MECHANIZATION OF CASSAVA PRODUCTION

A STUDY TO DETERMINE THE SUITABILITY OF PRESENT CASSAVA CULTIVARS FOR MECHANICAL HARVESTING

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SUMMARY

The rooting patterns of four commonly grown selected cassava cultivars (60444, 60447, 60506 and 44086) in Nigeria were studied. There was variation between cultivars in root weight, depth of penetration, number of roots per stand, and root length. Large numbers of correlations and linear regressions between cultivars have been computed. The rooting patterns of none of these cultivars allow easy mechanical harvesting. An attempt is advocated to select new cultivars whose roots can be harvested cheaply and effectively.

RESUME

La structure des racines de quatre cultivars de cassava (60444, 60447, 60506 et 44086) généralement cultivés au Nigéria ont été exposées. Les cultivars varient selong le poids de la racine, la profondeur de la pénétration, le nombre de racines par pied et la longueur des racines. Un nombre important de corrélations et de régressions linéaires entre les variétés ont été estimées. Aucun des cultivars ne présente une forme d'enrainement permettant une récolte mécanisée réalisable dans de bonnes conditions. L'accent a été mis sur la nécessité de sélectionner de nouveaux cultivars dont on peut récolter les racines aisément et à peu de frais.

RESUMEN

Se estudiaron los patrones de enraizamiento de cuatro cultivares selectos (60444, 60447, 60506 y 44086), comunes en Nigeria. Hubo variación entre cultivares en cuanto a peso de raíces, profundidad de penetración, número de raíces por mata y longitud de raíces. Se computaron un gran número de correlaciones y regresiones lineales entre variedades. Los patrones de enraizemiento de ninguno de estos cultivares permiten una cosecha mecánica fácil. Se hacen intentos para seleccionar nuevos cultivares cuyas raíces puedan ser cosechadas económica y efectivamente.

REVIEW

Cassava (*Manihot esculenta* Crantz) is widely used in tropical countries as a source of carbohydrates for both humans and livestock. FAO[2] estimated that in 1971 Nigeria produced 7.3 million metric tons of cassava which was grown on over one million hectares, making the country the second largest producer in Africa. Most of Nigeria's production is by peasant farmers. Two factors prevent there being much increase in production: (1) high labour requirement at harvest accounts for over 40 per cent of the total costs of production and (2) peasant methods of processing the roots for food are laborious and time consuming.

The development by the Nigerian Institute for Industrial Research of an integrated cassava processing plant which processes cassava roots into gari has opened the way for large scale production and processing. Thus, cassava may shortly become an important commercial crop in Nigeria.

An integrated plant is also being operated in Gambia. This processes 45 metric tons of raw cassava roots daily. With the present average yield levels in Nigeria, such a plant would require the production from three hectares daily at full capacity, approximately 1000 hectares of production per year. This would most conveniently be produced by a commercial operation and mechanized harvesting.

Activities are already under way in Nigeria to establish processing facilities which emphasize the urgency for the development of mechanical harvesting equipment.

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Attempts have been made in other countries to harvest cassava mechanically. The use of the mouldboard plough for cassava harvesting was suggested by Krochmal[3] in Mexico and Thailand. Bates[1] proposed the use of the potato spinner, the potato digger-lifter and the sugar beet harvester for cassava harvesting. All have since been tried and found unsuitable and uneconomical.

Makanjuola *el al.*[4] have shown that only 75% of the crop was exposed for hand picking when cultivar 53101 was mechanically harvested with a mouldboard ridger, but 81% when a mouldboard plough was used. In both instances there was about 40% of root damage.

Current opinion is that harvesting equipment of an entirely new design is necessary. To be suitable, a harvester must not only lift the roots but also separate loose soil, clods, and large stones while sufficiently exposing the roots for easy picking. A suitable device for loading the roots into a trailer would also be useful. We have therefore studied the rooting pattern of the important cultivars of cassava in Nigeria and suggest a different and desirable plant type for the future.

MATERIALS AND METHODS

Cassava was planted at the University of Ife Farm on a well-drained sandy loam soil classified in the Iwo series. The four cultivars of cassava used included three commonly grown improved cultivars; 60444, 60447 and 60506; and one other promising cultivar, 44086. These cultivars, together with some other locally adapted ones, have accounted for practically the entire crop harvested in Nigeria since 1967.

