), rapid vegetative growth (2-5 months) and a third stage (after 5 or 6 months)

Corresponding Author: H. Asumadu, CSIR-Crops Research Institute, P.O. Box 3785, Kumasi, Ghana
Tel: +233 24 454 3369 Fax: +233- (0)51-60142/60396

characterized by tuber development and maturation (Adiobo *et al*., 2011). The leaves and cormels which play major roles in the diet of Ghanaians need proper development to sustain the plant. Adoption of technical innovation by farmers demands precise and detailed information on cost and return so that farmers can choose the right combination of resources or enterprises. (Das *et al*., 2010). It became necessary therefore to find out the right time to start harvesting cocoyam leaves and at what frequency for optimum economic gains. The objectives of this investigation was to assess the effect of leaf harvesting on growth, development and cormel yield of cocoyam and to determine the appropriate age or stage of crop and frequency of leaf harvest for maximum economic returns.

MATERIALS AND METHODS

The trial was planted at the Fumesua Station of the Crops Research Institute (CRI), Ghana on 27th May 2010 on a well-drained Ferric Acrisol (FAO/UNESCO Legend) and Paleustult (U.S. Dept. of Agriculture Soil Taxonomy). A local planting material from Fanteakwa District of the Eastern region of Ghana was used as planting material. The experimental design used was Randomized Complete Block with 3 replications. Data was initially analyzed as 3x3factorial experiment with time to start harvesting and frequency of harvesting as the two factors. It was also analyzed as a two way ANONA by including a tenth treatment of no leaf harvesting as a control for the economic analysis. The treatment combinations were as follows:

- Start leaf harvesting at 12 WAP at 2 weeks intervals
- Start leaf harvesting at 12 WAP at 3 weeks intervals
- Start leaf harvesting at 12 WAP at 4 weeks intervals
- Start leaf harvesting at 16 WAP at 2 weeks intervals
- Start leaf harvesting at 16 WAP at 3 weeks intervals
- Start leaf harvesting at 16 WAP at 4 weeks intervals
- Start leaf harvesting at 20 WAP at 2 weeks intervals
- Start leaf harvesting at 20 WAP at 3 weeks intervals
- Start leaf harvesting at 20 WAP at 4 weeks intervals
- No leaf harvest until harvest maturity of cormels

Plot size was 4 rows 5 m long with plant spacing of 1×1 m. No. fertilizer was applied as the field had been followed for more than 10 years. Data collected included soil chemical and physical properties at planting time. Plant height (cm) was measured from the ground level to the shoot apex. Leaf area was estimated periodically using the mathematical model developed by Agueguia (1993) between linear measurements of leaves. It relates leave area (Y) to the product of Length (L) and Breath (B):

$$Y = K\ (LB) \tag{1}$$

Finally, data was collected on stem girth, fresh corm and cormel yields at harvest. Genstat 5 Release 3.2 (PC/Windows 95) was used for all statistical analyses. Where the ANOVA showed significant differences ($p<0.05$) of variables (e.g., plant height, leaf area, cormel yield, etc.) between treatments the Standard Error of Difference of means (SED) were used to compare between treatments. Partial budgeting was used to calculate the total costs that vary, gross and net benefits of the various treatments. Cormel and leaf yields were adjustment down by 10% to conform to farmers' management before calculation of gross benefit. The Marginal Rate of Return (MRR) was calculated as the marginal net benefit (i.e., the change in net benefits between treatments) divided by the marginal cost (i.e., the change in costs), expressed as a percentage (CIMMYT, 1988). Recommendation was made based on the agronomic results and the comparisons of the rates of return between treatments to the minimum rate of return acceptable to farmers.

RESULTS

Soil analyses at the site indicated moderate levels of nitrogen (0.13-0.15%), organic matter (2.12-2.33%) and potassium (70.3-87.04 ppm). Phosphorus level was however low at 6.38-14.35 ppm (Royal Tropical Institute, 1984). The soil physical properties indicated that the texture was sandy loam with 62.5% sand, 15.5% silt and 22% clay.

