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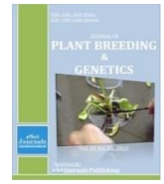

GENETIC VARIATION IN FOLIAGE AND PROTEIN YIELD OF SOME ELITE CASSAVA (*MANIHOT ESCULENTA* CRANTZ) GENOTYPES IN GHANA

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A B S T R A C T

Cassava (*Manihot esculenta* Crantz) contains high levels of proteins and minerals which can be utilized for human and animal consumption. A randomized complete block design with three replications was established to evaluate 25 cassava genotypes for their foliage and crude protein (CP) productivity as well as growth persistency under rain-fed conditions. The foliage comprising the leaves and the young tender stems were periodically harvested from 20cm above ground starting from three months after planting and every three months until root harvest at 12 months after planting. Apart from the first harvest, significant genotypic differences ($P \leq 0.05$) were established for foliage yield for the subsequent harvest days. The highest total cumulative fresh and dry foliage yields were 41.07t/ha and 15.73 t/ha respectively. Cumulative crude protein yield also ranged between 0.64 t/ha and 1.63 t/ha. Periodic pruning resulted in much higher foliage and protein yields than when the foliage was obtained only once at root harvest. Strong phenotypic correlations were observed among most of the different traits. Protein yield was observed to be highly correlated with fresh and dry foliage yield whereas a weak and non-significant correlation was recorded for protein content and all the other traits except with number of shoots and protein yield. Harvesting time also had a significant effect on foliage and crude protein yields with the second harvest giving a much higher foliage production for most of the genotypes. High heritability (broad sense) estimates were observed for most of the traits studied. These traits can be used to select genotypes for foliage and protein production.

Keywords: Cassava, (*Manihot esculenta* Crantz), heritability, crude protein, growth persistency.

INTRODUCTION

Cassava (*Manihot esculenta* Cranz) is a perennial tropical shrub grown for its starchy roots. It is the most important food security crop in Sub-Saharan Africa with more than 200 million people depending on it as their main staple (ACDI/VOCA, 2013). It is adapted to areas with relatively marginal soils and erratic rainfall conditions and can thrive well in areas where most crops will fail. The crop grows well at high elevations of not more than 2000 m above sea level and prefers a temperature range of 18^0C to 25^0C and an annual rainfall of 500 – 5,000 mm which is uniformly distributed throughout the year (Cock and Rosas, 1975). Though predominantly used as a human food in the boiled, baked, or in numerous processed forms (Lancaster *et al.,* 1982), there is also an emerging market for the crop as an industrial crop. As at 2011, Ghana was the 7th highest producer of cassava in the world and third in Africa (FAO, 2013). The crop has long been estimated to contribute up to 22% of Ghana's agricultural gross domestic product (AGDP) which is higher than any other crop including cocoa (Safo-Kantanka, 2004).

Root tuber yield and its characteristics are the most important goal of cassava breeding and ranks high in the choice of variety by farmers. Nweke *et al*. (1994) through a collaborative study identified early maturity, high root yield and good cooking quality among other traits as important goals of cassava breeding in Africa. Thus genotypes that failed to meet these objectives were often rejected at the initial stages of a breeding

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programme. Apart from the roots serving as a good source of carbohydrates for human and animal consumption (Wargiono *et al*. 2007), the foliage comprising the leaves and young tender stem contain good sources of protein, vitamins (Ravindran, 1991) and high levels of minerals and carotenoids (Ceballos, 2003). Except low levels of methionine, the amino acid profile of cassava leaves compares favourably with most leafy vegetables and to some extent high than that of soybean meal (Eggum 1970). The use of cassava leaves as a major source of protein, vitamins and minerals has been reported in certain parts of Africa (Bokanga, 1994). According to Preston and Rodriguez (2004) the crop can be managed as perennial forage and harvested to feed ruminants and pigs with no decline in performance. This implies that there is the potential for cassava foliage to be utilized in human and animal consumption to provide cheap sources of feed for livestock. However since the root tuber yield is the desired goal of cassava breeding, the suitability of cassava variety as a foliage producer depends on its ability to tolerate periodic pruning and give appreciable root yield. Most of the improved cassava varieties released in Ghana have been based on their root tuber yield attributes with little emphasis on their foliage production potential. No attempt has been made to explore the available cassava germplasm for foliage production ability. However there are reported cases of genetic variation in foliage production ability elsewhere. Ravindran (1991) reported significant genetic variation in terms of tolerance to periodic pruning. Limsila *et al*. (2007) however indicated that periodic harvesting of foliage at 20cm above ground starting from three months after sprouting and subsequently at three months intervals until harvesting at 12 months did not lead to any significant tuber yield reduction in some genotypes. Thus yield improvement can be achieved by exploiting the wide genetic variability that exist among cassava genotypes for root and shoot traits (Aina *et al*. 2007). In this study, cassava genotypes comprising nine released varieties, five advanced breeding lines and 11 elite local accessions were evaluated for their foliage protein production ability as well as recovery after pruning. The objectives were to: (1) assess the genotypic differences in foliage and protein yield; (2) assess the genotypic differences in foliage protein content; (3) assess the relationship between traits related to foliage and protein yield; and (4) assess the relationship between growth rate, frequency of foliage harvest and foliage yield.

