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A TWO-MACHINE SYSTEM FOR MECHANICAL PREPARATION AND PLANTING OF CASSAVA STEM CUTTINGS

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ABSTRACT

A P.T.O. driven machine capable of rapidly cutting cassava stems into uniform planting sticks of any desired length, and a two-row machine capable of planting these sticks on ridges or flat land at desired inter-and intra-row spacings, were designed, fabricated and evaluated. The stem cutting machine prepared planting sticks at about 3 times the rate normally achieved with manual cutting, and produced a higher quality of cut and a higher degree of uniformity of stick length. The two-row planter gave near perfect inter-row spacing and variations in intra-row spacing and planting depth were comparable to those achieved with manual planting. Planting rates of 0.6 ha hr^{-1} were achieved in a commercial 20 ha trial.

RESUMEN

Se diseñaron, fabricaron y evaluaron dos máquinas de transmisión P.T.O. una, capaz de cortar rápidamente tallos de yuca en trozos uniformes (iguales) de cualquier tamano deseado; y otra de dos surcos, capaz de sembrar estos trozos en serranías o llanos, en espacios deseados entre y dentro de los surcos. La máquina cortadora de tallos preparó trozos para plantar a una velocidad tres veces mayor que la del corte manual y produjo cortes de mayor calidad y mayor grado de uniformidad en el tamaño de los trozos. La máguina sembradora de dos surcos produjo espacios entre surcos casi perfectos; y tanto las variaciones en los espacios dentro de los surcos como la profundidad de los sembradíos fueron comparables a las que se obtuvieron sembrando manualmente. Se logró una tasa de 0.6 hectáres por hora en una prueba comercial de 20 hectáreas.

Traditionally, cassava planting sticks are cut manually from whole stems using a machete or other type of knife. The stem is held in one hand and cut manually into lengths approximating the desired stick length (Lozano *et al.*, 1977; Lorenzi, 1980). The cutting activity is usually followed by manual collection and chemical treatment of the cut sticks. The manual preparation of sticks is inherently slow and leads to significant variations in stick length. Work rates for manual cutting and collection of sticks at the University of the West Indies (UWI) vary from 250 sticks per man-hour for measured sticks to 300 per man-hour for sticks whose lengths are visually estimated.

Manual planting is rather time-consuming and labour intensive. An average of 12 man-days is required in Trinidad to plant a hectar of cassava.

Given the scarcity and high cost of agricultural labour in the Region, large-scale production of cassava would necessitate mechanization of stake preparation and planting activities.

This paper describes the design and evaluation of a two-machine system for high-volume preparation (cutting, collection and chemical treatment) and planting of cassava sticks.

Design requirements of the machines

Stem cutting machine

The design requirements considered for the stem cutting machine were as follows:

(1) Capability to cut stems into sticks of any length between 150 and 300 mm
(2) A clean, vertical transverse cut of the stem
(3) Ability to cut stems rapidly into planting sticks
(4) High uniformity of stick length
(5) Provision for adequate sterilization of cut sticks
(6) Provision for collection of the cut sticks
(7) Capability of being driven from the P.T.O. shaft of a standard tractor so as to eliminate the need for an auxiliary power source.
(8) Ease of transportation from one location to another.

The machine was essentially an integrally mounted table saw consisting of a welded steel frame and fitted with legs so that it stood rigidly on the ground during operation. Two shafts were fitted to the frame: an input shaft, which could be coupled directly to the PTO shaft of a standard tractor, and an output shaft on which the cutting element (a large-diameter circular saw blade) was mounted. Power was transmitted from the input to the output shaft by means of a triple V-belt and sheave drive designed to ASAE Standard S 211.3 (ASAE, 1984). A sheave diameter ratio was selected so as to achieve an output shaft speed of approximately 2,000 revolutions per minute (rpm).

In operation, a bundle of cassava stems is fed from the rear of the machine until contact is made with a pre-set stick length control plate, and then brought into contact with the rotating blade. Immediately after being cut, the sticks fall directly into a removable tank (mounted below the blade) in which they are simultaneously collected and chemically treated.

