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DEVELOPMENT OF ROOT SYSTEMS DURING THE GROWTH OF SOME VEGETABLE CROPS

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SUMMARY

The development of the root system of some locally important vegetable crops has been studied. The crops investigated were grown under mediterranean and tropical conditions with appropriate cultural treatment.

The development of root systems was more a reflection of soil conditions than a conformation to a growth pattern specific for the particular crop plant. Evidence for the restricting effect of greater soil bulk density on root development and a relation between soil bulk density and depth of root development was obtained. Frequent irrigation is considered to be a factor inducing shallow root development and also a lack of nutrients in the deep layers of soil.

Distinct asymetric development of the root system was correlated with the pattern of distribution of the irrigation water.

INTRODUCTION

Increasing attention is being directed to the study of the effect of soil conditions on the development of the root systems of cultivated plants.

In spite of the relevance of the traditional methods used in such studies, they have recently been criticized by Melhuish and Lang[6] but without new methods of general application being put forward. In addition, the classical methods, as modified by the Groningen school, 'provide a useful qualitative picture of the systems' (Barley [4]).

The characterization of the growth and development of the root systems of some vegetable crops of economic importance in medi-

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terranean and tropical horticulture has been the chief consideration in the present study. The crops were cultivated in two soils of the Caia region of Portugal and in one soil of the Chianga region of Angola, with the appropriate agro-technical procedures for each area (Portas [7]).

MATERIAL AND METHODS

Material

The crops investigated were lettuce 'Rainha de Maio.' Tomato 'H.1548' at Caia and a butterhead type, at Caia and Chianga; onions 'Valenciana' at Caia and 'Texas Early Grano' at Chianga; cabbage 'Mascote' at Caia; cauliflower 'Snowball' at Caia and Chianga and 'Express' at Caia; melon 'Tendral' at Caia and 'Marglobe' at Chianga†.

TABLE 1

Characteristics of the three soils

Layers (cm)	Bulk density*	Soil strength**	Air porosity***
At soil			
0– 8	1,46[a]	1,50[a]	35%
8– 30	1,66[b,c]	3,00[b]	27
30– 50	1,63[b]	1,75[a]	25
50– 80	1,74[c]	2,50[b]	21
80–120	1,87[c]	4,00[b]	15
Pag soil			
0– 6	1,35[a]	2,00[a]	37%
6–25	1,49[b]	3,75[a]	34
25–37	1,83[c]	—	22
37–60	1,76[c]	—	18
60–95	1,75[c]	—	16
Hb 32 soil			
0– 10	0,99[a]	1,00[a]	37%
10– 40	1,04[a]	1,50[a]	30
40– 70	1,01[a]	1,25[a]	31
70–110	0,97[a]	1,00[a]	30
—	—	—	—

* Mean of three field volumetric samples, g cm^{-3}.
** Six samples, kg cm^{-2}.
*** Total porosity minus field capacity, three samples.
Means within a column followed by the same letter are not significantly different at the 10% level.

† Other crops were studied but are not referred to in this paper.

TABLE 2

Data concerning climate, soil conditions, irrigation periods and growing seasons for the various crops for the two experimental areas

Caia				
	4 months of frost	Spring	4 months of irrigation	Fall
Soil temperature	< 10,0°C			8,9–10,9°C
Crops ←→				
Lettuce		←——→		
Onions		←———	———→	
Cabbage	——→			←——
Cauliflower				←——→
Wintermelon		←——	———→	
Tomatoes		←———	———→	
Chianga				
	No irrigation	Irrigation		(cold quarter) *
Lettuce		←———	———	———→
Onion		←———	———	———→
Cauliflower				←——→
Tomato	←——→			

* Light frost in the nights; day temperatures as in the other season; soil temperatures over 15° C.