MATERIALS AND METHODS

Genotypes and experimental conditions: The field work was carried out in the forest transition zone of Ghana. This zone is characterized by a bimodal rainfall with an average annual rainfall of 1200mm. The site was a fairly sloping ground with a well drained sandy clay loam soil. The experiment was carried out under rain-fed conditions during the 2004/2005 season. The study was conducted using eleven elite local cassava genotypes, nine advanced breeding lines and five already released varieties. The local genotypes were TCH 001, TCH 004, TCH 002, TANO 001, TANO 003, AWO 001, ADI 001, ADI 002, *Kyempo*, DMA 004, and *Adugyama* which were selected from a collection of cassava accessions being screened for early maturity and cooking quality. The five released varieties (*IFAD*, *Nkabom, Abasafitaa, Afisiafi* and *Gblemoduade*) were also under cultivation for various uses. These genotypes were arranged in a randomized complete block design with three replications. The land was slashed after which it was ploughed twice. Planting was done on the flat using a spacing of 60cm X 60cm. This is considered as the optimum spacing for optimum foliage production (Limsila *et al*. 2007). Each plot consisted of four rows of plants with 10 plants in a row. The plot size was thus 2.4mX6m giving a plant population of 27,778 plants/ha. Weeds were controlled as and when necessary.

Data collection: Measurement of growth rate (taken as change in plant height between subsequent measurements) was done at monthly intervals commencing at two months after planting (MAP) using a meter rule. Two central rows of each plot were chosen for the assessment. Height of regenerated shoots for each genotype was also taken prior to each harvesting to assess the relationship between the height at harvesting and the foliage yield. Cassava foliage (comprising the unlignified young stems, leaves and petioles) was hand harvested following Limsila *et al*. (2007). Subsequent harvestings were done at about 10cm above the previous cutting height. The foliage yields of the control plots were obtained by cutting the green tips of the matured stem at root harvesting. Fresh weights of the shoots were taken to determine the yield per plot in kilograms. Fresh foliage yield was then estimated in tons/ha.

Foliage protein analysis: The total nitrogen (%) of each of the samples was first determined according to the

Kjeldahl method for nitrogen determination (1990). The protein content was then computed using the formula;

$$Protein\ contents\ (\%) = N\ \times 6.25$$

Where N = % nitrogen in the sample.

Protein yield (t/ha) estimation: The protein yield (t/ha) for each of the genotypes was estimate as:

$$Protein\ Yield\ \left(\frac{t}{ha}\right) =$$

$$Dry\ foliage\ yield\ \left(\frac{t}{ha}\right) \times Protein\ contant\ of\ foliage\ (\%)$$

Statistical analysis: The data was subjected to analysis of variance (Anova) for randomized complete block design (RCBD) using the GenStat Release 9.2 (2007). A combined analysis was carried during the final harvest to ascertain effect of the different harvesting times on foliage and protein yield. Genotypic variance components for foliage yield were computed from the mean squares. Broad sense heritability was also estimated for the various determinants of foliage yield.

RESULTS

Total fresh and dry foliage yield: Genotypic variations were established for the different genotypes in terms of fresh and dry foliage yields (Table 1). Significant ($P \leq 0.05$) genotypic variations were also observed for both cumulative and dry foliage yields at each harvest except the 2nd harvest which recorded non significance ($P \geq 0.05$). Average dry foliage yield was found to be lower in the control compared to when the plants were pruned periodically. Periodic pruning gave an average dry foliage yield of 6.75 t/ha which is higher than the average yield obtained from the control (1.75 t/ha). *Dokuduade* gave the highest cumulative fresh and dry foliage yields of 41.07t/ha and 9.78t/ha respectively over the four harvests which were significantly higher ($P \leq 0.05$) than most of the other genotypes. The least cumulative fresh foliage yield of 15.23 t/ha was also recorded by 96/1569. However the least dry foliage yield of 3.58t/ha was obtained from *Agbelifia*. In the case of the control, the average fresh yield recorded was 5.71 t/ha which was significantly higher than the 2nd and the 3rd harvests. TCH 002 gave the highest fresh yield of 16.33t/ha while *Abasafitaa* gave the lowest yield of 2.27 t/ha. The time of harvesting also had a significant effect on the amount of fresh foliage obtained. Generally, the second harvest which was done at six months after planting gave the highest average fresh and dry foliage yields of 10.59t/ha and 2.17t/ha which were significantly different from the other harvest times (Fig. 1). The least average fresh and dry foliage yields were recorded at the 4th harvest which coincided with root harvesting and this was also lower than the average yield obtained from the control. There were exceptions however as few of the genotypes produced the highest foliage yields at first and third harvests. Genotypes ADI 001, 96/0160 and *Kyempo* produced their peak yields at the 3rd harvest. Periodic pruning resulted in a much higher cumulative fresh foliage yield than when the foliage was obtained only once at root harvest.