Plant height and number of leaves per plant were significantly ($p<0.05$) lower when leaf harvest began earlier than 20 Weeks After Planting (WAP). However, this differences diminished towards harvest maturity at 67 DAP resulting in similar leaves and petiole weights (Table 1). Frequency of leaf harvest did not significantly change plant height and number of leaves per plant, however, at harvest maturity, weight of leaves and petioles was higher for less frequent leaf harvest, i.e., 4 weekly intervals (Table 1).

There was the tendency for leaf area to increase when leaf harvest was delayed till 20 WAP but this was significant ($p<0.05$) only at 44 WAP. Likewise, there was the tendency for less frequent leaf harvest (4 weekly intervals) to produce larger leaf areas but it was

Table 1: Effect of leaf harvesting on plant height, number of leaves per plant and weight of leaves and petioles per plant

	Plant height (cm)		No. of leaves per plant	Wt. of leaves and) petioles/plant (kg)
Factor	33 WAP	67 WAP	44 WAP	67 WAP
Time				
12 WAP	44.5	47.3	0.60	2.40
16 WAP	51.0	47.9	0.90	2.50
20 WAP	52.0	49.6	1.30	2.60
Frequency				
2 weeks	48.1	47.4	0.90	2.10
3 weeks	49.1	47.2	0.90	2.70
4 weeks	50.3	50.3	1.00	2.80
Mean	49.2	48.3	0.90	2.50
S.E.D.	03.06	03.67	0.20	0.19

Table 2: Effect of leaf harvesting on leaf area per plant (cm^{-2}) at 24, 42, 44, 61 and 63 WAP

Factor	24 WAP	42 WAP	44 WAP	61 WAP	63 WAP
Time					
12 WAP	1772	1602	628	2212	2382
16 WAP	1984	2024	1122	2770	2999
20 WAP	2050	2290	1394	3096	3202
Frequency					
2 weeks	1871	1955	994	2431	2157
3 weeks	1961	1978	974	2758	2888
4 weeks	1973	1984	1176	2889	3537
Mean	1935	1972	1048	2693	2861
S.E.D.	262	448	300	531	516

Table 3: Effect of leaf harvesting on number of cormels per plant, cormel yield and corm weight, Corm diameter and Corm length

Factor	No. of cormels per plant	Cormel yield (kg ha^{-1})	Corm weight (kg ha^{-1})	Corm diameter (cm)	Corm length (cm)
Time					
12 WAP	3.1	3467	5500	6.0	13.2
16 WAP	4.6	4611	7055	5.9	15.0
20 WAP	5.8	5111	7111	6.1	14.2
Frequency					
2 weeks	4.1	3833	6222	6.0	14.2
3 weeks	4.7	4778	6444	6.1	14.9
4 weeks	4.8	4778	7000	6.0	13.3
Mean	4.5	4463	6555	6.0	14.1
S.E.D.	0.87	804	830	0.34	1.27

significant ($p<0.05$) only at 63 WAP (Table 2). Delayed (20 WAP) and less frequent harvesting (4 weekly intervals) produced and maintained their larger leaf areas for longer durations even at 44 WAP when environmental conditions were not favorable for high leaf production (Fig. 1 and 2).

Delayed harvesting at 20 WAP produced significantly ($p<0.05$) more fresh cormels and cormel yield (kg ha^{-1}) than 12 WAP but fresh corm yield differences were not statistically significant. (Table 3). Delayed leaf harvesting at 20 WAP produced higher cormel yield than early harvesting at 12 and 16 WAP by 47 and 11%, respectively. Cormel and corm yield differences between frequencies of leaf harvest were not significant. Time and frequency of leaf harvesting did not affect corm length and diameter (Table 3).

There were no significant interactions between time to begin leaf harvest and frequency of leaf harvest. There were significant positive correlation between plant height, leaf area, number of leaves and cormel yield (Table 4).