The rooting characteristics studied included: the lateral spread of individual roots; depth of root penetration; number, weight and length of each root per stand and length of the neck (i.e. that part of the root proximal to the tuberized section). The distribution of dry matter along the length of every root was also studied. Cuttings were spaced one meter apart.

In order to measure these criteria accurately, the point at which the stem emerges from the soil was marked. The soil around the stand was carefully removed until the roots were completely exposed but undisturbed. The point at which each root was attached to the stem was determined, as was the radius of root spread by measuring the horizontal distance from the central point of root stalk attachment to a point above the tip of each root (Fig. 1). The depth of root penetration was measured as the vertical distance between the point at which the stem emerged from the soil to the distal (tail) end of the root (Fig. 2). The distal tip of the roots were usually the lowest point on the root. These two measurements were recorded for all stands.

Weights of individual roots were taken and the number of roots per stand was recorded.

In addition each root was measured to determine the length of the neck and that of the entire root. Diameter of the roots at 2.5 cm intervals were also recorded. The purpose of this was to study the concentration of dry matter along the root length.

Conventional statistical methods were used for analysis of the data.

RESULTS

Mean weights (Table 1) of individual roots varied markedly between roots within cultivars and also between cultivars. The standard deviation for tuber weights in cultivar 60506 was higher than the mean tuber weight, and for 44086 was almost as high as its mean tuber weight. Cultivar 60447 had three times the mean tuber weight of 44086 and about twice that of 60444. The standard deviation for 60447 was highest among the cultivars.

Mean depth of penetration varied from 204mm for 60444 to 256.8mm for 60447. Again the standard deviation for depth for 60506 was greater than its mean depth of penetration.

Mean radius of spread ranged from 303mm in 44086 to 386mm in 60447. The frequency distribution diagrams for the radius of spread, depth or root growth, and weight of individual tubers indicated a normal distribution in all cultivars.

Table 2 shows that the total length of the root including the neck plus tuber measurements and the variations within one cultivar were small. Cultivar 44086 had both the shortest tubers and root length (neck plus tuber).

Individual tuber weights (Table 3) were highly correlated with the radius of spread for all the cultivars. As the plant aged and stored more carbohydrate in the tuber there was not only an increase in girth of the tubers but also a greater lateral spread.

The radius of spread was highly correlated with depth of penetration in cultivars 60444, 44086 and 60506. Simple regression equations relating these parameters are presented.

Tables 1 and 2 show that cultivar 60447 differs greatly from 44086 in root weight, depth of penetration and radius of spread. Thus there is clearly genetic variation within the species which can be subjected to selection.

Cultivar 60447 is an erect growing plant with a medium canopy. It is a widely grown variety in Nigeria.

Tuber weight to tuber length relationship determines to a great extent the probability of success in mechanical lifting of the tubers. Table 4 shows a high correlation between root weight and tuber length in all the cultivars, that is, the greater the length of the tuber, the heavier it is.

Length of the tuber was significantly correlated with neck length in 60447 and 44086. Root weight is also correlated with the sum of length of tuber plus length of neck in all the cultivars except 44086.

The measurements taken at 254mm intervals along the tuber showed that the average cassava tuber tapers rather from the proximal end and that this tapering is greater beyond 38cm from the proximal end of the tuber in cultivars 60444 and 60447. For the other cultivars the roots tapered off more rapidly from about 25cm from the proximal end. Thus, the commonly grown cassava cultivars concentrate their stored carbohydrates within 25-38cm from the proximal end of the tuberous part of the roots. To lift all this length of root would require a large amount of soil to be turned over.

Table 5 shows considerable variability both within a cultivar and between cultivars for mean tuber weight per stand, mean depth of penetration and mean radius of spread. The mean number of roots per stand was less pronounced. Cultivar 60447 again contrasted sharply with 44086 in tuber weight, root spread and depth of penetration.

Table 6 shows that variability in the mean total length of the root per plant was low. Appropriate regression equations for the parameters studied, are presented in Table 7.

Tuber weight per stand was strongly correlated with depth of penetration for cultivars 60447, 60506, and 44086. Tuber weight per stand was also highly correlated with radius of spread in cultivars 60444, 60506, and 44086. This confirms that tuber expansion occurs by both increased girth and soil penetration.