Protein content (%) and foliage protein yield (t/ha) at different harvest days: Foliage protein content of the different genotypes at the different times of harvesting is presented in Table 2. From an initial average protein content of 17.9%, there was a rise in the protein content to a peak of 18.5% at the second harvest which was significantly higher than the 3rd and 4th harvest and the control. Genotypic differences were observed with the highest protein content being recorded by *Nkabom* (19.8%) with DMA 004 recording the least of 13.3%. Crude protein yield which was calculated as a product of foliage dry weight and protein content (%) was also significantly ($P \leq 0.05$) affected by genotype and harvesting time. Pruning periodically also resulted in significantly ($P \leq 0.05$) higher protein yield than the control which was harvested only at root harvest. Periodic pruning gave an average protein yield of 1.16 t/ha which was significantly higher than the average of 0.78 t/ha obtained from the control. Genotypic variations were again in this trend. For example genotype *Dokuduade* produced the highest protein yield of 1.63 t/ha when it was pruned periodically compared with the 0.28 t/ha obtained from the control.

TANO 003 and TANO 001 also produced much higher yield of 1.6 t/ha which was far higher than the protein yield obtained from their respective controls (0.38 and 0.22 t/ha respectively). The least cumulative protein yield was obtained from *Agbelifia* (0.64 t/ha) and this was to be expected since it had the lowest foliage dry weight. However, in the case of the control, *Abasafitaa* gave the least protein yield of 0.12 t/ha. The average protein yield also varied significantly with harvesting time. The 2nd harvest gave the highest average protein yield before it started to decline at the 3rd and 4th harvests (Fig. 1). The 4th harvest gave the least average protein yield which was significantly lower ($P \leq 0.05$) than the previous harvests and the protein yield obtained from the control.

Table 1 Fresh and dry foliage yields of 25 genotypes at different times of harvesting.

Genotypes	Time of harvesting/ months											
	Fresh foliage yield (t/ha)						Dry foliage yield (t/ha)					
	3	**6**	**9**	**12**	**Total**	**Control**	**3**	**6**	**9**	**12**	**Total**	**Control**
Adugyama	8.50	6.43	2.77	3.47	21.17	3.67	2.28	1.43	0.77	0.91	5.39	1.11
96/0603	5.57	6.50	4.87	2.80	19.74	4.63	1.99	1.50	1.37	0.71	5.56	1.28
Nkabom	3.87	9.30	5.50	4.33	23.00	4.47	1.10	1.67	1.33	1.09	5.19	1.30
AWO 001	4.90	11.80	7.93	3.30	27.93	5.53	1.22	2.57	1.99	0.81	6.60	1.75
TCH 004	5.27	14.87	8.13	8.37	36.64	4.47	1.57	2.77	1.98	1.89	8.20	1.30
Afisiafi	4.63	12.17	9.17	8.27	34.24	3.87	1.21	2.58	2.16	1.96	7.91	1.26
ADI 001	4.23	8.27	9.43	4.20	26.13	3.20	1.13	1.77	2.07	1.04	6.02	0.99
TANO 003	8.10	12.07	11.03	4.93	36.13	7.80	2.73	2.53	2.61	1.23	9.10	2.48
96/1569	1.97	4.90	5.33	3.03	15.23	3.57	0.67	1.05	1.41	0.78	3.91	1.07
IFAD	5.70	6.73	4.73	3.07	20.23	3.53	1.72	1.40	1.24	0.77	5.13	1.03
Agbelifia	2.50	5.97	3.27	3.03	17.43	2.73	0.77	1.23	0.85	0.74	3.58	0.78
Esambankye	4.00	8.63	4.40	5.10	19.47	6.20	1.25	1.81	1.19	1.31	5.56	1.82
Gblemoduade	5.83	11.87	7.00	6.5	31.2	10.90	1.59	2.47	1.79	1.64	7.48	3.20
TANO 001	9.57	12.00	6.4	4.57	32.54	4.43	3.31	2.47	1.73	1.20	8.70	1.42
96/0160	3.37	8.73	10.00	8.03	30.13	7.23	0.95	1.82	2.25	1.79	6.86	2.13
Dokuduade	6.70	19.00	7.47	7.90	41.07	5.73	2.06	3.82	1.96	1.93	9.78	1.86
TCH 001	3.43	12.17	7.17	4.33	27.1	7.80	0.91	2.77	1.70	1.10	6.47	2.83
Kyempo	4.63	6.97	9.53	8.43	29.56	3.50	1.23	1.41	2.67	2.25	7.57	1.17
DMA 004	6.77	9.13	6.90	4.60	27.4	7.03	2.52	1.98	1.76	1.19	7.44	2.19
96/1565	8.00	9.83	6.83	6.03	30.69	4.33	2.52	2.00	1.7	1.50	7.72	1.32
96/1642	5.03	14.17	8.63	7.53	35.36	6.93	1.28	2.60	2.04	1.74	7.66	2.25
Abasafitaa	4.43	10.00	4.20	2.5	21.13	2.27	1.19	2.15	1.08	0.58	4.99	0.66
ADI 002	6.43	17.50	8.63	5.30	37.86	4.17	1.74	3.25	1.99	1.33	8.30	1.27
Bankyehemaa	4.10	12.43	6.73	5.47	28.73	8.37	1.45	2.46	1.70	1.41	7.02	2.57
TCH 002	5.07	13.87	6.53	3.27	28.74	16.33	1.55	2.67	1.51	0.79	6.52	5.09
Lsd (0.05)	NS	9.911	5.581	2.871	14.2	5.673	1.552	NS	1.2739	0.73	3.741	1.714
Mean	5.30	10.59	6.90	5.13	27.95	5.71	1.60	2.17	1.71	1.27	6.75	1.75
Lsd (0.05)	1.295**						0.2918**					

NS= Not significant according to the least significant different test (P>0.05); * = Lsd value comparing mean foliage protein content (%) for the different harvest times and the control; ** = Lsd value comparing mean foliage protein yields for the different harvest times and the control.