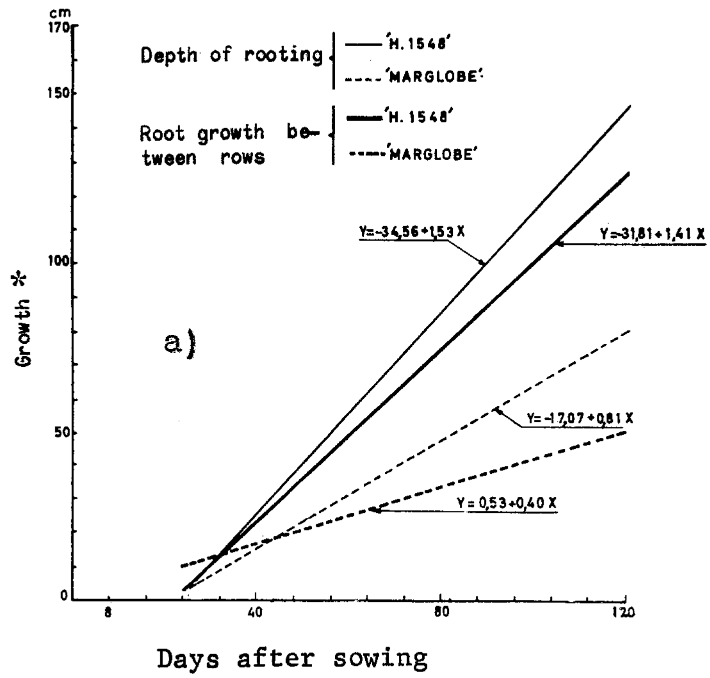
In Caia the crops were grown in 2 different types of soil. One, a sandy loam, is an Entisol (At soil), the other, a coarse-textured para-hydromorfic soil (Pag) is an Alfisol. In Chianga the soil (Hb 32) is a fine-textured Oxisol. Data relating to different soil profiles are given in Table 1.

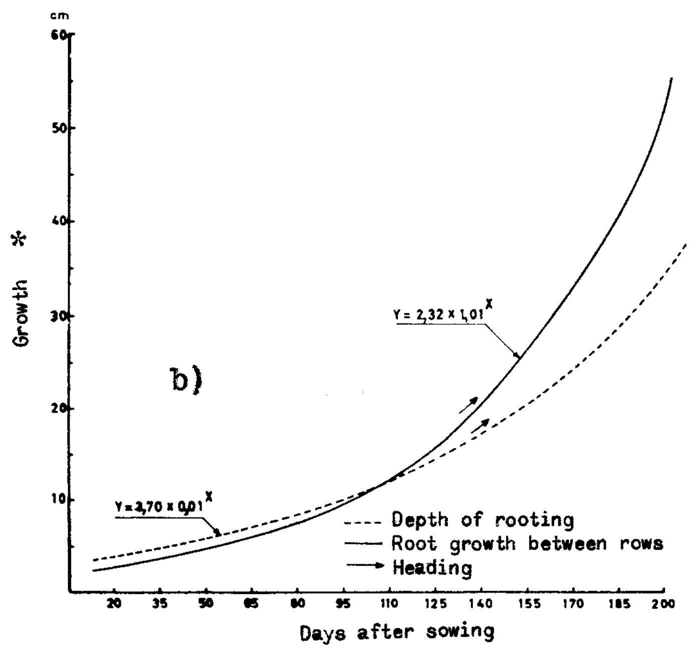
The strength of the soils was determined, at field capacity, by means of a hand-operated penetrometer having a base 6 mm in diameter. The coarse-textured 25–37 cm layer of the Pag soil has a very high impedance and, differs from the 6–25 cm layer only by its high bulk density, is a typical plow-sole according to the definition of Taylor *et al.*[10] For further particulars concerning these soils reference should be made to the earlier paper (Portas [7]).

The different crops were cultivated during widely differing seasons throughout the year. Variations in the climatic conditions, that have considerable influence on plant growth during the year, are given in Table 2. For example, at Caia soil temperatures at a depth of 20 cm were low during the last 2 months of the growth of cauliflower and the soil was rather cold for 4 months during the growth of the cabbages.

