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ORIENTATION OF CASSAVA CUTTINGS: THE EFFECT ON ROOT GEOMETRY AND ON THE FORCE NEEDED FOR MANUAL HARVEST

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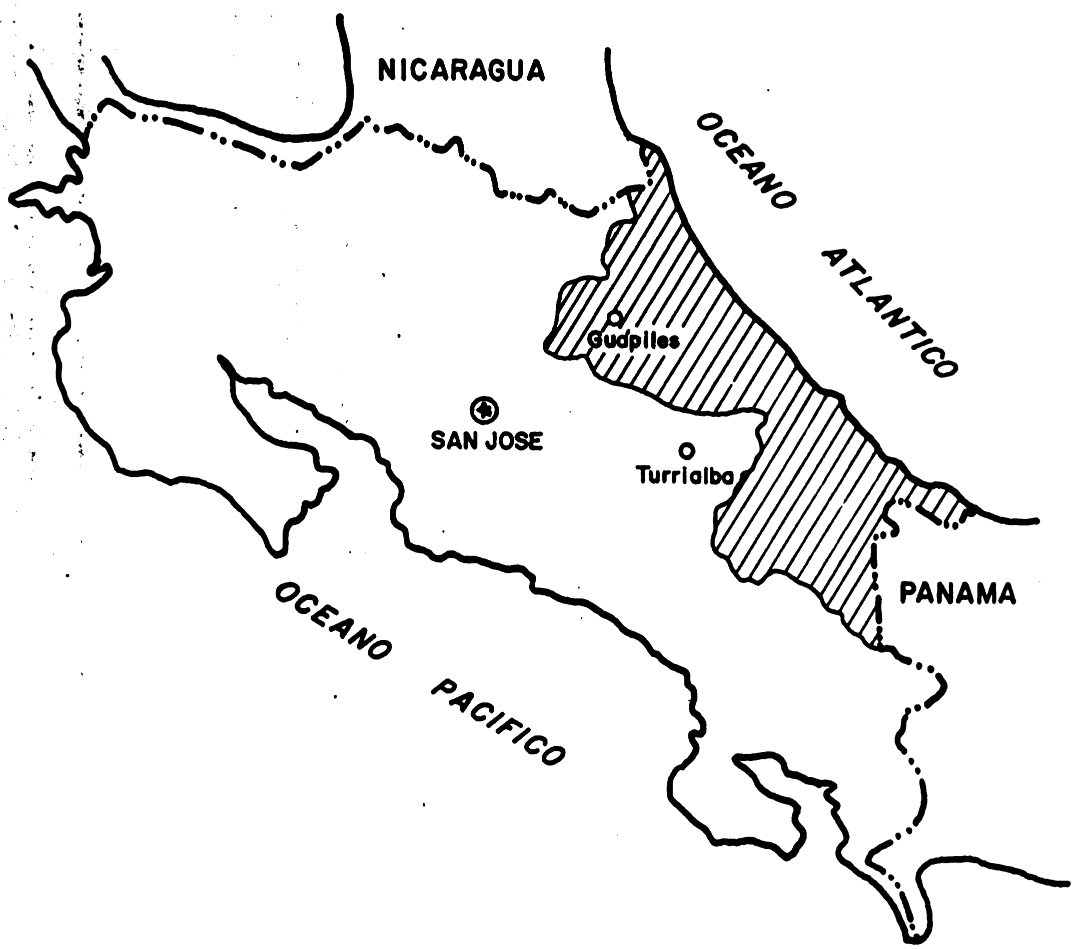

Figure 1. Location of the study area.

PREFACE

General description of the research programme on sustainable Landuse.

The research programme is based on the document "elaboration of the VF research programme in Costa Rica" prepared by the Working Group Costa Rica (WCR) in 1990. The document can be summarized as follows:
To develop a methodology to analyze ecologicaly sustainable and economically feasible land use, three hierarchical levels of analysis can be distinguished.
1. The Land Use System (LUS) analyses the relations between soil type and crops as well as technology and yield.
2. The Farm System (FS) analyses the decisions made at the farm household regarding the generation of income and on farm activities.
3. The Regional System (RS) analyses the agroecological and socio-economic boundary conditions and the incentives presented by development oriented activities.

