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The root system of the husk tomato (Physalis ixocarpa Brot.)

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Abstract

The husk tomato (*Physalis ixocarpa* Brot.) is widely cultivated in central Mexico, and may be grown in countries with a temperate climate. The experiment was set up during the dry period of the year (average weekly temperature 17-22°C) in the State of Morelos, Mexico, using the cv. 'Rendidora' in loamy clay soil and furrow irrigation. The roots were investigated by the pinboard method modified by García Blancas and Grajeda Gómez (in print), partly adapted by us for quantitative estimation of root systems. Two plants were investigated every second week. They had a well developed tap root. Most of their lateral roots were found in the superficial soil layer, 0-20 cm. The root dry mass was also concentrated near the central axis of the plant. The majority of root apices were, however, found in the soil cylinders 10-40 cm from the central axis. During the senescence of the aerial part (14th week after emergence) the root system lost a large part of its small roots. The modification of the pinboard method by García Blancas and Grajeda Gómez (in print) permited us investigating the root systems with very simple tools, in situ.

INTRODUCTION

The husk tomato cultivated on over more than 12 000 ha, is an important vegetable crop in Mexico. It is indispensable for the preparation of traditional dishes known from the time of the Aztecs. It can be cultivated in countries with a temperate climate, such as Poland (Borkowski — pers. comm.) due to its short period of vegetative growth 85-105

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days (Saray Meza, 1977; Curtujano Escobar et al., 1985). During the last years, some cultivars have been selected from among the cultivated populations of this plant. One such selection, 'Rendidora', being the most productive, has become popular among the growers from the State of Morelos (Saray Meza and Loya, 1978; Saray Meza et al., 1978; Saray Meza, 1982).

There is very scarce horticultural literature on the husk tomato (see Saray Meza, 1982) and especially on its root system (Medvedev, 1958).

When investigating the root system of any plant, there is the problem of choosing the method suitable for the local conditions (Kolesnikov, 1971; Böhm et al., 1977; Böhm, 1979). We have choosen the pinboard method modified by García Blancas and Grajeda Gómez (in print).

MATERIAL AND METHODS

The experiment was set up in the Experimental Field (Campo Agrícola Esperimental) of the National Institute for Agricultural Investigation (INIA) in Zacatepec, Morelos 18°39′N, 99°12′W, 900 m above sea level with the climate Aw_0 (w) (i′) g (García, 1981). The experiment was localized in a field with deep homogenous soil of the loamy clay type. The experimental field was divided into 8 blocks. During every second week, two pairs of healthy plants were choosen. Since the plants of the cv. 'Rendidora' occur in two different types: prostratred and erect (with some per cent of intermediate plants), we have choosen for each sampling one pair of prostrated and one of erect plants. Initially, the roots of each plant of the pair were investigated separately, but very soon it was not possible to separate them, and they were investigated jointly (from the 8th week after emergence).

As it was mentioned, the method of García Blancas and Grajeda Gómez (in print) is a modification of the pinboard system introduced by Rotmistrov in 1908 (see Schuurman and Goedewaagen, 1964) and developed by other authors (see Böhm, 1979). In this study we followed the principles of the method of García Blancas and Grajeda Gómez (in print): the root system was investigated in situ; the column of the soil was washed gradually with a hand or other type of sprayer. Before starting the investigation, a plant or a pair of plants were chosen at random among those growing in wholly competitive conditions. The chosen plants were cut near the soil level. The aerial part was discarded because observations on the development of above ground parts were done separately (M u l a t o B r i t o et al., 1958; C a r t u j a n o E s c o b a r et al., 1985). Then, a thread (or string) "1" (Fig. 1) was extended over the stem between two sticks. The thread "1" was oriented East-West and demarked the longitudinal axis of the soil column to be investigated. The orientation East-West was chosen so that the profile wall (see further text) would be exposed to the North, which greatly diminishes drying of roots during the work. The length of the soil column to be investigated was as large as the diameter of the root system in the East-West direction (in our experiment, the rows of the plants were situated in South-North direction). The column was, however, very thin in South-North direction: its width was calculated as 10-20% of the diameter of the aerial part multiplied by a factor of 1.33. Therefore, the width of a column gradually increased as the plants were growing: it was 6 cm at the 1st sampling (6 weeks AE) and 14 cm at the last one. When the width of the soil column was already decided, thread "2" was placed (Fig. 1) to delimit its border form the North. Thread "2" was parallel to thread "1" and placed at a distance equal to 1/2 of the column width to have the stem of the plant in the center of the column. After doing this, the trench was excavated sufficiently enough to permit a man to work in. Usually, the trench was 1.20 m wide and