Table 2 Foliage protein content (%) and protein yield (t/ha) of 25 cassava genotypes at different times of harvesting

Genotypes	Months after planting											
	Protein content (%)						Foliage protein yield (t/ha)					
	3	**6**	**9**	**12**	**Total**	**Control**	**3**	**6**	**9**	**12**	**Total**	**Control**
Adugyama	15.5	16.9	15.6	16.9	16.2	16.1	0.38	0.23	0.12	0.16	0.89	0.18
96/0603	17.8	19.6	15.0	16.0	17.1	16.0	0.34	0.32	0.20	0.11	0.97	0.21
Nkabom	15.2	16.9	16.2	16.7	16.3	19.8	0.16	0.27	0.21	0.19	0.83	0.26
AWO 001	17.9	17.8	16.1	16.4	17.1	17.9	0.21	0.45	0.31	0.13	1.11	0.30
TCH 004	18.2	19.1	16.8	14.2	17.1	15.2	0.28	0.52	0.33	0.26	1.40	0.20
Afisiafi	19.9	17.0	16.0	14.7	16.9	15.2	0.23	0.43	0.35	0.29	1.31	0.19
ADI 001	16.7	18.8	17.8	17.9	17.8	16.6	0.19	0.31	0.36	0.19	1.05	0.16
TANO 003	18.2	18.6	15.7	16.5	17.3	15.7	0.50	0.47	0.43	0.20	1.60	0.38
96/1569	17.4	21.4	17.5	17.7	18.5	16.6	0.11	0.23	0.25	0.14	0.73	0.17
IFAD	19.1	19.5	17.2	18.9	18.7	15.7	0.33	0.27	0.21	0.14	0.96	0.15
Agbelifia	18.0	20.0	15.2	17.3	17.6	16.0	0.14	0.24	0.13	0.13	0.64	0.16
Esambankye	17.4	20.1	15.7	14.6	17.0	15.2	0.22	0.36	0.19	0.19	0.96	0.29
Gblemoduade	17.4	19.1	16.3	14.8	16.9	19.7	0.28	0.48	0.28	0.24	1.28	0.59
TANO 001	18.7	19.4	15.0	17.1	17.6	15.9	0.65	0.48	0.26	0.21	1.60	0.22
96/0160	18.6	20.0	16.8	13.8	17.3	18.2	0.19	0.36	0.41	0.25	1.21	0.34
Dokuduade	17.5	16.8	16.4	15.6	16.6	15.3	0.37	0.64	0.32	0.30	1.63	0.28
TCH 001	15.6	17.7	15.9	18.4	16.9	17.7	0.14	0.44	0.26	0.20	1.05	0.42
Kyempo	18.7	17.7	16.4	14.5	16.8	14.5	0.23	0.23	0.45	0.33	1.23	0.16
DMA 004	18.2	17.9	17.3	17.6	17.8	13.3	0.47	0.32	0.30	0.21	1.29	0.29
96/1565	17.6	19.7	16.8	15.9	17.5	15.8	0.44	0.39	0.27	0.23	1.34	0.20
96/1642	19.4	18.0	15.8	15.9	17.3	14.7	0.23	0.45	0.31	0.28	1.27	0.32
Abasafitaa	19.1	19.6	15.7	17.6	18.0	17.5	0.22	0.41	0.17	0.10	0.90	0.12
ADI 002	18.2	15.9	15.2	13.9	15.8	15.7	0.31	0.54	0.30	0.18	1.34	0.19
Bankyehemaa	19.5	19.5	16.07	18.3	18.3	16.7	0.28	0.44	0.26	0.26	1.24	0.42
TCH 002	17.9	16.2	15.7	18.5	17.1	15.0	0.30	0.43	0.23	0.15	1.10	0.71
Lsd (0.05)*	3.156	4.119	NS	2.607		2.949	0.3044	0.332	NS	0.1380	0.67	0.1340
Mean	17.9	18.5	16.2	16.4		16.2	0.29	0.39	0.28	0.20	1.16	0.28
Lsd (0.05)**	0.641*						0.05056**					

NS= Not significant according to the least significant different test (P>0.05); * = Lsd value comparing mean foliage protein content (%) for the different harvest times and the control; ** = Lsd value comparing mean foliage protein yields for the different harvest times and the control.

Relationship between growth rate, foliage, protein content and traits associated with foliage and protein yield: Strong phenotypic correlations were observed among most of the traits (Table 3). For instance high positive correlation (over 90%) was observed between both fresh and dry foliage yield and a number of traits. Foliage protein yield was also found to relate highly with foliage fresh (95%) and dry (97%) yields. The relationship between foliage protein content and most of the other traits were negative and insignificant except for number of shoots (-25%) and protein yield (13%). High protein yield also coincided with periods when high foliage yields (Fig. 1) which in turn also depended on the rate of growth.