Methods

In the Caia region, the monolith and needleboard methods (Schuurman and Goedewaagen [9]) were used for the investigation of the root systems. All the needleboards used had bores 50 cm square and rods 1 cm in diameter.


cm
170
150
100
50
0
Growth *
Depth of rooting
'H.1548'
'MARGLOBE'
Root growth between rows
'H.1548'
'MARGLOBE'
Y=-34,56+1,53 X
Y=-31,81+1,41 X
a)
Y=-17,07+0,81 X
Y=0,53+0,40 X
8
40
80
120
Days after sowing


cm
60
50
40
30
20
10
Growth *
b)
Y = 2,32 × 1,01^X
Y = 3,70 × 0,01^X
---- Depth of rooting
—— Root growth between rows
→ Heading
20
35
50
65
80
95
110
125
140
155
170
185
200
Days after sowing

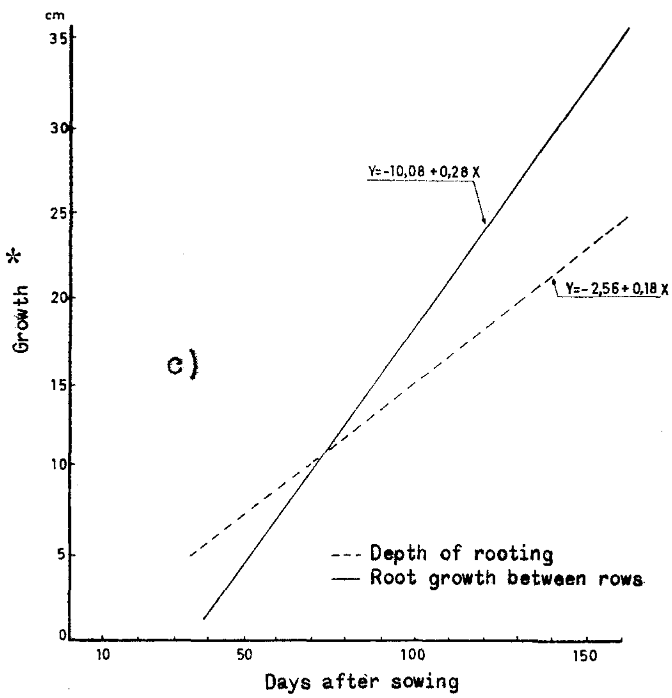


Fig. 1. Development of root systems of different plants. ($P < 0.01$)
a) Tomatoes ('H. 1548' and 'Marglobe')
b) Cabbage ('Mascote')
c) Cauliflower ('Express').

Some boards had rods 50 cm in length, others had rods 30 cm in length, and others had rods 10 cm in length.

Root systems were collected at intervals during the growth of the plants; 3 to 7 collections being made during the period of development of the various crops. Collections began while the plants were in the nursery, except in the case of the melon that was sown directly in the field and not transplanted, and at this stage consisted of 12 plants from each of the different crops.

At Caia, attempts were made, to collect from each of the twelve 240-m^2 plots established for the rotation trials on each type of soil, a single plant representing the average characteristics of the plants of a particular plot.

In Chianga the root systems of 4 plants were collected using the excavation method, from a plot containing 16 plants.

The purpose of the investigations at Caia and Chianga was to ascertain the morphology of the root systems and the volume of soil ultimately occupied by the roots.

In the case of herbaceous crops, the *root volume* (Baeyens [2]) for each plant collected is normally estimated from the maximum dimensions attained by the root system in 2 dimensions: *depth* in the plane vertical to the planting line and *horizontal* at right angles to the row of plants in a plane parallel to the surface of the soil. A third dimension is obtained from maximum root extension horizontally along the row of plants taking into account interpenetration of the roots of adjacent plants.

The term *root volume* in the above sense, used also by Russell [8], will be replaced in this paper by the term *rooted-soil volume*.