Ecological aspects of the analysis comprise comparison of the effects of different crops and production techniques on the soil as ecological resource. For this comparision the chemical and physical qualities of the soil are examined as well as the polution by agrochemicals. Evaluation of the groundwater condition is included in the ecological approach. Criterions for sustainability have a relative character. The question of what is in time a more sustainable land use will be answered on the three different levels for three major soil groups and nine important land use types.

Combinations of crops and soils

	Maiz	Yuca	Platano	Piña	Palmito	Pasto	Forestal I II III
Soil I	x	x	x		x	x	x
Soil II						x	x
Soil III	x			x	x	x	x

As landuse is realized in the socio-economic context of the farm or region, feasibility criterions at corresponding levels are to be taken in consideration. MGP models on farm scale and regional scale are developed to evaluate the different ecological criterions in economical terms or visa-versa.

Different scenarios will be tested in close cooperation with the counter parts.

The Atlantic Zone Programme (CATIE-AUW-MAG) is the result of an agreement for technical cooperation between the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), the Agricultural University Wageningen (AUW). The Netherlands and the Ministerio de Agricultura y Ganadería (MAG) of Costa Rica. The Programme, that was started in April 1986, has a long-term objective multidisciplinary research aimed at rational use of the natural resources in the Atlantic Zone of Costa Rica with emphasis on the small landowner.

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ABSTRACT

Most studies on methods of planting cassava cuttings have focused on the effect on tuber yield. The studies on the root geometry have mostly been done with a view to mechanizing the harvest. The present study relates the angle at which the cuttings are planted and the resulting geometry of the roots to the force needed for the manual harvest. Compared with planting cuttings obliquely, planting vertically resulted in a more symmetrical horizontal distribution of the roots and more vertically oriented roots at the tip of the cutting, and more force was needed to loosen the plants (175 kgf compared with 106 kgf).

KEYWORDS

Cassava, *Manihot esculenta*, cuttings, planting methods, root types and distribution, force for manual harvest.

INTRODUCTION

Most of the cassava in the Atlantic Zone of Costa Rica is grown for export to the USA and Europe. Harvesting is manual: the tops are cut off at a height of about 30 cm and the remaining stems are used as a handle or lever to pull the tubers out of the soil. In most cases a single man can do the job, but sometimes two or even three are needed to handle an unwieldy plant.

Farmers have outspoken ideas about the effect of the size, shape and planting angle of cassava cuttings on tuber yield, weed control, wind resistance, root geometry and ease of harvesting. Few farmers are in full agreement, but all share the view that the way of planting affects many aspects of the production process.

Most of the research published to date has been limited to the effect of planting methods on tuber yields, as shown in reviews by ONWUEME (1978) and MONTALDO (1985). The few references to root geometry and ease of harvesting have been made with a view to mechanization (ONOCHIE et al., 1973) or are not very specific (JOHNSON et al., 1981) or qualitative (WEITE et al., 1988).

In 1987 I helped a group of farmers in La Lucha, Guácimo canton, Costa Rica, to harvest cassava. They claimed that the angle at which the cutting was planted and the shape and orientation of its tip had little influence on the yield but did determine the geometry of the roots and the force required for the manual harvest. In 1990 a small experiment was planted to test these hypotheses.

MATERIALS AND METHODS

Experimental site

The experiment was carried out in a farmer's field in La Lucha, Guácimo Canton, Atlantic Zone of Costa Rica (mapsheet 3446 I, 584.2 E, 248.3 N). The site was located on a flat, recent, alluvial terrace at an altitude of about 15 m above sea level.

The field had been used for annual crops, mainly maize, for several years. In March 1989 the land had been cultivated with a tractor-drawn disk harrow, but since then it had remained fallow, under various grasses, predominantly *Eleusine,*, *Digitaria*, *Rottboellia*, *Paspalum* and *Cyperus* spp.