Cassava Planter

The design requirements for the machine were as follows:-

(1) Opening of a planting furrow to a predetermined depth
(2) Placement of planting sticks (one at a time) horizontally at the bottom of the furrow
(3) Planting of sticks at desired uniform inter-row and within-row spacing
(4) Provision for selecting different inter- and intra-row spacings to achieve various plant population densities
(5) Complete coverage of the planted sticks with soil
(6) Planting of two rows of sticks simultaneously, but with a provision for upgrading the machine to a 3-row planter
(7) Ease of transport from one field to another
(8) Provision of an acceptable level of comfort for planter operators
(9) Simplicity of construction and operation
(10) Relatively low cost

The planter was essentially a two-row, semi-automatic, integrally mounted machine fed manually with pre-cut sticks prepared by the cassava stem-cutting machine described above. It consisted of a main tool carrier on which the following functional components were mounted:-

(1) A hopper for carrying the planting sticks
(2) A delivery chute and furrow opener assembly
(3) A stick covering device
(4) An intra-row spacing device
(5) Operators' seat and foot rest assemblies.

The intra-row spacing was controlled by a spacing wheel fitted with a standard bicycle bell as a signalling device, and having a circumference equal to the desired within-row spacing. With the completion of one complete revolution of the wheel, the bell was activated and two operators riding on the planter each responded to the signal by releasing a cassava stick into the delivery chute.

Performance evaluation of the machines

Stem cutting machine

Machine performance was determined for two frequently used stick lengths of 200 and 250mm. During the test, at least 200 sticks were cut with the machine at each stick length setting. The time required to cut each batch of sticks was recorded and a sample of randomly selected sticks was retained from each batch for statistical analysis. The performance criteria on which the evaluation was based were as follows:-

- uniformity of stick length
- quality of the cut
- rate of stick preparation
- efficiency of collection of cut sticks

Uniformity of stick length was evaluated by randomly sampling the cut sticks and determining the mean stick length, the standard deviation of stick length, the coefficient of variation and the uniformity coefficient.

The quality of cut of a sample of sticks prepared by the stem cutting machine was visually assessed, the standard for comparison being a perfectly even and vertical face obtained by cutting a straight stem very carefully.

The rate of stick preparation (number of sticks prepared per hour) was calculated from the time taken to cut and collect 200 sticks at each stick length setting, while the efficiency of stick collection was evaluated by observing the percentage of cut sticks in a given run which fell directly into the collection box.

Cassava planter

The two-row cassava planter was evaluated on River Estate loam soil at the UWI Field Station on both ridged and flat land. In both cases, an intra-row spacing of 90cm and an inter-row spacing of 1m were used and during the test the following activity times were recorded:- (1) the time required for the planter to cover a distance of 100m, (2) the turning time at the headland, and (3) the time required to fill the hopper with planting sticks.

The planter was evaluated based on the following criteria:-

- uniformity of intra-row spacing
- uniformity of planting depth
- planting rate
- degree of coverage of the planted sticks.

The uniformities of intra-row spacing and planting depth were evaluated in a manner similar to that described for uniformity of stick length.

Planting rate was determined by calculating the effective field capacity of the planter using equation (1) (after Hune, 1977 and Kepner *et al.*, 1980)

$$c = S\,w\,e/10 \quad \ldots\ldots\ldots\ldots \quad (1)$$

where c = effective field capacity (ha hr^{-1}); S = speed of operation (km hr^{-1}), w = rated width of implement (m); and e = field efficiency (expressed as a decimal).

The degree of coverage of the planted sticks was assessed visually by observing the percentage of sticks that was adequately covered with soil by the covering mechanism of the planter.

Results and discussion

Uniformity of stick length

Frequency distributions of measured stick lengths at the two settings are presented in Figure 1, and statistics calculated from these data are presented in Table 1. The table indicates that the length of sticks prepared by the stem cutting machine is normally distributed, and that the uniformity of length of such stakes is high, the uniformity coefficient, Cu, being almost equal to one. There was no appreciable difference in uniformity of stick length between the two stick length settings, indicating that the stick preparation machine is likely to produce acceptably uniform sticks at any stick length setting.