Cormel yield for no leaf harvest (6333 kg ha^{-1}) was higher than all the other treatment combinations (Table 5). It was 217% higher than the yield (2000 kg ha^{-1}) of the earliest (12 WAP) and more frequent leaf harvest (2 weekly intervals). On the contrary, marketable leaf yield (2019 kg ha^{-1}) was highest from the latter option and zero for the former option. Obviously, the no leaf harvest option also had zero cost that vary while the earliest and more frequent leaf harvest option had the highest cost that vary of GH¢325.00. No leaf harvest however, gave the lowest net benefit of GH¢1824.00 while leaf harvesting at 16 WAP at a frequency of two weekly intervals gave the highest net benefit of GH¢3065.32 (Table 5). The marginal rate of return MRR for changing from beginning leaf harvest at 20 WAP at 4 weekly intervals to 3 weekly intervals and subsequently to 16 WAP at 2 weekly intervals were 424 and 521%, respectively (Table 6).

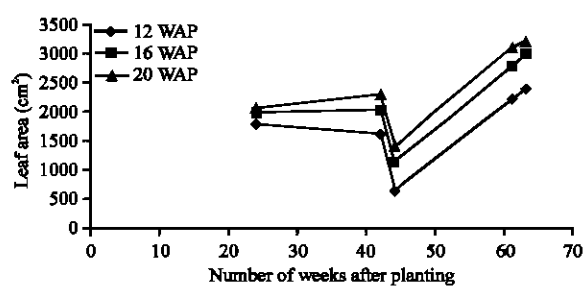

Fig. 1: Time courses of leaf area (cm^2) of three different times (12, 16 and 20 WAP) of commencement of leaf harvest in cocoyam

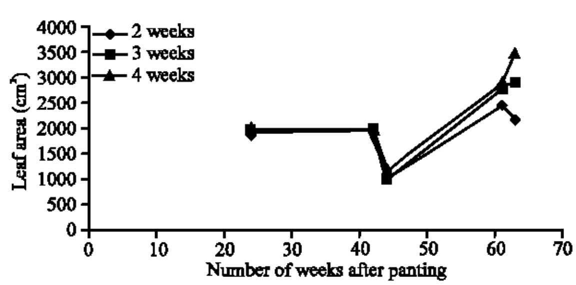

Fig. 2: Time courses of leaf area (cm^2) of three different frequencies (2, 3 and 4 weekly intervals) of leaf harvest in cocoyam

Table 4: Correlation matrix between vegetative and reproductive structures

	Cormel yield (kg ha^{-1})	Leaf area (cm^2)	Plant height (cm)	No. of leaves /plant	Corm yield (kg ha^{-1})	Leaves and petioles weight/plant
Cormel yield (kg ha^{-1})	0					
Leaf area (cm^2)	0.655***	0				
Plant height (cm)	0.701***	0.878***	0			
No. of leaves/plant	0.592**	0.837***	0.581**	0		
Corm yield (kg ha^{-1})	0.664***	0.863***	0.863***	0.658***	0	
Leaves and petioles weight/plant	0.631***	0.807***	0.903***	0.509**	0.802***	0

**p<0.001; ***p<0.0001

Table 5: Partial budget for the treatment combinations

	Treatments									
	Start leaf harvest at 12 weeks			Start leaf harvest at 16 weeks			Start leaf harvest at 20 weeks			No leaf harvest
Parameter	1	2	3	4	5	6	7	8	9	10
Freq. of leaf harvest (wks)	2	3	4	2	3	4	2	3	4	0
Cormel Yield (kg ha^{-1})	2000	4167	4833	5667	4500	3667	3833	5667	5833	6333
Leaf yield (kg ha^{-1})	2019	1398	1086	1709	1243	933	1399	1087	777	0
Gross benefit (GH¢ ha^{-1})	2594.00	2598.01	2478.90	3340.32	2538.00	1988.10	2502.00	2719.32	2457.00	1824.00
Total Cost that vary (GH¢ ha^{-1})	325.00	225.00	175.00	275.00	200.00	150.00	25.00	175.00	125.00	-
Net benefit. (GH¢ ha^{-1})	2269.00	2373.00	2303.90	3065.32	2338.00	1838.00	2277.00	2544.32	2332.00	1824.00

