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Cassava (Mannihot esculenta Cranz) Varieties and Harvesting Stages Influenced Yield and Yield Related Components

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Abstract

Cassava (Mannihot esculenta) is the second most important staple food being the major source of food energy in sub-Saharan Africa that could play a major role in sustaining food security. In order to determine the appropriate growth stage for cassava harvesting, this study was conducted in Jimma Agricultural Research Center (JARC) during the 2008/2009 and 2009/2010 cropping seasons. Accordingly, ten cassava genotypes praised for root yield were planted in Randomized Complete Block Design harvested at six stages. Different growth and yield parameters were collected and found Significant difference (p=0.000)1across stages in all cultivars. Based on combined analysis, the effects of harvesting stages on yield and yield related traits of cassava genotypes were found to be significant with the highest fresh root yield 23.06 t/ha after 18Months After Plant(MAP). Except number of branch/ plant, root fresh and dry weight kg/plot, the effects of harvesting stages and genotypes on yield related traits investigated in the research were generally non significant. In addition, correlation between root fresh weight and plant height, number of main stem/plant, number of branch/plant, average length of roots, weight of above ground plant biomass and root dry weight were positively significant. As a result, under the ecological condition of Jimma and its vicinity cassava should be harvested at 18MAP to get desirable yield and 15MAP for using as vegetative materials though it requires further study in quality aspect.

Keywords: Cassava; Mannihot esculenta; Harvesting stages; yield components.

Introduction

Cassava (Mannihot esculenta Cranz) is a tropical woody shrub being one of the most consumed crops in the world (Bensi et al., 2004). In sub-Saharan Africa it is the second most important staple food being the major source of food energy providing up to 285 calories per person per day (Bensi et al., 2004).

Cassava is mainly grown for the roots which are consumed in fresh form after boiling or consumed in processed form. Its contribution as an alternative to bread is very pronounced in rural and urban households (Sahel et al., 2004).

Besides, there is also an interest in using high quality cassava flour as a substitute for wheat flour in food and non food industries (Kappinnga et al., 1998). Apart from being staple food and foliage in the major producing areas, cassava products are also popular in international trade under different forms such as chips, pellets, flour and starch, thus contributing to the economy of exporting countries (Schott et al., 2000).

The most important feature of cassava is its adaptability and produce yield in various ecological and agronomic conditions and it often grows where most other crops fail (Mesut and Ahmet, 2002). In Ethiopia, the crop has been found to have an excellent adaptation and growth performance in different agro ecologies with productivity variation (Amsalu, 2003), which is by far greater than the global average tuber yield of 10.5t/ha (FAO, 2005). Although reliable information on the area and production of cassava in Ethiopia is lacking, the crop has been in cultivation, particularly, in the south, southwest and western parts since its introduction (Amsalu, 2003). Nationally two recently released cassava cultivars named 44/72 NW (Kello) and 44/72 NR (Qule) in the year 2006 known for their high quality yield (tuber yield 36t/ha).

Previous studies have demonstrated organoleptic properties of cooked roots and physio-chemical characteristics of extracted starch are affected by the age of harvested roots and environmental conditions during plant and root development, such as rainfall amount and soil temperature (Defloor et al 1998 a, b; Santisopasri et al., 2001).

These factors can influence the quality of flour and ultimately the final products made from the flour. However, little was known about the phsico-chemical and functional properties of flour and starch from the cultivated cassava varieties in relation to how they are affected by age at harvest (Apea-Bah et al., 2011).

To obtain the maximum possible quality yield understanding an appropriate harvesting date, which indicates the yield potential of these varieties, is crucial. Accordingly, this study has been designed to identify critical harvesting stages of cassava for better root yields and yield related traits.