RESULTS

In general the rate of lateral growth of root systems – maximum *horizontal* root development at right angles to the row of plants (*root growth between rows*) – was greater than the rate of downward extension – maximum *depth* of root development (*depth of rooting*). This type of development is depicted in Fig. 1a for tomatoes and is essentially similar for cabbage and cauliflower (Fig. 1b and c). Onion root growth is, however, far better characterized by the number of roots and the average diameter of the surviving roots (Fig. 2) since the roots of onions tend to break off while being washed.

The general pattern of root systems that cannot be included neither in the tap type nor in the fibrous type – we call them *divergent* – is indicated diagrammatically in Fig. 3, using the mean diameters of the various orders of roots. The root systems of onions (transplanted plants in both cases) were of the fibrous type.

The stage of development of the crops at sampling was such that each of the root depth classes, as differentiated by Knott [5], was represented. The lettuce and onion plants were characterized by shallow root development in both areas (Fig. 4). The cauliflower and cabbage plants developed root systems penetrating more deeply into the soil. The crops considered to have a capacity for deeper root development, *i.e.* melon and tomato, did not provide (always) evidence of this under the conditions of the experiments.

The observations on root development will be considered in relation to the soil factors most likely to influence root development. Soil bulk density is greatest in the Pag soil at a depth of 25 to 37 cm. In this soil only the roots of cabbage penetrate into this layer; the depth to which the roots of melon and tomato develop in this soil

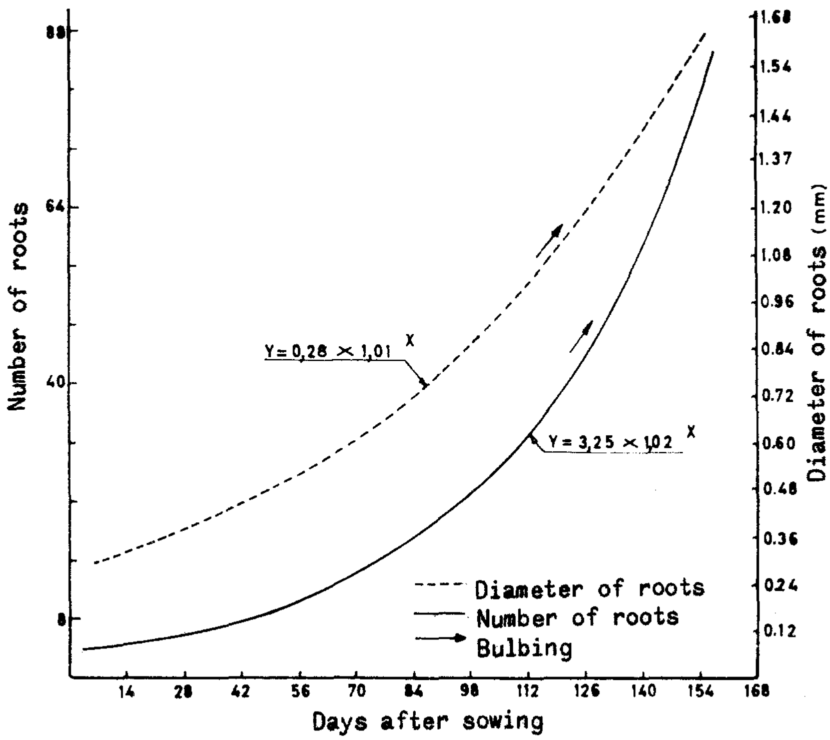


Fig. 2. Development of the root system of 'Valenciana' onions. ($P < 0{,}01$)

is restricted by this layer. Root development of the various crops growing in a sandy soil, having both a plowsole and a clay pan with similar bulk densities as the Pag soil, is indicated in Fig. 5.