As the plants were periodically pruned, more shoots were produced which resulted in increased number of shoots and subsequently increased foliage yield with harvest time. Foliage yield however begun to decline after the second harvest. This is illustrated by the relationship between average number of regenerated shoots and foliage yield is presented in Fig. 2. The results indicated that increase in fresh foliage yield corresponded with the increase in the number of shoots especially at the 2nd harvest. The dry foliage yield did not appear to correlate to the changes in the number of shoots. The average number of shoots then increased from 1.68 to 3.39 but increased only marginally to an average of 4.02 at the final harvest. Genotypic variations were observed for this trait too. For instance some genotypes (TANO 003, 96/1565 and 96/0160) the number of shoots increased considerably to between five and eight shoots per stand at the final harvest. On the contrary, some genotypes (*Kyempo* and DMA 004) could only manage a marginal increase in the number of shoots after the second harvest. Unlike the number of shoots which increased with subsequent foliage harvests, the average height of shoots/stems at harvests decreased from the second to the final harvest. This pattern also reflected in the foliage yield pattern over the period as the foliage yield increased considerably at the 3rd and 4th harvests.

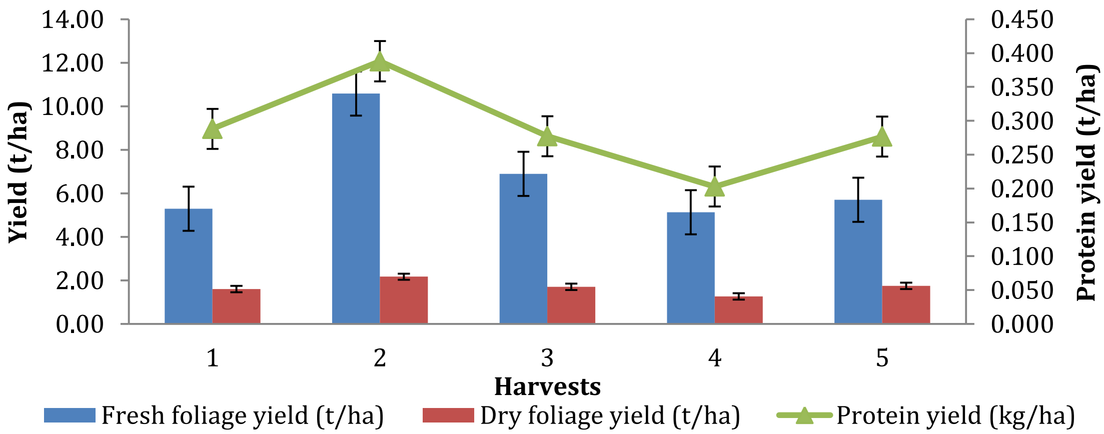

Fig 1 Foliage and protein yield at different times of harvest.

Table 3 Phenotypic correlation between foliage, protein yield and related traits of 25 cassava genotypes.

DF_t_ha	1.00						
DM_%	-0.21**	1.00					
FW_t_ha	0.95**	-0.45**	1.00				
No_shoots	0.31**	-0.42**	0.39**	1.00			
PLT_HT_cm	0.75**	-0.59**	0.84**	0.34**	1.00		
PT_%	-0.07NS	-0.03NS	-0.06NS	-0.25**	-0.02NS	1.00	
PT_YD _t_ha	0.97**	-0.19**	0.92**	0.27**	0.72**	0.13*	1.00
	DF_t_ha	DM_%	FW_t_ha	No_shoots	PLT_HT_cm	PT_%	PT_YD_t_ha

** = significant at P≤0.001, * = significant at P≤0.05 Where: DF_t_ha = dry foliage yield (t/ha), DM_% = Dry matter content (%), FW_t_ha = fresh foliage yield (t/ha), No. Shoots = number of shoots/plant at foliage harvest, PLT_HT_cm = plant height at each harvest (cm), PT_% = foliage protein content (%), PT_YD_t_ha = foliage protein yield (t/ha).

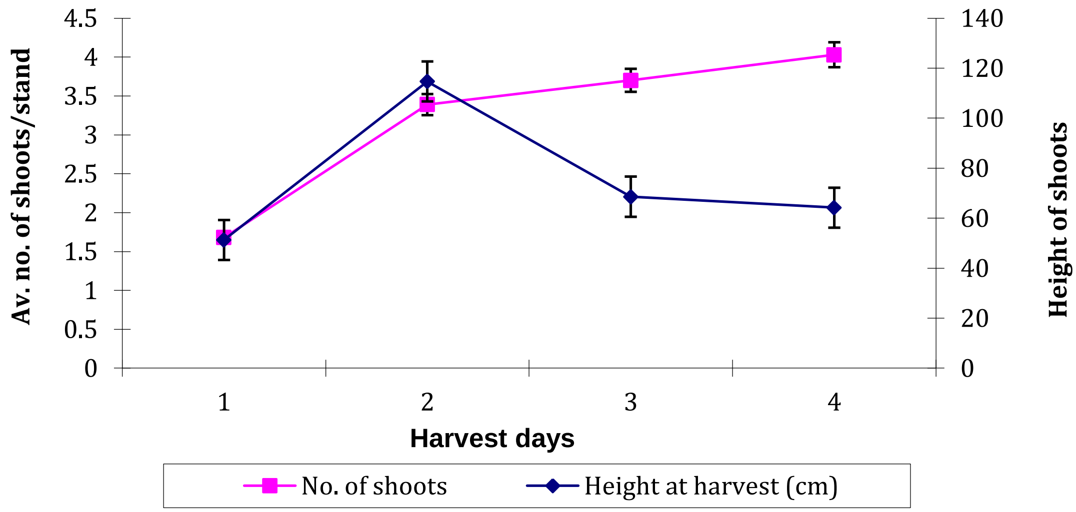

Fig. 2 Average number of regenerated shoots and plant height at different harvest.