Materials and Methods

Description of the Study Area

The experiment was conducted at Jimma Agricultural Research Center during 2008-2009 and 2009-2010 cropping seasons which is located at latitude 7^o 46' N and longitude 36^o E with an altitude of 1753 m.a.s.l. The soil of the study area is Eutric Nitosole with a pH of 5.3 whereby total precipitation and average temperature data are given in annex 1.

Genetic Materials

Ten genotypes (44/72 NR, 44/72 NW, 45/72 NR, 45/72 NW, AAGT 028, AAGT 108, AAGT 189, AAGT 191, AAGT 192 and AAGT 2000) and six different harvesting stages (6, 9, 12, 15, 18 and 24 months after planting, MAP) were used for this study. The genotypes were collected from south and southwestern parts of Ethiopia, during the period 2008-2009 that covered diverse agro-ecologies with an altitude range of 1375-2500 m.a.s.l, representing major cassava production areas in the country.

Experimental design

The experiment was laid in split plot design with harvesting stages as main plots and genotypes as sub-plots and randomized in three replications. Each main plot size of $36m^2$ was used with 1m x 1m spacing between rows and plants. All agronomic practices were carried out as needed for two consecutive years.

Accordingly data on plant height (cm), number of main stem/plant, number of branch/plant, average canopy diameter/plant (m), average stem girth (cm), average number of roots/plant, average length of roots/plant (cm), average diameter of roots/plant (cm), root fresh weight (kg/plot), above ground biomass weight (kg/plant) and root dry weight (kg/plot) were recorded. Five plants were (100g each) randomly taken from the plot and were floured to get the dry matter yield of the product according to Apea-Bah *et al. (2011)*.

Statistical analysis:

Individual and combined data from 2008-2010 were analyzed using SAS software package (SAS, 9.1) and means were separated by LSD at $p= 0.01$ and 0.05 level of significance and their correlation.

Results and Discussion

In this study, yield and yield components have indicated how harvesting stage of different cassava genotypes are affected significantly ($p<.0001$). In line with this, Fresh Weight of roots varies significantly through time though varietal changes have an influence on its level. Accordingly, highest fresh weight of root was observed to increase starting from month 12 after planting till 24 months which were significantly different from each other except decreasing at 9^{th} month after planting for 44/72 NR and AAGT191 variety and increased at later stages highly (Table 1).

Varietal difference was seen to influence yield and yield components at different level though their general trend is similar at significant level. Similar varietal observation was seen by Apea-Bah *et al.* (2011) on the effect of genotypic difference on yield and yield components. Accordingly the highest fresh weight of roots was observed from AAGT191 followed by 45/72 NW being 44/72 NW variety the least. Due to quality aspects like cellulose accumulation and HCN increment considering 18MAP is safe and observed the highest root fresh weight from 45/72NW variety.

Dry weight of cassava varieties showed an increment trend similar to root fresh weight as shown in Table 2 being highest performance for AAGT191 at 24MAP and 45/72 NW 18MAP.

Moreover, the effect of harvesting stages and its interaction with genotypic difference showed very high significant difference ($p<.0001$) in fresh weight of root and most of the characters considered (Table 9). Nevertheless, there are no characters that showed significant difference with the interaction of genotypes, harvesting stage and year at the same time (Table 9) so that both years repeated experiments showed similar observation and repeatable.

It has been seen the increment of yield is closely related to changes in root related parameters. This is accompanied with including number of roots; their length and an associated diameter increment through time

directly enhance higher root fresh weight (Table 3, 4 and 5). Accordingly 45/72NW provided the widest diameter roots in addition to possessing root number which is highly and positively related.

Such a higher yield obtainment could be the result of phenotypic advancement associated with increased plant height that creates the potential to prepare more food through photosynthesis and increased root length with its diameter, which are yield related components. In addition to this, the understanding of stages related to obtainment of higher above ground biomass could help in selecting stages of cassava for vegetative propagation. Accordingly, 15MAP provided the highest number of branches and longer plants that could be used for vegetative propagation (Table 6 and 7).