These differences in depth of penetration by roots can be correlated with differences in the diameters of the thicker roots. In the case of cabbage the maximum average root diameter was 2.7 mm, while for melon it was 6.2 mm and for tomato 3.3 mm. Vertical root development in cauliflower and melon was halted by a soil layer of bulk density 1.70; in the case of tomatoes by a soil layer of bulk density 1.75 and cabbage by a layer of bulk density 1.83.

Another factor having important influence on depth of root penetration is the water supply. The shallow root development by crops growing in the At soil during the summer was associated with

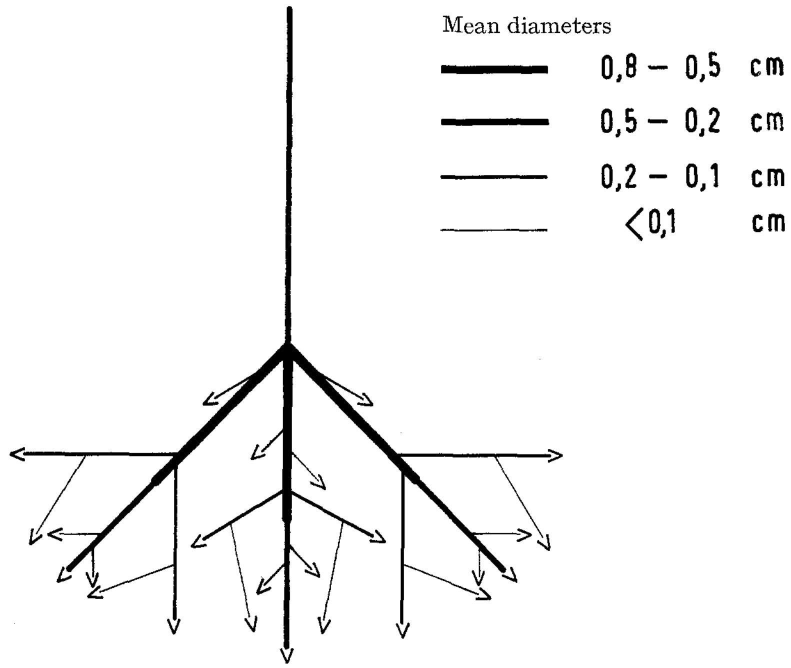


Fig. 3. General pattern of root systems applicable to cabbage, cauliflower, tomato, and melon.

frequent irrigation that results in reduced soil oxygen content to the extent that it becomes limiting for species having a high oxygen requirement such as members of the Solanaceae and the Cucurbits. In the Hb 32 soil at Chianga the roots of 'Marglobe' tomatoes do not attain the depth reached by the H1548 cultivar on another soil (Fig. 1). Such behaviour was a general phenomenon on this soil; it may be related to the practically daily rainfall during the growth period, the lack of nutrients in the Ap horizons of the soil, and the presence of nematodes.

Clear evidence of the importance of the distribution of water in the soil on root morphology was also obtained. A good example is