The soil was an Andic Dystropept with a loamy texture, friable and well drained. The topsoil (0-20 cm) had the following properties: bulk density 1.07 g/cm^3, water retention 0.50 g/cm^3 at pF 2.0 and 0.33 g/cm^3 at pF 4.2, pH-H_2O 6.5, organic matter 4.8 %, CEC 29.0 meq/100 g soil and base saturation 84 %. The profile was uniform with depth and had no physical or chemical obstructions to root development.

Weather conditions

Table 1 presents the monthly rainfall at El Carmen, a nearby meteorological station. During the first months after planting the rainfall was favourable. Thereafter, the crop was sufficiently well established to rely on the moisture reserves of the soil.

Plant material

The most widely grown cultivar, "Valencia", was used. The stems were harvested on 10th September 1990, cut into pieces on 12th September, and planted on 14th September. Between harvest and planting they were kept in the shade. Cuttings from the middle part of the stems were used. On average, they were 28 cm long, weighed 110 g and had 10 nodes.

Design and treatments

The experiment had a random block design: 4 blocks x 5 treatments = 20 plots, consisting of 3 rows of 7 plants each. Each block was surrounded by a border row. During the course of the experiment two blocks were severely damaged by gophers (*Orthogeomys cherriei*); the others escaped attack and were left almost completely intact. The treatments consisted of combinations of the angle at which the cutting was planted and the shape and orientation of its tip; see Figure 2. In all treatments the tips of the cuttings were at the same depth below soil level.

Cultivation methods

Land preparation consisted in cutting the grass, waiting for its regrowth, spraying with Roundup (glyphosate) and later carrying out a superficial hand weeding. The spacing of the cassava was 1 m x 1 m. Each cutting was planted in a small hole, made just large enough to accommodate it. The land was not tilled, in order to avoid creating an abrupt boundary between loose topsoil and more compact subsoil. No fertilizer was given, as that might influence the orientation of roots. The crop was weeded by hand, with a machete.

Observations and analysis

Two blocks had to be written off because of severe gopher damage. In the other two blocks the following observations were made:

- The two outer rows of each plot (2 x 7 plants) were harvested with a tripod - lever - balance combination (Figure 1). The lever was pushed down slowly and the force at which the plant started to move was recorded, as well as the fresh weight of the storage roots.

- The central 5 plants from the inner row of each plot were dug out carefully and transferred to the laboratory. The following characteristics were determined from all storage roots (tubers) that were thickened over a length of 10 cm or more: length, circumference and fresh weight of the thickened part, position on the cutting (cm from tip), length of the peduncle, orientation.

- Four samples of 500 g fresh tuber material were taken and the dry weights were determined after oven-drying for 48 hours at 75 °C.

The means per plot were calculated and submitted to an analysis of variance using SPSS-PC+ software.

RESULTS AND DISCUSSION

Force required for harvesting

All treatments gave the same yield but, as the farmers had predicted, vertical cuttings required much more force for the harvest than oblique ones (Table 2).

The method used might have overestimated the force required for oblique cuttings, as farmers normally exert lateral force as well as pulling upwards. Moreover, they do not lift the plants in one slow steady movement, but shake and wrench them out of the soil.

A better estimate of the energy required for the manual harvest would have been the integral of force over time, but the method described above had to be used because no sophisticated instruments were available. Although not perfect, it gives a good approximation, which fits in well with the farmers' experience that most cassava plants can be pulled out by a single able-bodied person and nearly all can be pulled out by two.

Types of storage roots

In all treatments two very different types of storage root were distinguished:

- Most plants had three to six "terminal" roots, here defined as those starting from the very tip of the cutting or within 5 cm from it. They had a mean fresh weight of about 250 g, were sessile or had a very short and thick peduncle, and were difficult to free from the cutting without breaking them or causing a large wound surface. The latter made them unfit for export.

- In addition most of the plants had one or two "lateral" roots, originating from 5 cm or more behind the tip of the cutting. These had a mean weight of about 530 g, a thin peduncle with a mean length of 10 cm, and were easy to separate from the cutting, with a small, clean wound. Unless too large and woody, they were of good quality for export.