In addition, extending time further leads to the re-assimilation of reserve food to root for tuber development decreasing the regeneration capacity of the cuttings at later stages of 18 and 24 MAP.

In addition, changes related to plant height and associated parameters affected yield positively in this study (Table 6 and Table 7). Similarly, the lowest fresh weight of root is obtained from 6 month old plants in all the varieties used in this study which is similar to the finding of Ngeve (2003). In addition such observation goes hand in hand with the findings of Apea-Bah *et al.* (2011) and Chotineeranat *et al*. (2006) too.

In addition to yield performance, chemical composition of cassava roots is important and varies based on time of harvest as it is indicated by *Chotineeranat et al. (2006)* including HCN content, which makes cassava flour poisonous.

Inline with this, concentration of HCN will significantly reduced with ages of cassava Chotineeranat *et al*. (2006) and the obtainment of good amount of fresh root yield in this study on 18 MAP can be safely recommended on this aspect though similar effect from 24 MAP.

Even though the highest fresh root yield is obtained at 24 MAP, there is an associated problem in relation to composition/ quality of the flour due to starch accumulation. At later stages higher accumulation of starches is indicated by Apea-Bah *et al.* (2011) due to conversion of glucose which makes 24 MAP unpalatable and uneconomical time-wise whereby18 MAP could be the best option according to this study.

Correlations of yield components

In this study, the correlation coefficients of root fresh weight was significantly and positively correlated with plant height, number of main stem/plant, number of branch/plant, average length of roots/plant, above ground plant part and root dry weight (Table 8). Average number of roots/plant was showed non-significant and positive correlation with root fresh weight/plot. Based on the correlations between characters, genotypes with high plant height, number of main stem/plant, number of branch/plant, average length of roots/plant, weight of above ground plant part and root dry weight will maximize root fresh yield and may need high consideration efforts towards root yield improvement of cassava. Nevertheless, average stem girth was showed significant and negatively correlation with root fresh weight and has no contribution for cassava root yield.

Weight of above ground plant parts and roots dry weight were showed a high significant positive correlation with most of the characters except average canopy diameter (m), average stem girth (cm) and average number of roots/plant. In addition, average stem girth (cm) also showed significant and negative correlation with plant height and number of main stem/plant.

Plant height showed strong and positive correlation with most of the characters including number of main stem/plant, number of branch/plant, average length of roots/plant (cm), weight of above ground bio mass kg/plot and root dry weight (Table 8).

Conclusions

This study was conducted in order to investigate the effects of six different harvesting stages on yield and yield related traits of ten cassava genotypes. The result indicated that harvesting stages have very high significant differences in all characters of studied; moreover, both the fresh root and dry matter yields of cassava been increased till 24MAP. For yield related traits, most the characters showed dramatic yield increment in harvesting between 12-15 months after plant. Although, the highest fresh root yield is obtained at 24 MAP, there is an associated problem in relation to composition/ quality of the flour due to cellulose accumulation.

Based on the results of correlation, characters such as, plant height, number of main stem/plant, number of branch/plant, average roots length/plant, weight of above ground plant part and root dry matter yield have a great contribution for fresh root yield of cassava. Consequently, through investigation on plant height, number of main stem/plant, number of branch/plant, and average length of roots/plant, weight of above ground plant bio mass and root dry matter yield on cassava is critical to get desirable root yield and yield components of cassava.

Therefore, harvesting cassava on 15 MAP is recommended for production of planting material whereas 18 MAP can be safely recommended for fresh root yield of cassava under Jimma and its vicinity for the above 10 genotypes in general.