DISCUSSION

The results show that the mode of lateral and vertical (downward) spread of the roots in the soil is not well adapted to allow simple mechanical harvesting. To harvest the roots in their present form would require large machinery and still entail considerable crop losses. It is apparent that the form of the root system needs to be changed in order to have a plant type whose roots are so bunched that they can be lifted cheaply and with minimum of crop damage and loss. Our study has shown that considerable variation exists between different genotypes (cultivars) as well as within cultivars (non-heritable variation) in the radii of spread, depths of penetration, numbers and weights of roots per stand and the lengths of individual roots. Thus there is scope for genetic selection for root form and number.

It is hoped that this report will create interest among plant breeders in seeking to develop a plant type which will be suitable for mechanical harvesting. The studies suggest that a desirable type of cassava plant would be one with two well formed, carrot-like roots per plant. These two roots should be bunched closely together (i.e. spreading as little as possible laterally, and short and fat rather than deep.) It would be desirable to have more than eighty percent of the stored carbohydrate occurring within the top 15 cm of the root tubers. In addition, the above ground plant type should be small so it can be grown at a much higher population (10,000 to 12,000 plants/ha.). The stem and leaves should be easy to chop and shred before the roots are lifted.

These attributes should be combined with other desired characteristics such as low cyanide content, high tuber yield, high gari/starch ratio, etc. However, as Rogers and Appan[5] have pointed out, the need to breed a new type of cassava plant should not interfere with the ability of cassava to produce a reasonable yield on marginal and submarginal land. The problems posed in trying to mechanize cassava production are many and varied, and a multi-disciplinary approach appears necessary to meet the challenge.

REFERENCES

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TABLE 1

Variations in tuber weight, depth of penetration and radius of spread for individual roots of different cultivars of cassava

Cultivar	Mean tuber weight (gms)	Standard Devia-tion (gms)	Depth of Pene-tration (mm)	Standard Devia-tion (mm)	Radius of Spread (mm)	Standard Devia-tion (mm)
60447	1005.46	847.64	256.80	81.0	385.60	158.00
60444	549.65	435.41	204.00	45.0	375.20	457.00
44086	383.88	360.37	205.00	54.40	302.80	82.80
60506	755.30	765.91	224.00	226.80	369.80	134.40

TABLE 2

Variations in tuber length, neck and total root length for individual roots of different cultivars of cassava

Cultivar	Mean length of tuber (mm)	Standard Devia-tion (mm)	Mean length of neck (mm)	Standard Devia-tion (mm)	Mean length whole root (mm)	Standard Devia-tion (mm)
60447	341.63	16.89	28.19	1.23	369.82	6.98
60444	358.06	16.13	11.47	0.86	369.53	6.45
44086	254.00	9.35	25.15	1.49	279.15	4.60
60506	320.60	12.75	50.83	2.02	371.43	7.90

TABLE 3

Relationship between individual weight of each tuber (X), depth of penetration (Y) and radius of spread (Z) for four cultivars of cassava

Cultivar	Correlation Coefficient between X & Y	X & Z	Y & Z	Linear Regression Equation (where correlation coefficient is significant)
60447	0.80**	0.68**	0.05	X = 67.80Y + 320.07 X = 93.20Z - 409.32
60444	0.1478	0.53**	0.23*	X = 37.692 - 7.03 Y = 0.06 + 7.41
44086	0.16	0.64**	0.53*	X = 45.47Z - 62.64 Y = 0.35Z + 3.90
60506	0.60**	0.38**	0.22*	X = 268.22Y-1639.81 X = 54.63Z - 40.02 Y = 0.07Z + 7.91

* Denotes significance at 5% level
** Denotes significance at 1% level

TABLE 4

Relationship between individual root weight (X), length of tuber (L), neck (P) and total root length (L + P) of four cultivars of cassava

Cultivar	Correlation Coefficient Between X & L	X & (L+P)	L & P	Linear Regression Equation (where correlation coefficient is significant)
60447	0.66**	0.61*	0.32**	X = 85.12L - 139.40 X = 74.36(L+P)-77.22 P = 0.06L + 0.30
60444	0.55**	0.52**	0.05	X = 37.78L + 16.95 X = 34.06(L+P)+40.98
44086	0.52**	0.37	0.61 **	X = 51.40L-130.32 P = 0.25L - 1.59
60506	0.56**	0.27 *	0.01	X = 84.48L-223.36 X = 54.77(L+P)-45.90