According to some farmers the presence of lateral storage roots is not only a trait of the cultivar but can also be stimulated: lateral roots are more numerous if the cuttings have been inserted more deeply into the soil, and they originate only where the cutting was bruised or cut during its handling. The latter agrees with experience in Venezuela, where farmers made some cuts in the cortex of cuttings in order to stimulate root development (MONTALDO, 1972).

Geometry of storage roots

The observations on root geometry are summarized in Figure 2. The treatments had no effect on the geometry of the lateral roots. These grew at mean angles of 9-18° (standard error of means = 3°) with the horizontal plane, without a clear preference for a specific direction. The treatments did influence the horizontal and vertical distribution of the terminal roots. The roots of cuttings planted obliquely followed the direction of the cuttings and grew at a mean angle of 25° with the horizontal plane, while those of vertical cuttings grew in all directions, and at a mean angle of 43° with the horizontal plane (standard error of means = 3°). No clear effects of the shape of the tip (cut straight across or obliquely) were observed.

When interpreting Figure 2 one should keep in mind that all the graphs represent the means of 8-10 plants. Therefore they give the impression that each plant had numerous storage roots in many directions, whereas in reality most had only 1-2 lateral roots and 2-6 terminal roots. The plants of treatment 5 had an above-average yield (2.4 kg) and number of lateral (2) and terminal (6) roots.

However, given the still moderate tuber sizes and numbers in this treatment it is unlikely that crowding influenced the orientation of the roots.

The findings confirm the farmers' opinion, that the roots of cuttings planted vertically grow "deeper" and they indicate that the large force required for harvesting such plants may be related to their root geometry. Here, "deeper" does not mean that vertical cuttings are usually inserted relatively deep into the soil and that therefore the tubers are deep-lying (ONWUEME, 1978), because in the experiment all cuttings were planted at the same depth. Instead, it means that roots from cuttings planted vertically, starting from the same depth in the soil, had a more vertical orientation than those from cuttings planted obliquely.

CONCLUSIONS AND RECOMMENDATIONS

As predicted by the farmers, the planting angle of the cutting had no influence on the yields but had a major effect on the force needed for the manual harvest. Plants from vertical cuttings were more difficult to harvest than those from oblique ones. This was related to the geometry of their terminal roots, which grew in all directions and tended to grow deeper than those of oblique cuttings.

Some farmers suggested there is a relation between bruises or cuts on the cutting and the presence of lateral roots. It may prove useful to study this hypothesis, because of the possibility it offers of manipulating the proportions between the different kinds of roots and hence of improving the quality of the product.

Farmers are keen and down-to-earth observers and their ideas may help researchers to see reality from a different angle and to formulate hypotheses for research.

ACKNOWLEDGEMENTS

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Table 1 Rainfall in El Carmen, Costa Rica (mm/month).

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1990/91	205	164	360	431	86	99	82	199	530	301	723	526	308
Average	225	287	393	401	314	204	157	220	264	326	452	397	225

Table 2 Planting angle of the cutting, shape of the tip, fresh weight of the tubers and force required for the manual loosening of cassava plants.

Treatment	1	2	3	4	5
Angle of the cutting	oblique	oblique	oblique	vertical	vertical
Shape of the tip	straight	oblique, upwards	oblique, downwards	oblique	straight
Fresh weight of the tubers (kg/plant) * (S.E. of means = 0.5)	1.8	1.9	1.8	1.9	1.9
Force required for loosening (kgf/plant) ** (S.E. of means = 15)	99	113	107	175	175

*) About 38 % D.M.
**) 1 kgf ≈ 9.8 N.

Figure 1 Sketch of the geometry of the storage roots and of the method for estimating the force required for loosening the cassava plants (not to scale).

Figure 2 Orientation of the cutting, shape of the tip, and geometry of the cassava roots thickened over a length of 10 cm or more (horizontal and vertical distribution are in classes of 30 ° and 10°, respectively).