Quality of cut

The quality of cut obtained was generally good since over 90% of the sticks examined were cut in a near perfect transverse manner. The power and speed of rotation of the cutting element were such that even the thickest stems were cleanly cut. In the few instances where stems received angular cuts. the

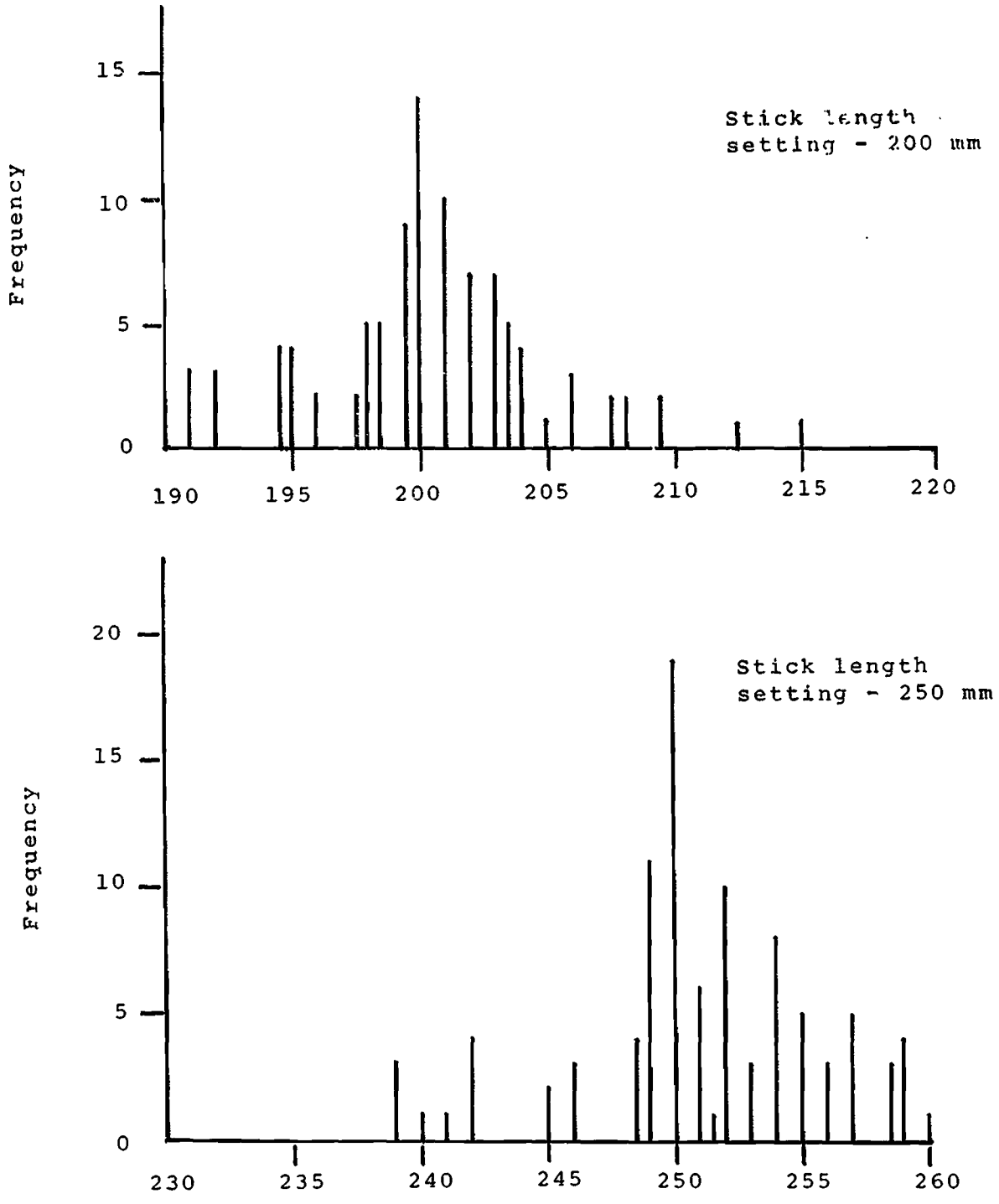

Figure 1. Measured lengths of two samples of 100 sticks cut at two different stick length settings.

Table 1. Summary of statistical analysis of observed data for stakes cut at two stake-length settings.