Heritability of traits associated with foliage productivity: As can be seen from Table 4, traits such as number of regenerated shoots, protein yield, dry matter content and dry foliage yield have high heritability. This implies that genotypic variations in these traits are highly heritable. Number of regenerated shoots was the trait with the highest heritability of 94%. Plant height at harvest had the lowest heritability of 5%. This trait was more dependent on the environmental conditions that prevailed during the months prior to the harvesting day.

Table 4 Genotypic variance, Genotype X harvest time (GXH) variance and heritability estimates of various traits for 25 cassava genotypes.

Trait	G variance	GXH variance	Heritability % (broad sense)
Fresh foliage yield	1.81	0.63	50.6
Dry matter content	3.62	1.49	80.0
Dry foliage yield	2.01	0.79	88.0
Protein content	1.44	1.12	70.0
Protein yield	1.77	0.74	90.0
No. of regenerated shoots	5.43	1.01	94.0
Plant height at harvest	3.33	0.69	6.0

DISCUSSION

Total fresh and dry foliage yield: According to Ravindran (1991) genotype, soil fertility, frequency of foliage harvesting and climate are the major determinants in cassava foliage productivity. Conceicao (1973) (as cited by Tung *et al*. 2001) also pointed out that certain cassava varieties are better foliage producers than others. This genotypic effect was confirmed by the results of this study. For example the total fresh foliage yield ranged between 15.23 t/ha and 41.07 t/ha whilst the total dry foliage yield also ranged between 3.58 t/ha and 9.78 t/ha. The results from this study also corroborate the findings of a similar work by Tung *et al*. (2001) who evaluated three cassava varieties MM92, Black Twig and a local, for growth persistence and foliage productivity. After five harvests, the observed total dry foliage yield ranged between 6.16 t/ha and 8.53 t/ha. The differences in the foliage producing ability exhibited by the different genotypes could be due to the ability of the different genotypes to tolerate periodic pruning. Limsila *et al*. (2007) also found genetic variation in dry foliage yield (t/ha) among 16 cassava genotypes in the range of 4.0 to 7.7t/ha when they were pruned three times at 31/2, 51/2 and 12 months after planting. They also indicated the ability of some of some of the genotypes to regenerate their leaves and produce appreciable root yields as well. This implies that genotypes that are able to recover and produce more shoots after cutting are more likely to produce more foliage than others. This trait was however exhibited to different degrees by the different genotypes as some produced more regenerated shoots than others. For example genotype 96/0160 continued to increase significantly in the number of regenerated shoots while others like, TANO 001 and AWO 001 did not significantly increase in shoots production after the first cutting.

Foliage production was also observed to generally decline with repeated pruning. This agrees with Wong and Sharudin (1986) who reported that dry foliage production declined over time irrespective of defoliation frequency practiced. As the cassava plants were regularly injured during the pruning, recovery ability became lower causing lower foliage production. Ravindran (1991) reported that foliage productivity in cassava depends on soil fertility status among other things. Therefore failure to appreciate the need to return some soil amendments to replace those removed by the periodic pruning will result in a decline in foliage production (Preston, 2001). Khang and Preston (2005) also observed an increase in dry foliage yield from 4.3 to 5.4 t/ha when cassava plants were fertilized with effluents from biodigester charged with cattle manure and applied at a rate of 5 t/ha. The need for some form of soil amendments, to sustain cassava foliage productivity was further supported by Preston (2007) that with adequate fertilizer and irrigation, cassava can be maintained as a semi-perennial foliage crop with high foliage yields up to three years. In the case of this study, no soil amendments were applied after each harvest. However the different genotypes responded differently to the decline in foliage production and regrowth after pruning indicating different level of tolerance.

Growth rate and foliage yield: High foliage yields were also found to be associated with periods of vigorous growth as indicated by plant height (Fig. 2). The highest foliage yield which was obtained at the second harvest coincided with periods of high rainfall which promoted the growth of tall plants. This was confirmed by the low the heritability (broad sense) recorded for plant height at harvest indicating a high environmental influence. Therefore treatments and conditions such as application of soil amendments and irrigation that will promote vigorous and rapid growth will promote high foliage yield (Preston, 2007).