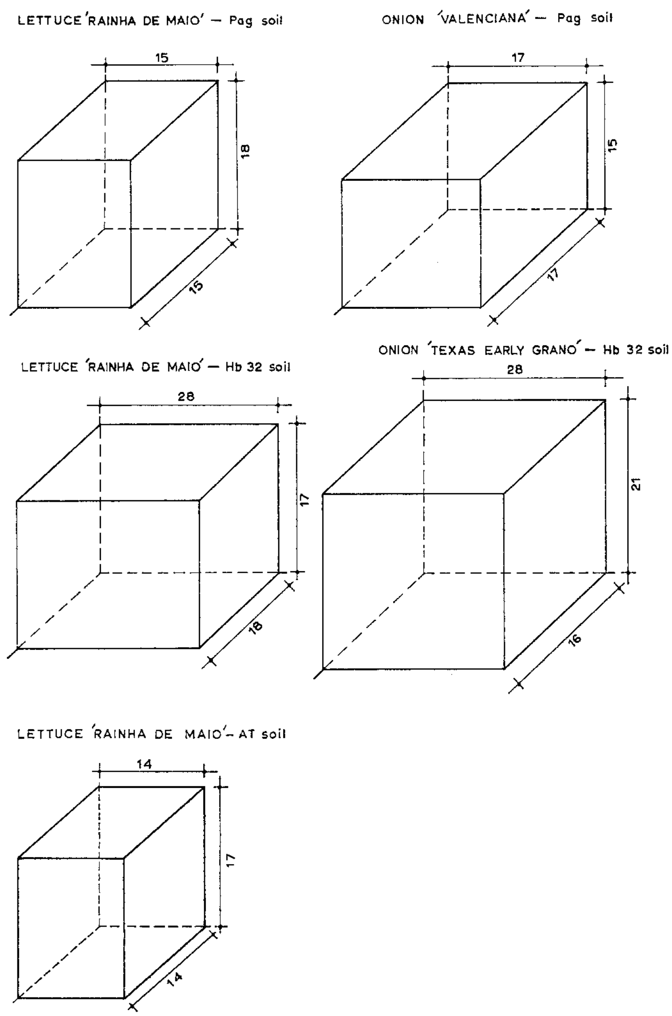


Fig. 4. Rooted-soil volumes of lettuce and onions on the different soils (cm).

that of development of the roots of melon in soils where a root obstructing pan is absent (Fig. 6). In the absence of irrigation, root development is predominantly downward, while irrigation results in a much larger and shallower development of the root system.

Assymetric development of the root system resulted when the

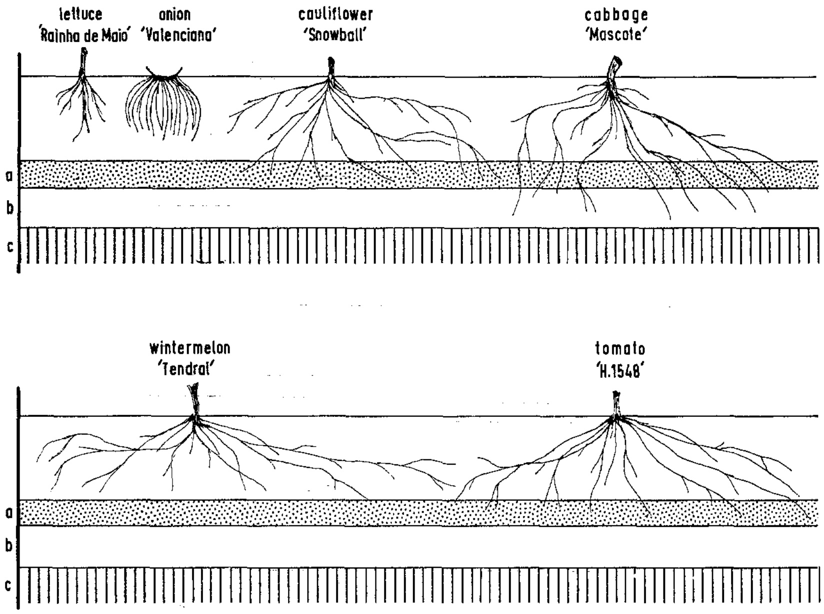


Fig. 5. Behaviour of root system in a Pag-like soil.
a) Zone of transition to the plowsole
b) Plowsole
c) Clay pan.