Data for partial budget. Field price of cocoyam cormel = GH¢ 0.32 kg^{-1}, Field price of cocoyam leaves = GH¢ 1.11 kg^{-1}, Cost of harvesting cocoyam leaves = GH¢ 25.00 ha^{-1}, Minimum rate of return = 100%, Cormel and leaf yields were adjustment down by 10% to conform to farmers' management before calculation of gross benefit

Table 6: Marginal analysis of un-dominated treatments

Treatments	Total cost that vary	Marginal cost	Net benefit	Marginal net benefit	Marginal rate of return (%)
Start harvest at 20 WAP at 4 weekly intervals	125.00	-	2332.00	-	-
Start harvest at 20 WAP at 3 weekly intervals	175.00	50.00	2544.00	212.00	424
Start harvest at 16 WAP at 2 weekly intervals	275.00	100.00	3065.00	521.00	521

DISCUSSION

Majority of cocoyam farmers in Ghana cultivate the crop for both the cormel and leaves, but very few of them cultivate it purposely for the cormels. However, the bulk of the returns from their investment is realized when the cormels are ultimately harvested after one year. Harvesting of leaves are therefore scattered so as not to affect cormel yield and also harvest frequency widely separated to get tender fresh leaves weekly (Quaye *et al*., 2010).

Results from the present investigation showed that delayed harvesting at 20 WAP produced more number of fresh cormels than early harvesting and cormel yield was also higher than early harvesting at 12 and 16 WAP by 47 and 11%, respectively (Table 3). These results are similar to those obtained by Safo Kantanka *et al*. (1987) who worked on the effect of leaf harvesting and spacing on the yield of Xanthosoma sagittifolium and colocasia esculenta in Ghana. They found out that leaf harvesting of X. sagittifolium resulted in a significant reduction in cormel yield. Alternate (i.e., harvesting of every other new leaf) and complete defoliation (harvesting all new leaves) reduced cormel yields by 31.4 and 58.6%, respectively. Corm and cormel size were not affected by leaf harvesting as observed in the present investigation (Table 3). Similarly, Olasantan (1990) investigating the response of cocoyam, *Xanthosoma sagittifolium* (L.) Schott, to row arrangement, maize intercrop and frequency of young leaf harvest observed that without defoliation the pink and white fleshed cultivars yielded 10.9 and 11.0 t marketable tubers ha^{-1}, respectively. However, leaf removal every 2 weeks reduced yields to 4.8 and 5.6 t, respectively but leaf removal every 3 weeks had little effect.

It was also observed in the present work that early and more frequent leaf harvest reduced vegetative growth (i.e., plant height, leaf area, etc.,) at some stages of the crop development (Table 1 and 2) and these had strong positive correlation with yield (Table 4). The longer cocoyam leaf area is retained on the plant the higher its opportunity for assimilation. Figure 1 and 2 show that delayed (20 WAP) and less frequent harvesting (4 weekly intervals) produced and maintained their larger leaf areas for longer durations which resulted in higher cormel yields (Table 3). The relationship between Leaf Area Index (LAI), leaf area duration (LAD) and yield of cocoyam had been studied by Igbokwe (1984) and Wilson (1984b). They all reported similar observations that LAI and LAD were closely related to yield and that there was a strong positive correlation between corm or cormel yields and leaf area. Adiobo *et al*. (2011) have also reported positive correlations between leaf area index, plant height, number of leaves and cormel yield which is in agreement with the findings of the present investigation (Table 4).