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Annex 1 Climatic data on the research site during the growth period

Months	Precipitation(mm)			Temperature (°C)				
	Long period	2008-2009	2009-2010	Long-Period Mean	2008-2009		2009-2010	
					Minimum	Maximum	Minimum	Maximum
January	(35.4)	60.2	45.54	(9.8)	9.7	29.7	11.2	27.9
February	(43.3)	34.2	78.4	(11.0)	11.5	29.6	13.6	27.4
March	(98.9)	78.9	119.0	(12.7)	13.6	30.7	13.1	28.1
April	(125.9)	127.6	124.6	(13.5)	13.8	28.5	19.2	27.7
May	(181.0)	242.4	290.8	(13.6)	13.9	26.0	14.8	23.5
June	(212.4)	232.0	368.4	(13.3)	14.8	25.2	14.3	25.6
July	(222.8)	219.0	228.2	(13.4)	15.4	23.5	14.2	24.3
August	(220.0)	248.0	250.1	(13.4)	15.0	23.8	15.1	26.1
September	(192.2)	178.0	185.7	(13.1)	15.2	24.5	14.2	24.8
October	(110.5)	169.0	115.2	(11.5)	14.4	26.0	14.2	27.2
November	(52.7)	82.6	128.5	(9.6)	11.2	26.5	14.5	23.9
December	(34.3)	38.4	48.9	(8.6)	14.0	27.7	14.1	26.2
Total	**1529.40**	**1710.30**	**1983.3**	**143.50**	**162.50**	**321.70**	**172.50**	**312.70**
Average	**127.45**	**142.52**	**165.27**	**11.96**	**13.54**	**26.80**	**14.37**	**26.05**

Table 1. Fresh weight of 10 cassava varieties at different ages at harvest

Stage	44/72 NR	44/72 NW	45/72 NR	45/72 NW	AAGT 028	AAGT 108	AAGT 189	AAGT 191	AAGT 192	AAGT 2000
6MAP	122.0	93.8	163.3	198.5	183.0	172.5	101.3	537.8	166.5	203.4
9MAP	119	179.6	271.3	257.8	304.1	301.4	240.5	244.1	277.0	276.7
12MAP	211.9	197.8	373.4	370.0	336.1	343.8	319.1	340.1	351.7	313.3
15MAP	255.6	321.5	572.2	443.1	412.0	510.0	359.7	438.6	400.8	626.8
18MAP	324	302.5	557.5	831.3	711.9	711.3	596.5	605.9	643.1	785.9
24MAP	707.0	691.0	1055	1468.0	1220.0	1077.0	1223.0	1542.0	1176.0	1271.0

Table 2. Dry weight of 10 cassava varieties at different ages at harvest

Stage	44/72 NR	44/72 NW	45/72 NR	45/72 NW	AAGT 028	AAGT 108	AAGT 189	AAGT 191	AAGT 192	AAGT 2000
6MAP	44.7	32.0	46.4	63.8	66.9	67.2	32.5	192.8	62.2	75.4
9MAP	52.7	76.31	105.9	108.7	124.0	124.6	91.3	101.9	119.4	117.3
12MAP	81.9	66.04	131.3	135.3	125.0	129.9	120.2	124.8	128.4	114.0
15MAP	127.1	153.7	261.6	223.2	205.2	231.3	164.6	218.8	195.2	311.2
18MAP	128.5	135.9	203.9	327.5	270.9	275.1	231.1	239.2	251.8	309.3
24MAP	325.2	316.6	428.29	665.4	584.1	495.7	554.0	716.5	551.3	600.7

Table 3. Average number of roots per plant of 10 cassava varieties at different ages at harvest

Stage	44/72 NR	44/72 NW	45/72 NR	45/72 NW	AAGT 028	AAGT 108	AAGT 189	AAGT 191	AAGT 192	AAGT 2000
6MAP	9.30	11.3	12.0	9.3	13.4	9.9	9.8	11.8	12.2	13.2
9MAP	9.08	10.67	13.0	8.7	13.3	14.0	9.2	12.1	10.4	14.4
12MAP	9.62	10.21	12.6	9.8	12.1	11.6	8.6	9.8	9.3	10.6
15MAP	8.17	9.25	10.8	6.4	8.9	7.5	7.00	7.6	8.7	10.3
18MAP	8.58	8.375	8.5	8.4	8.5	10.1	5.9	8.0	8.3	10.4
24MAP	8.92	11.0	11.875	11.1	13.8	9.9	10.0	11.2	11.7	12.2