Statistics	Stake-length setting (mm)	
	200	250
Sample size, n	100	100
Sample mean, x	200.69	250.86
Sample Standard Deviation, s	4.39	4.70
Uniformity Coefficient, Cu	0.80	0.98
Lower Confidence Limit	200.25	250.39
Upper Confidence Limit	201.13	250.86

angularity was attributable to curvature and irregularity of shape of the stems at the points where the cuts were made.

Rate of stick preparation

The stem cutting machine was operated by two men, one of whom fed the machine with whole stems, while the other interchanged full and empty stick collection boxes and maintained the required concentration of chemical sterilant in the collection box. At stick length settings of 200 and 250mm sticks were cut, collected and treated at rates of 38 sticks min^{-1} and 32 sticks min^{-1} respectively, yielding production rates of 11,400 and 9,600 sticks per 10-hour man-day.

As indicated earlier, work rates for manual preparation of cassava planting sticks at the U W I. Field Station range from 2,000 sticks per 10-hour man-day for measured sticks to 3,000 sticks per man-day for sticks whose lengths are visually estimated. The use of the stem cutting machine herein described therefore offers a time saving of 4:1 which, for large scale cassava production, may be highly significant.

Uniformity of intra-row spacing and planting depth

Figures 2 and 3 give frequency distributions for intra-row spacing and planting depth respectively, while Table 2 summarises the statistics calculated from these distributions, based on procedures outlined by Bhattacharyya and Johnson (1977). For both ridged and flat land, the parameters are seen to be normally distributed.

The relatively high values of uniformity coefficients obtained for these two parameters on both ridged and flat land indicated that the machine performed acceptibly in both situations. However, the lower standard deviations obtained for both parameters when planting on ridges as opposed to flat land, indicated that the planter's performance on ridges was somewhat superior. In addition, work carried out by Granger (1985) has shown that, in a commercial setting in Trinidad, the uniformity of intra-row spacing and planting depth obtained with this planter was at least as good as and, in several cases, better than that achieved with manual planting.

Planting rate

During the tests, an average of 20.5 mins. were lost per hour of planter operation due to time for turning at headlands, refilling of the hopper and clearing blockages around the furrow-opener, resulting in a field efficiency of 0.66. The speed of operation was 5 km hr^{-1} and the effective (rated) width of the planter was 1.8m. These values, when substituted into equation (1) yielded an effective field capacity of 0.6 ha hr^{-1} which, for 8 - and 10 - hour work day, is equivalent to planting rates of 4.8 and 6.0 ha day^{-1} respectively.

Since three persons are required to operate the planter (one tractor driver and two planter operators) the above planting rates represent productivities of 1.6 and 2.0 ha man-day^{-1} respectively. Based on manual planting rates at UWI Field Station, comparable productivity figures for manual planting are 0.09 and 0.13 ha man-day^{-1}. It is evident, therefore, that use of two-row mechanical planter can very significantly increase labour productivity and reduce the time required for crop establishment.

Degree of coverage of planted sticks

In almost all cases, the cassava sticks were adequately covered with soil after being planted. In the few instances where coverage was incomplete, this was due to the presence of physical obstructions, such as stones or plant residue, which temporarily blocked the action of the covering coulters.

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Table 2. Summary of statistical analysis of observed data for intra-row spacing (n=100) and planting depth (n=75)

	Intra-row spacing (cm)		Planting depth (mm)	
	Ridged land	Flat land	Ridged land	Flat land
Nominal dimension	100	100	100	90
Sample Mean, X	102.73	100.14	102.56	90.76
Sample Standard Deviation, s	8.12	14.27	13.09	14.32
Uniformity Coefficient Cu	0.92	0.89	0.87	0.91
Lower Confidence Limit (95% Level)	101.14	97.34	99.59	88.97
Upper Confidence Limit (95% Level)	104.32	102.94	105.52	92.55