* Denotes significance at 5% level
** Denotes significance at 1% level

TABLE 5

Variation in the mean tuber weight, depth of penetration, radius of spread and number of roots for individual plants within cultivars of cassava

Cultivar	Mean tuber weight per stand (gms)	Standard Deviation (gms)	Mean Depth of Penetration per stand (mm)	Standard Deviation (mm)	Mean Radius of spread (mm)	Standard Deviation (mm)	Mean Number of roots per stand	Standard Deviation
60447	7034.08	2720.14	25.58	6.40	41.81	9.47	6.75	2.05
60444	4259.75	1537.50	19.84	37.01	3.30	8.36	2.62	
44086	2175.33	734.00	19.46	3.79	25.48	5.21	6.44	2.35
60506	4729.07	2457.70	22.12	3.12	35.84	6.71	6.14	2.04

TABLE 6

Variation in mean tuber length/stand, tuber neck/stand and total tuber length per stand for individual plants within cultivars of cassava

Cultivar	Mean tuber length per stand (mm)	Standard Deviation (mm)	Mean total tuber neck lengths per stand (mm)	Standard Deviation (mm)	Mean total length per stand (mm)	Standard Deviation (mm)
60447	338.43	68.28	27.18	40.64	339.50	68.78
60444	357.12	46.74	47.75	83.31	359.50	48.51
44086	260.78	33.40	98.81	14.22	262.08	34.11
60506	317.63	57.61	50.29	20.57	322.10	130.02

TABLE 7

Relationship between weight of tubers per stand (X_2), mean depth of penetration (Y_2) and mean radius of spread (Z_2) for individual plants within each of four cultivars of cassava

Cultivar	Correlation Coefficient Between X_2 and Y_2	X_2 and Z_2	Y_2 and Z_2	Linear Regression Equation (where correlation coefficient is significant)
60447	0.56*	0.23	0.31	X = 238.79Y + 931.56
60444	-0.03	0.96**	-0.32	X = 444.93Z + 12206.24
60506	0.60**	0.56*	0.51	X = 469.45Y - 9956.73 X = 206.22Z - 2261.89
44086	0.50*	0.99**	0.42	X = 97.80Y + 272.43 X = 140.03Z-1392.19

* Denotes significance at 5% level
** Denotes significance at 1% level

FIG. 1: RADIUS OF SPREAD

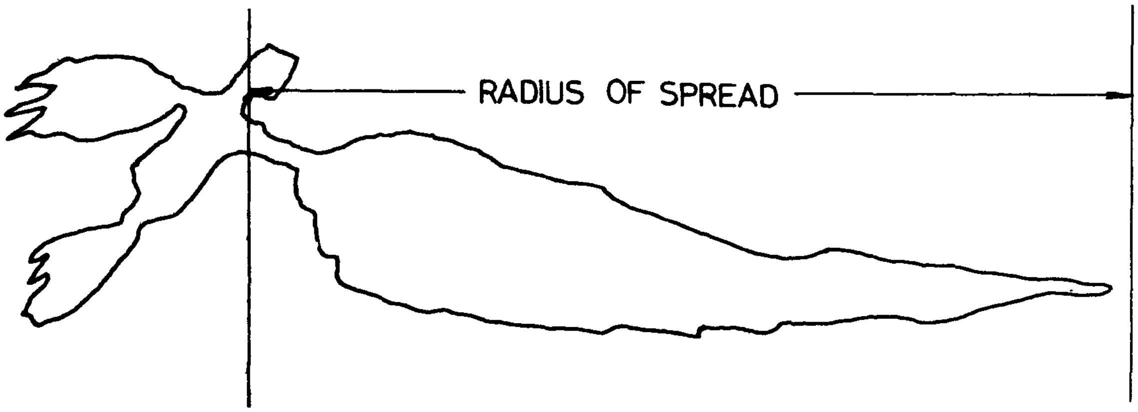

FIG. 2: DEPTH OF GROWTH