Table 4. Average diameter of roots of 10 cassava varieties at different ages at harvest

Stage	44/72 NR	44/72 NW	45/72 NR	45/72 NW	AAGT 028	AAGT 108	AAGT 189	AAGT 191	AAGT 192	AAGT 2000
6MAP	1.70	1.9	2.4	2.5	2.2	2.3	2.2	2.3	2.2	2.1
9MAP	2.13	2.63	2.7	2.9	3.1	3.0	2.9	3.1	2.9	2.9
12MAP	2.80	2.798	3.5	3.6	3.2	3.3	3.5	3.9	3.3	3.3
15MAP	3.24	3.408	4.4	4.0	4.1	4.0	4.5	3.9	3.9	3.9
18MAP	3.47	3.587	3.9	5.0	4.8	4.5	4.3	4.7	4.8	4.9
24MAP	5.58	5.8	6.8	7.7	7.5	7.2	7.1	8.1	7.2	7.4

Table 5. Average length of roots of 10 cassava varieties at different ages at harvest

Stage	44/72 NR	44/72 NW	45/72 NR	45/72 NW	AAGT 028	AAGT 108	AAGT 189	AAGT 191	AAGT 192	AAGT 2000
6MAP	30.5	31.2	30.5	31.1	33.4	31.4	27.9	30.5	32.6	33.3
9MAP	38.7	34.04	32.5	35.5	36.9	37.0	35.3	36.7	38.5	40.1
12MAP	32.2	28.17	29.5	39.2	35.3	39.7	36.1	37.0	38.4	35.3
15MAP	36.54	38.72	30.9	37.6	31.4	39.5	38.3	39.1	37.6	39.8
18MAP	41.36	42.41	34.9	38.9	39.4	42.6	35.4	36.6	37.2	39.8
24MAP	50.09	49.8	43.6	49.8	51.8	49.1	49.5	50.5	50.8	46.5

Table 6. Plant Height of 10 cassava varieties at different ages at harvest

Stage	44/72 NR	44/72 NW	45/72 NR	45/72 NW	AAGT 028	AAGT 108	AAGT 189	AAGT 191	AAGT 192	AAGT 2000
6MAP	187.4	178.8	153.4	202.9	184.0	186.3	216.3	179.7	183.5	191.7
9MAP	211.8	208.7	197.8	234.4	229.3	233.3	241.6	229.1	221.9	233.8
12MAP	227.3	247.1	222.5	249.2	259.3	281.5	279.6	268.0	249.0	252.4
15MAP	272.5	282.8	245.6	272.0	275.2	271.2	312.9	275.1	258.0	273.1
18MAP	270.7	306.2	260.3	311.8	305.8	284.4	315.9	291.4	285.2	350.2
24MAP	262.9	306.5	290.85	297.5	328.4	328.2	372.7	303.4	309.2	325.4

Table 7. Number of branch per plant of 10 cassava varieties at different ages at harvest

Stage	44/72 NR	44/72 NW	45/72 NR	45/72 NW	AAGT 028	AAGT 108	AAGT 189	AAGT 191	AAGT 192	AAGT 2000
6MAP	9.70	11.8	7.6	6.3	9.9	6.8	8.5	7.6	7.8	8.1
9MAP	9.38	10.79	8.4	6.4	7.2	7.0	6.5	7.9	6.8	8.2
12MAP	8.83	13.92	7.6	7.6	9.0	10.0	8.5	8.7	6.9	7.8
15MAP	7.82	13.42	7.9	7.3	8.3	7.1	7.3	7.9	8.1	7.5
18MAP	7.88	10.83	7.5	7.3	6.3	5.8	7.3	6.1	7.3	7.9
24MAP	8.21	8.3	7.5	7.2	6.3	7.3	8.8	7.5	6.2	6.8