Igbokwe (1984) worked on growth and development of Colocasia and Xanthosoma spp. under upland conditions and observed that leaf production and cormel bulking peaked at 16-20 and 26 WAP, respectively. Farmers in the forest areas of Ghana are aware of the growth stages of cocoyam and normally harvest cocoyam leaves when cormels mature after one year so as not to decrease cormel yield (Quaye *et al*., 2010). The question is whether farmers will make more economic gains if they start harvesting earlier at the second stage so that they can make more money by selling cocoyam leaves to compensate for the little loss they will incur from the cormel yield. As observed in this investigation when harvesting began after 16 WAP (4 months) cormel yield difference was just 11% compared with 20 WAP. However, there were no cormel yield differences when harvesting was done at a frequency of 2, 3 and 4 weekly intervals (Table 3).

Data on cost of production and return are of special interest to farmers since they reveal the input output relationship of their enterprises and bring out the differences in unit cost between the less efficient and more efficient farm enterprises. The partial budget for the various treatments showed that no leaf harvest treatment obviously had no cost that vary while the earliest (12 WAP) and more frequent leaf harvest (2 weekly intervals) treatment had the highest cost that vary of GH¢325.00. No leaf harvest however, gave the lowest net benefit of GH¢1824.00 because there was no income from cocoyam leaves. Leaf harvesting beginning from 16 WAP at a more frequent leaf harvest of two weekly intervals gave the highest net benefit of GH¢3065.32 (Table 5).

Treatments which had net benefits less than or equal to those of treatments with lower costs that vary were eliminated because they were dominated and do not represent a feasible option to the farmer or producer. From table 5, it is clear that only three options were not dominated and therefore were subjected to marginal analysis (Table 6). The marginal analysis revealed that if leaf harvest began at 20 WAP at 3 weekly intervals and at 16 WAP at 2 weekly intervals they were beneficial. They gave marginal rates of return of 424 and 521%, respectively. This means that for each GH¢100 ha^{-1} on average invested in harvesting cocoyam leaves at 20 WAP at 3 weekly intervals by a farmers who previously was harvesting at 4 weekly intervals, they will recover their GH¢100, plus an extra GH¢ 424 ha^{-1}. Similarly, for each GH¢100 ha^{-1} on average invested in harvesting cocoyam leaves at 16 WAP at 2 weekly intervals, by farmers who previously harvested cocoyam leaves at 20 WAP at 3 weekly intervals, then they will recover their GH¢100, plus an extra GH¢ 521 ha^{-1}. Experience and empirical evidence have shown that for the majority of situations the minimum rate of return acceptable to farmers will be between 50 and 100% (CIMMYT, 1988). Therefore, the two options with MRR above the acceptable rate of return are more likely to be accepted by farmers.

CONCLUSION

Early (12 WAP) and more frequent (2 weekly intervals) leaf harvest reduced vegetative growth and cormel yield of cocoyam. This meant that if leaves were removed early and more frequently from the plant, source (leaves) strength was decreased and therefore photosynthate accumulation into the sink (corm and cormels) was also decreased. However, if cocoyam plants are not completely defoliated but one tender leaf is harvested at a time as done in the present investigation, the optimum time to begin leaf harvest and frequency of harvest which gave the highest cash returns was 16 WAP at 2 weekly intervals.

ACKNOWLEDGMENT

We are grateful to the West Africa Agricultural Productivity Programme (WAAPP) for providing funds for this work. Our special thanks also go to technicians of the Roots and Tubers Division of the Council for Scientific and Industrial Research - Crops Research Institute for data collection and performance of other field operations.

REFERENCES

Adiobo, A., X. Ndzana and M. Hofte, 2011. COCOYAM (*Xanthosoma sagittifolium*). Jay PJ Biotechnology Laboratory, Institute of Agricultural Research for Development (IRAD), Ekona, Cameroon and Laboratory of Phytopathology, Department of Crop Protection, Ghent University, Belgium.