Protein content and protein yield: Ravindran (1991) indicated that genetic variability exists between cassava cultivars in leaf protein content and this is suggestive of the potential response to selection. Factors such as sampling procedure, stage of maturity of the plant, and ecological conditions also affects the protein content of cassava foliage. Total crude protein yield was however found to be more dependent on dry foliage yield than the crude protein content of the cassava foliage in this study. The correlation analysis showed a strong positive correlation (97 %) between dry foliage yield and protein yield as against a weak correlation between protein content and protein yield (13%). This indicates that the actual amount of protein obtained at any harvest depends on the amount of foliage obtained at that particular harvest. This is possibly due to the fact that the crude protein content of the foliage may vary within a narrow range, while the total foliage production may vary widely because it is greatly influenced by a number of factors such as genotypic attribute. Tung *et al*. (2001) in evaluating three cassava varieties for foliage protein production similarly observed quite stable crude protein content (%) but declining foliage yield with repeated pruning thereby resulting in lower protein yield in subsequent harvests. The results again revealed that high protein content alone did not necessarily result in a high protein yield but rather high foliage yield was the determinant. Therefore any attempt to select for a high amount of fresh and dry foliage yield will indirectly improve the efficiency of selection for a genotype with the potential high foliage protein yield.

Periodic pruning which resulted in higher foliage yield was found to result in a corresponding higher protein yield than the protein yield obtained only at root harvest. For instance periodic pruning gave an average protein yield of 1.16 t/ha as against 0.28 t/ha obtained from the control. Ravindran (1991) therefore suggested that for exclusive foliage protein production, foliage-harvesting frequency can be shorter in order to increase the total cumulative foliage and protein yield.

Rate of foliage harvesting and foliage yield: In order to maximise foliage yield, it is important to harvest the foliage a number of times before the final root tuber harvest. Foliage production increased tremendously at the second harvest before it started to decline with subsequent harvests. The reason for the decline is explained by the fact that as foliage was periodically pruned, there was a reduction in the rate of foliage production resulting in lower foliage yield with repeated pruning. Periodic pruning produced a much higher cumulative foliage yield (6.75 t/ha) than when the foliage was harvested only once at root harvest (1.75

t/ha). These findings agree with a similar work by Ahmad (1973) who obtained total cumulative foliage yield of 7.5 t/ha when the foliage was harvested five times at six weeks intervals before root harvest at 12 months. Gomez and Rajaguru (1984) also evaluating two cassava genotypes for foliage production after 12 months reported low dry foliage yield of 1.2 – 2.8 t/ha. The periodic pruning triggered more foliage production after each harvest possibly with energy from the stored carbohydrates in the roots. This resulted in the higher cumulative foliage yield as a result of more regenerated shoots. However, this was never the case in the control as the rate of leaf production slowed down as a possible maximum leaf area index was reached for root bulking to be initiated. Howeler and Cadavid (1983) stated that between 90-180 days after planting, maximum canopy size and maximum dry matter partitioning to leaves and stems are reached while bulking of storage root continues. At this time too, partitioning of photo assimilates from leaves to roots is accelerated. This explains why foliage yield is low at root harvest. Genotypic differences were also established for the foliage yields from the control. For example the dry foliage yields for the control ranged between 0.66 t/ha for *Abasafitaa* and 5.09 t/ha for TCH 002 which were far lower than the dry foliage yields obtained from the periodically pruned plants

CONCLUSION

Genotypic variation in foliage production ability exists for different cassava genotypes as a result of differences in tolerance to periodic pruning. Harvesting time and frequency also had much influence on foliage and protein yield. Foliage production was greatly increased during the second harvest for most of the genotypes but subsequent harvests resulted in reduced yield. Periodic pruning results in much higher than when the foliage was obtained only at root harvest but there can be possible decline in yield with subsequent harvest. This suggests that optimum number of prunings should be determined for different cassava genotypes. Foliage protein yield depended more on the total dry foliage yield than the protein content of the different genotypes. Therefore it will be more critical to select for genotypes with high foliage producing ability instead of genotypes that have very high protein content but low foliage production. However plant height which influenced total foliage yield appeared to have been dependent more on the growth conditions prevailing at the time on measurement implying high environmental influence. High heritability (broad sense) was observed for traits such as dry foliage yield, number of regenerated shoots and foliage dry matter content. Therefore selection based on these traits for specific genotypes could result in genetic gain in subsequent trials. This work thus opens a new page in cassava research that targets foliage production ability and agronomic practices that will make cassava a dual purpose crop.

REFERENCES

ACDI/VOCA, 2013. ACDI/VOCA report on cassava in Uganda. Assessed on 22/05/2013 at: http://www.acdivoca.org/site/ID/ugandacassava

Ahmad, M.I. 1973. Potential fodder and tuber yields of two varieties of tapioca. Malaysian Agricultural Journal 49: 166–174.

Balagopalan, C. 2002. Cassava Utilization in Food, Feed and Industry. *In* Hillocks, R.J., J.M. Thresh and A.C. Bellotti (eds.). Cassava: Biology, Production and Utilization. CABI Publishing, New York, pp.301–318.

Boampong, E. 2001. Collection and characterization of local cassava germplasm from the Brong-Ahafo Region. A Thesis submitted to the Department of Crop and Soil Sciences, Faculty of Agriculture, KNUST Kumasi in partial fulfillment of a Master of Science degree in plant breeding.

Bokanga, M. 1994. Processing of cassava leaves for human consumption. Acta Hort. 375: 203 – 207.

Ceballos, H. 2003. Cassava as a vehicle for delivering pro-vitamin A carotenoids HarvestPlus: Breeding crops for better nutrition. International Center for Tropical Agriculture. Apdo Aéreo 6713, Cali, Colombia.