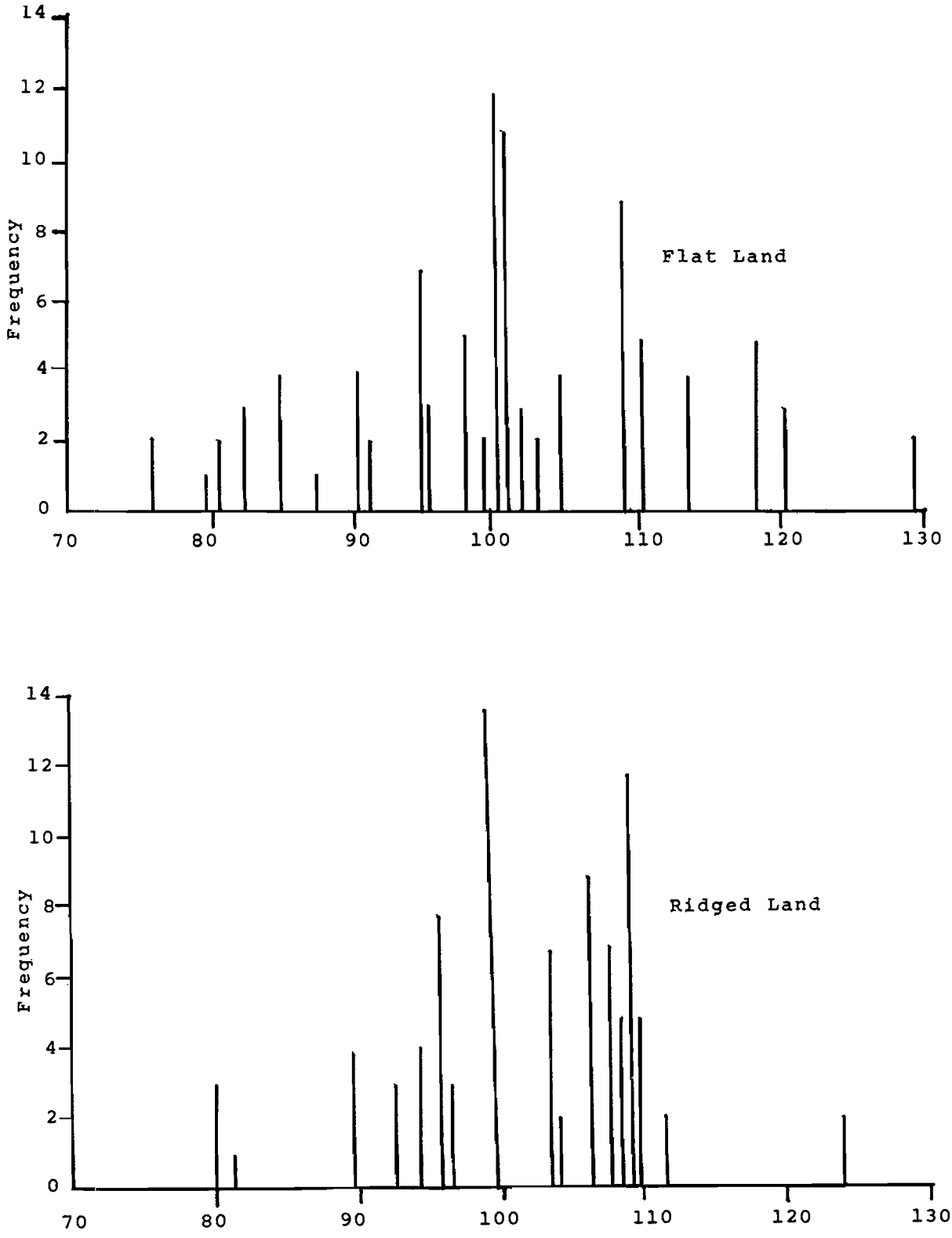
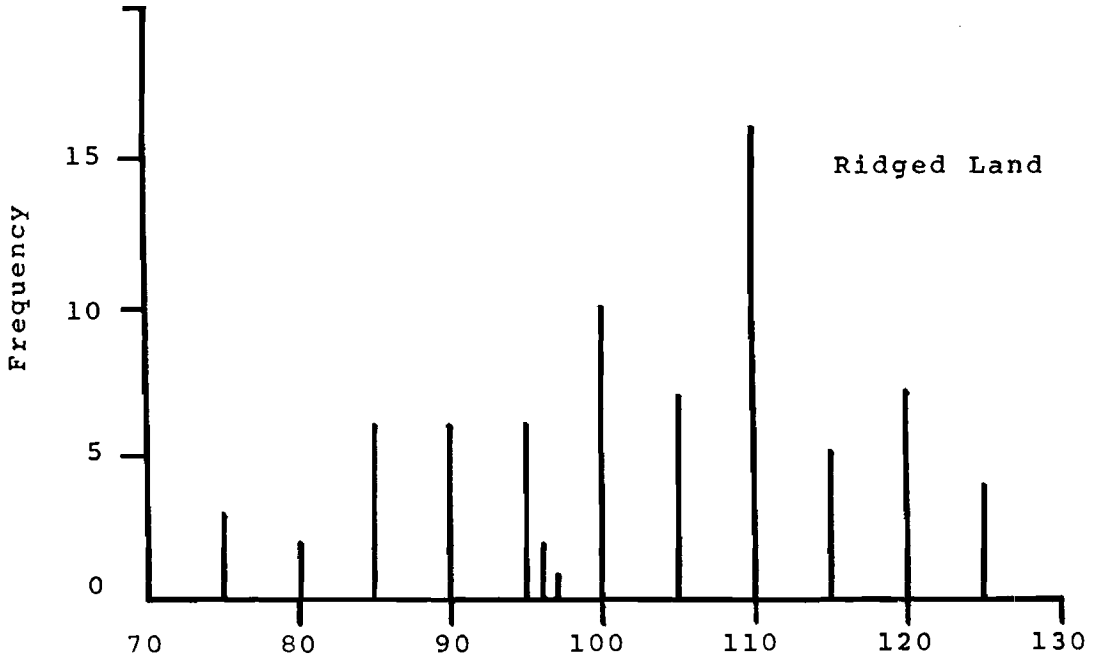