Agueguia, A., 1993. Non-destructive estimation of leaf area in Cocoyam (*Xanthosoma sagktifolium* [L.] Schott). J. Agron. Crop Sci., 171: 138-141.

CIMMYT, 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely Revised Edn., CIMMYT Economics Program, Mexico, DF., ISBN-10: 9686127186, pp: 79.

Das, A., M. Biswas and N. Mandal, 2010. An economic analysis of stevia (*Stevia rebaudiana* Bert.) cultivation through stem cutting and tissue culture propagule in India Trends Agric. Econ., 3: 216-222.

Giacometti, D.C. and J. Leon, 1994. Tannia, Yautia (*Xanthosoma sagittifolium*). In: Neglected Crops: 1492 from a Different Perspective, Bermejo, J.E.H. and J. Leon (Eds.). Food and Agriculture Organization, Rome, Italy, ISBN-13: 9789251032176, pp: 253-258.

Igbokwe, M.C., 1984. Growth and Development of *Colocasia* and *Xanthosoma* spp. Under Upland Conditions. In: Tropical Root Crops: Production and Uses in Africa, Terry, E.R., E.V. Doku, O.B. Arene and N.M. Mahungu (Eds.). International Development Research Centre, Ottawa, Canada, ISBN-13: 9780889364097, pp: 172-174.

Ministry of Food and Agriculture, 2010. Agriculture in Ghana. Facts and figures (2009). The Statistics Research and Information Directorate, April 2010.

Ndon, B.A., N.H. Ndulaka and N.U. Ndaeyo, 2003. Stabilization of yield parameters and some nutrient components in cocoyam cultivars with time in Uyo, Southeastern Nigeria. Global J. Agric. Sci., 2: 74-78.

Olasantan, F.O., 1990. The response of cocoyam, *Xanthosoma sagittifolium* (L.) Schott, to row arrangement, maize intercrop and frequency of young leaf harvest. Contrib. Trop. Agric. Vet. Med., 28: 49-58.

Quaye, W., K. Adofo, K.O. Agyeman and F. Nimoh, 2010. Socioeconomic survey of traditional commercial production of cocoyam and cocoyam leaf. Afr. J. Food Agric. Nutr. Dev., 10: 4060-4078.

Royal Tropical Institute, 1984. Analytical Methods of the Service Laboratory for Soil, Plant and Water Analysis. Part I: Methods for Soil Analysis. Royal Tropical Institute, Amsterdam, The Netherlands.

Safo Kantanka, O., E.R. Terry, M.O. Akoroda and O.B. Arene, 1987. Effect of leaf harvesting and spacing on the yield of *Xanthosoma sagittifolium* and *Colocasia esculenta*. Proceedings of the 3rd Triennial Symposium of the International Society for Tropical Root Crops-Africa Branch, August 17-23, 1986, International Development Research Centre, Owerri, Nigeria.

Sagoe, R., 2006. Climate change and root crop production in Ghana. A Report Prepared for the Environmental Protection Agency (EPA), ACCRA, Ghana, Nigeria. http://www.nlcap.net/fileadmin/NCAP/Countries/Ghana/ROOT_TUBERS_DRAFT_FINAL_REPORT.pdf.

Sefa-Dedeh, S. and E.K.A. Sackey, 2002. Starch structure and some properties of cocoyam (*Xanthosoma sagittifolium* and *Colocasia esculenta*) starch and raphides. Food Chem., 79: 435-444.

Wilson, J.E., 1984a. Cocoyam. In: The Physiology of Tropical Field Crop, Goldsworthy, P.R. and N.M. Fisher (Eds.). John Wiley and Sons Ltd., New York and London, pp: 589-605.

Wilson, J.E., 1984b. Taro and Cocoyam, What is the Ideal Plant Type. In: Edible Aroids, Chandra, S. (Ed.). Oxford Clarendon Press, Oxford, UK., pp: 157-159.