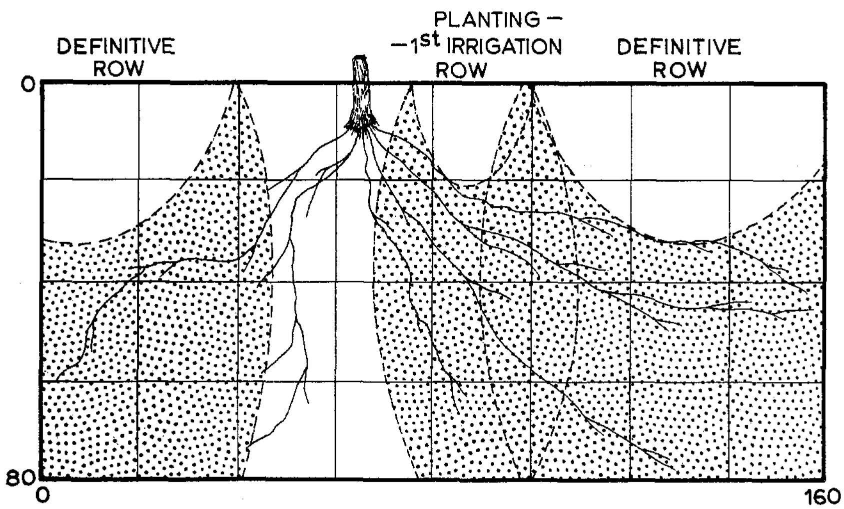


Fig. 7. Asymetric development of tomato root system resulting from the position of the line of the first irrigation after planting in relation to the planting line where the subsequent irrigations are provided. (Values in *cm*).

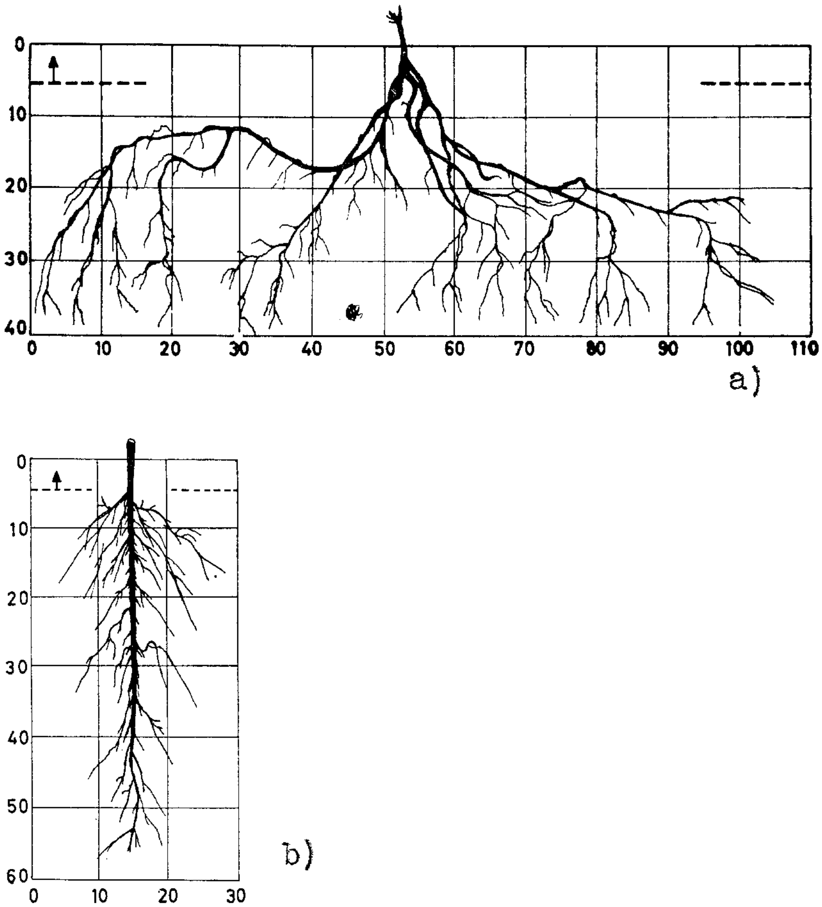


Fig. 6. Root system of melon 'Tendral'. (Values indicate *cm*).
a) Last sampling, At soil, irrigated
b) Last sampling, Pag soil, not irrigated. (deep, clay-loamy)
--- Hilling

starter solution and the first 2 irrigations were applied on one side only of the row and close to it. The more extensive development of the system in the moister soil is illustrated in Fig. 7.

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