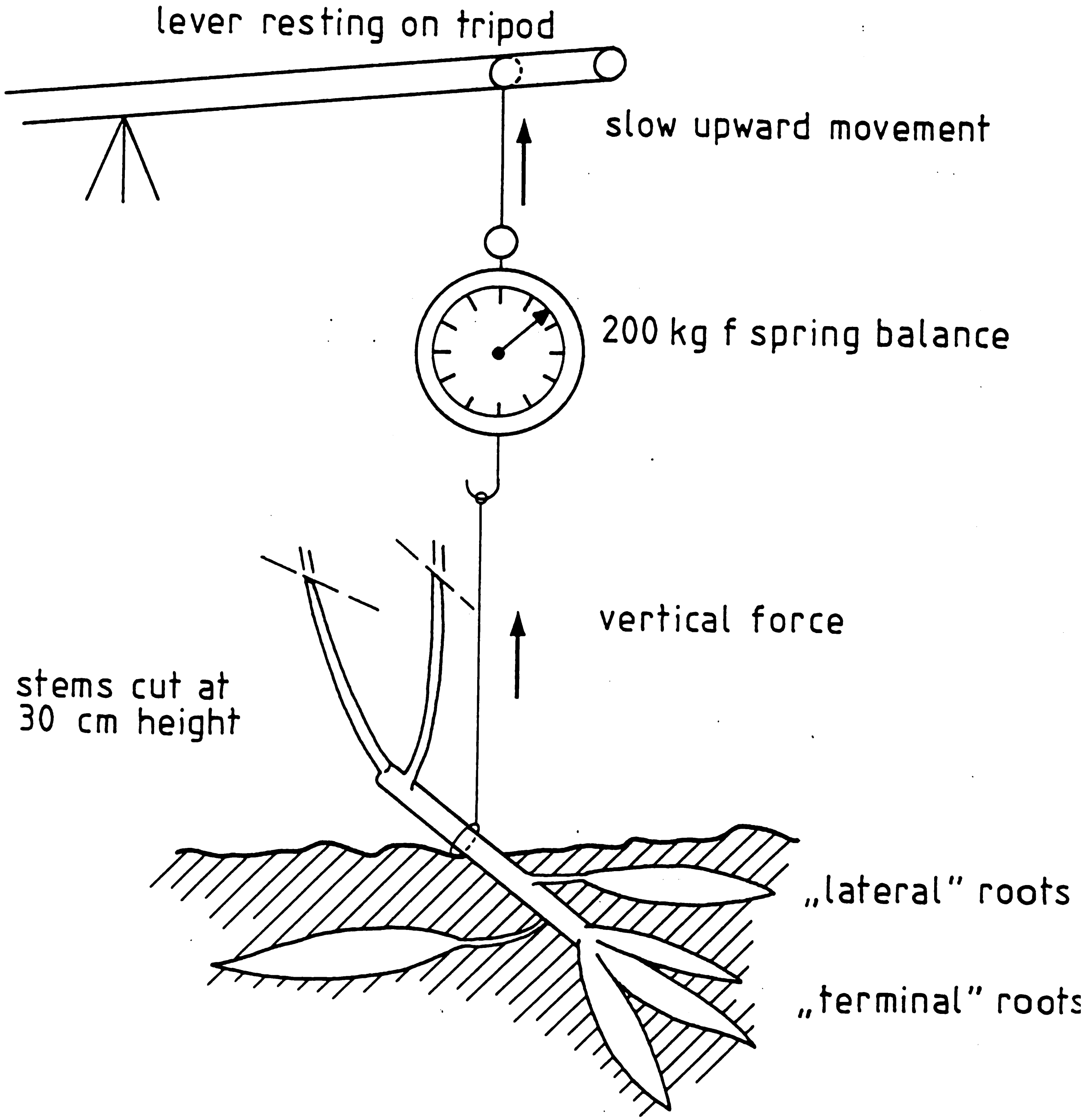
lever resting on tripod
slow upward movement
200 kg f spring balance
vertical force
stems cut at
30 cm height
„lateral" roots
„terminal" roots