Figure 2. Observed intra-row spacings for two samples of sticks planted on ridged and flat land.



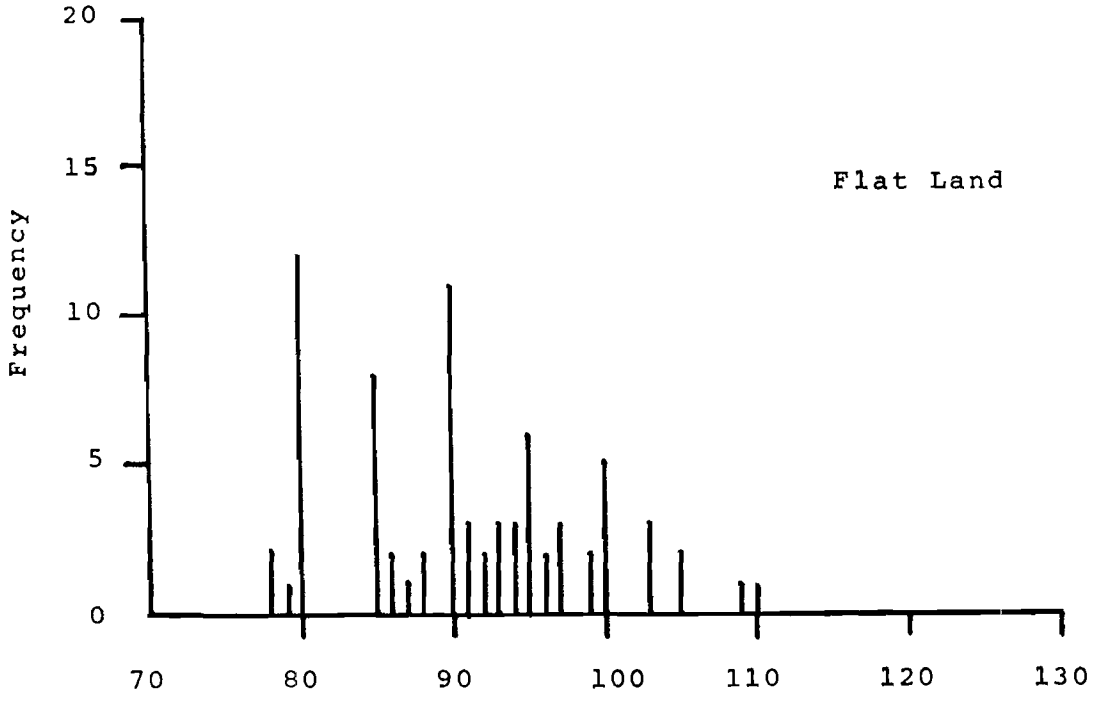


Figure 3. Observed planting depths for two samples of 75 sticks planted on ridged and flat land.