Cock, J.H. and S.C. Rosas. 1975. Ecophysiology of cassava. Cali, Colombia: CIAT. 14pp.

Conceicao, A. J., C. V. Da Sampaioy and M.A. Mendez. 1973. Competition of varieties of cassava for foliage production. Federal University of Bahia. School of Agronomy of North-East Brascan Series, Brazil. 1(1):115-127.

Eggum, B. O. 1970. The protein quality of cassava leaves. Br. J. Nutr. 24: 761-768.

FAO, 2013. Food and agriculture organization of the United Nations Rome. FAOSTAT Database. http://faostat.fao.org/site/339/default.aspx

GenStat. Resease 9.2. 2007. GenStat for Windows (9th ed.). Introduction. VSN International, Hemel Hempstead.

Howeler, R.H. and L.F. Cadavid. 1983. Accumulation and distribution of dry matter and nutrients during a 12-month growth cycle of cassava. Field Crops Res. 7: 123–139.

Khang, D.N. and T.R. Preston. 2005: Effect of effluent from low-cost plastic film biodigester on yield and chemical composition of cassava foliage and tuber yield. Workshop-seminar "Making better use of local feed resources" *In* Preston T.R. and R.B. Ogle (eds.). MEKARN-CTU, Cantho, 23-25 May, 2005. Article No.6.

Kjeldahl Method 1990. Protein (Crude) Determination in Animal Feed: $CuSO_4/TiO_2$ Mixed Catalyst Kjeldahl Method. (988.05) Official Methods of Analysis. 1990. Association of Official Analytical Chemists. 15th Edition.

Lancaster, P.A., J.S. Ingram, M.Y. Lim and D.G. Coursey. 1982. Traditional cassava-based products: Survey of processing techniques. Econ. Botany 36: 12-45.

Limsila, A., S. Tungskul, W. Wattananonta, A. Boosing, S. Pichitporn and R.H. Howeler. 2007. Cassava Leaf Production Research in Thailand. *In* R.H. Howeler (ed.): Cassava Research and Development in Asia: Exploring New Opportunities for an Ancient Crop. Proc. of the 7th Regional Cassava Workshop held in Bankok, Thailand. Oct 28– Nov 1, 2002.

Nweke, F.I., A.G.O. Dixon, R. Asiedu and S.A. Folayan. 1994. Cassava Varietal Needs of farmers and Potential for Production growth in Africa. Collaborative Study of Cassava in Africa (COSCA). IITA, Ibadan. Working paper No. 10 1994.

Preston, T.R. 2001. Potential of cassava in integrated farming systems. International Workshop Current Research and Development on Use of Cassava as Animal Feed. Khon Kaen University. Thailand, July 23-24, 2001.

Preston, T.R. 2007. Production and Utilisation of Cassava in Integrated Farming Systems for Small-holder farmers in Vietnam and Cambodia. *In* Howeler, R.H. (ed.): Cassava Research and Development in Asia: Exploring New Opportunities for an Ancient Crop. Proc. of the 7th Regional Cassava Workshop held in Bankok, Thailand. Oct 28– Nov 1, 2002.

Preston, T. R. and L. Rodríguez. 2004. Production and utilization of cassava foliage for livestock in integrated farming systems. Livestock Research for Rural Development 16 (5). http://www.lrrd.org/lrrd16/5/pres16028.htm.

Ravindran, V. 1991. Preparation of cassava leaf products and their use as animal feed. *In* Machin, D. H. and S. W. Speedy (eds.). Roots, tubers, plantains and bananas in animal feeding. FAO Animal Production and Health Paper No. 95:111-126.

Ravindran, G. and V. Ravindran.1988. Changes in the nutritional composition of cassava (*Manihot esculenta* Crantz) leaves during maturity. Food Chemistry 27: 299-309.

Rogers, D.J. and M. Milner. 1963. Amino acids profile of manioc leaf protein in relation to nutritive value. Economic Botany 17: 211-216.

Safo-Kantanka, O. 2004. Cassava can replace cocoa in Ghana (I) and (II). Ghanaian Daily Graphic. May 11-12, 2004. pp9.

Tung, C.M., J.B. Liang, S.L. Tan, H.K. Ong, and Z.A. Zelan. 2001. Foliage productivity and growth persistency of three local cassava varieties. Asian-Aust. J. Anim. Sci. 14(9):1253 – 1259.

Wargiono, J., N. Richana and A. Hidajat 2007. Contribution of cassava leaves used as vegetables to improve human nutrition in Indonesia. *In* Howeler, R.H. (ed.): Cassava Research and Development in Asia: Exploring New Opportunities for an Ancient Crop. Proc. of the 7th Regional Cassava Workshop held in Bankok, Thailand. Oct 28– Nov 1, 2002.

Wanapat, M. 2007. The role of cassava hay as animal feed. *In* Howeler, R.H. (ed.): Cassava Research and Development in Asia: Exploring New Opportunities for an Ancient Crop. Proc. of the 7th Regional Cassava Workshop held in Bankok, Thailand. Oct 28– Nov 1, 2002.

Wong, C.C. and M.A. Sharudin 1986. Forage productivity of three fodder shrubs in Malaysia. Mardi Res. Bull. 14(2):178-188.