Table 8. Correlations between root fresh weight and yield components of cassava

	RFW	PH	NS	NB	CD	GR	NR	LR	DR	WAGP
PH	0.895**									
NS	0.969**	0.923**								
NB	0.826**	0.958**	0.839**							
CD	-0.224	-0.394	-0.217	-0.608						
GR	-0.681*	-0.643*	-0.666*	-0.552	0.351					
NR	0.234	0.482	0.266	0.682*	-0.709**	0.139				
LR	0.940**	0.880**	0.942**	0.878 **	-0.347	-0.477	0.488			
DR	0.038	-0.301	-0.054	-0.493	0.858**	0.076	-0.790**	-0.154		
WAGP	0.977**	0.935**	0.991**	0.881**	-0.282	-0.621	0.360	0.973**	-0.100	
RDW	0.810**	0.882 **	0.811**	0.884**	-0.260	-0.244	0.642	0.892**	-0.210	0.862 **

**, *, ns = significant at 1%, 5%, and non significant at 5%, respectively.
RFW= Root fresh weight (kg/plot)PH=Plant height(cm), NS= number of main stem/plant, NB= number of branch/plant, CD=average canopy diameter(m), GR=average stem girth(cm), NR= average number of roots/plant, LR= average length of roots/plant(cm), DR=average diameter of roots/ plant(cm), RFW=root fresh weight kg/plot, WAGP=weight of above ground biomass/plot(kg) and RDW=root dry weight t/plot

Table 9. Combined Analysis of variance, coefficient of variation for 11 quantitative characters of cassava genotypes grown at Jimma in 2008/09/10 cropping seasons

Source of variation	DF	Mean Squares										
		PH	NS	NB	CD	GR	NR	LR	DR	RFW	WAGP	RDW
Var	9	10274.6**	1.67**	59.02**	601.90ns	0.66**	48.10**	99.03**	4.84**	7505.89**	0.20**	1905.3**
Trt	5	133524.9**	1.79 **	22.38**	24338.97**	18.91**	115.74**	1175.61**	173.94**	128789.89**	3.67**	131596.9**
Var* Trt	45	1110.7ns	0.40ns	5.80**	933.99ns	0.15ns	6.26ns	35.96ns	0.57ns	1026.13*	0.07ns	301.00**
Year	1	388556.3**	1.95 **	107.33**	334082.4**	4.58**	37.81**	445.68**	1.84ns	57244.86**	76.96**	16235.4**
Year* Var	9	2490.4**	1.53**	3.87ns	1375.40ns	0.23ns	20.76**	69.98ns	0.86ns	1131.31**	0.09ns	299.65**
Year* Trt	5	9047.5**	1.47**	14.43**	16003.85**	0.67**	36.30**	519.63**	15.91**	5208.05**	4.19**	3307.76**
Var* Trt* Year	45	1149.89ns	0.36ns	3.50ns	1246.91ns	0.14ns	4.47ns	29.66ns	0.33ns	669.68ns	0.08ns	191.46ns
CV%		**12.31**	**26.30**	**23.36**	**21.60**	**13.46**	**22.54**	**16.79**	**19.31**	**29.14**	**26.37**	**34.47**

**, *, ns = significant at 1%, 5%, and non significant at 5%, respectively

PH=Plant height(cm), NS= number of main stem/plant, NB= number of branch/plant, CD=average canopy diameter/plant(m), GR=average stem girth(cm), NR= average number of roots/plant, LR= average length of roots/plant(cm), DR=average diameter of roots/plant(cm), RFW=root fresh weight kg/plot, WAGP=weight of above ground biomass kg/plot and RDW=root dry weight kg/plot.