Fig. 1

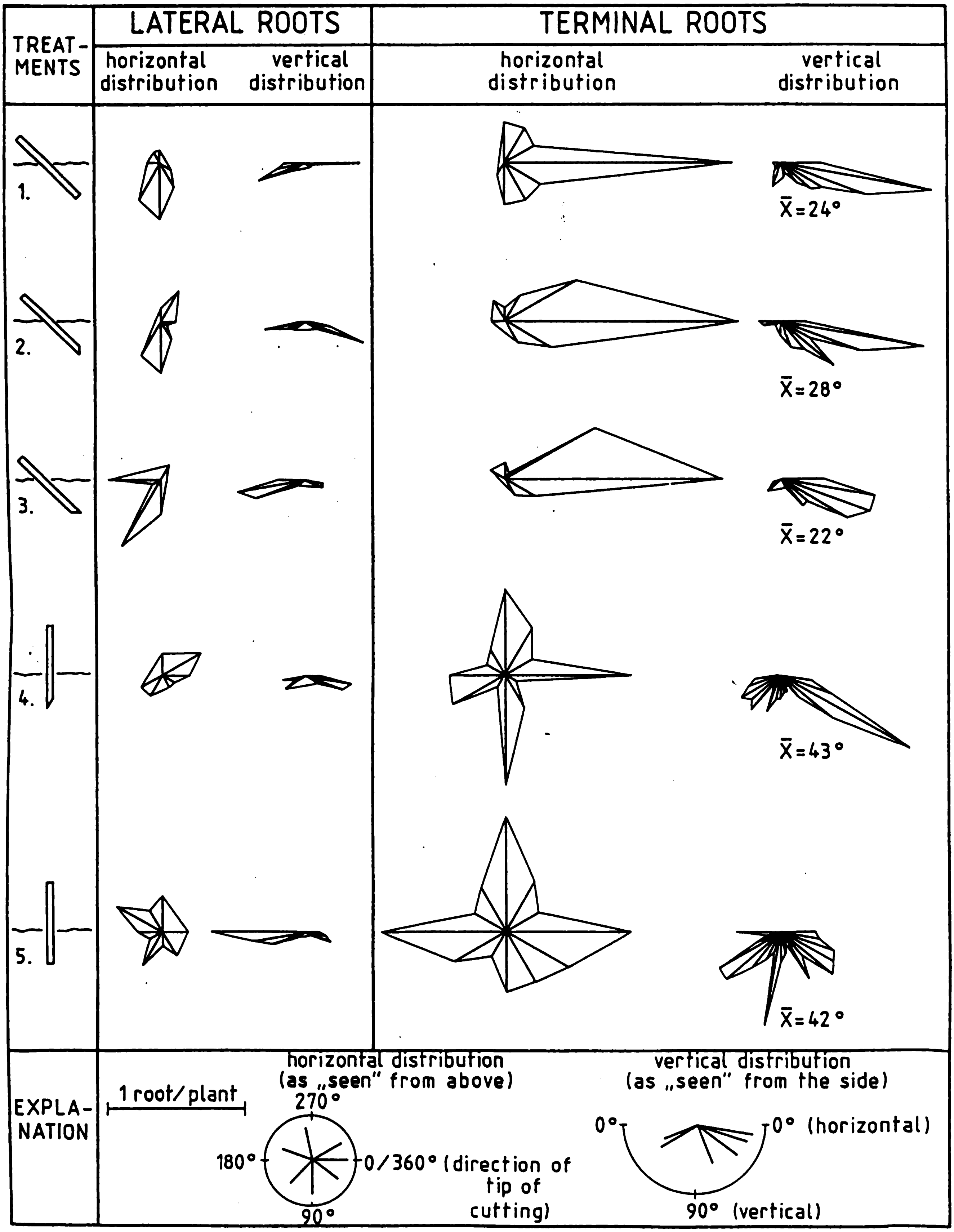
TREATMENTS
LATERAL ROOTS
TERMINAL ROOTS
horizontal distribution
vertical distribution
horizontal distribution
vertical distribution
1.
2.
3.
4.
5.
X̄=24°
X̄=28°
X̄=22°
X̄=43°
X̄=42°
EXPLANATION
1 root/plant
horizontal distribution (as „seen" from above)
270°
180°
0/360° (direction of tip of cutting)
90°
vertical distribution (as „seen" from the side)
0°
0° (horizontal)
90° (vertical)

Fig. 2