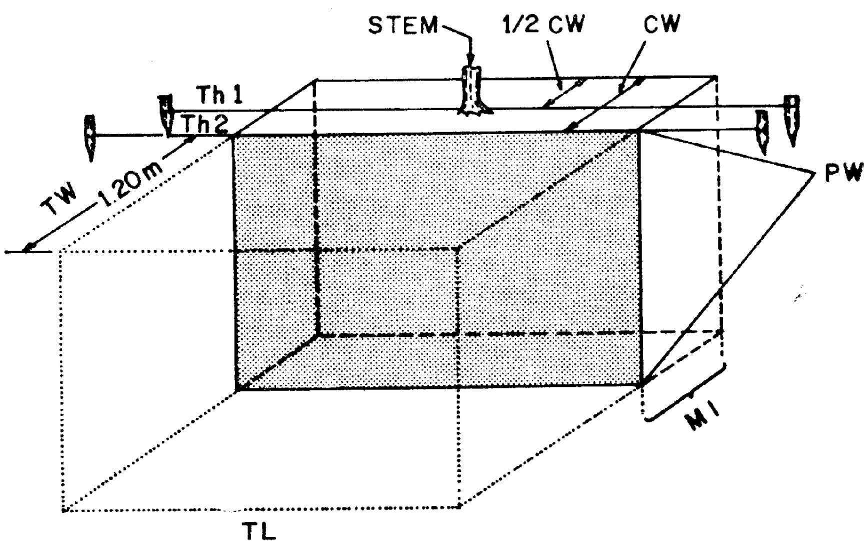

Fig. 1. Diagram of the column (monolith) of soil to be investigated (MI) and a trench in which the researcher works. STEM — the cut stem of the plant investigated; Th1 — thread "1" demarking the longitudinal axis of the investigated column; Th2 — thead demarking the distance where the profile wall (PW) is made; CW — column width, TW and TL — trench width and length

its length accomodated to the horizontal extension of the root system. The trench should be at least 10 cm deeper than the vertical extension of the roots. The northern wall of the trench, which was intended to be

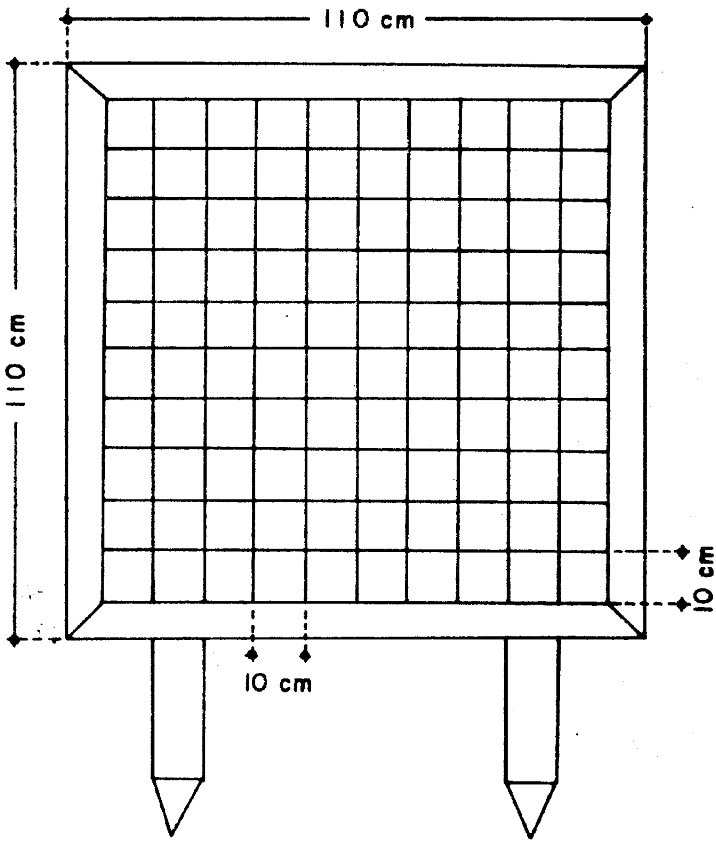

Fig. 2. Frame with plastic threads used to place it on the profile wall. The dimensions of the squares were 10 cm × 10 cm, but may be different for other plants

a profile wall, was made 3 cm ahead of thread "2". This 3 cm layer was thereafter utilized during smoothing over the surface of the profile wall and making it exactly vertical. When this was done, the frame with plastic threads (Fig. 2) forming the 10×10 cm squares (Fig. 2) was placed tightly on the profile wall (for other species of plants the dimensions of the squares may be different). The central vertical thread of the frame coincided with the central axis of the plant, and the upper, second horizontal thread coincided with the average surface of the soil. Afterwords, 30 cm long nails were hammered into the profile wall at each

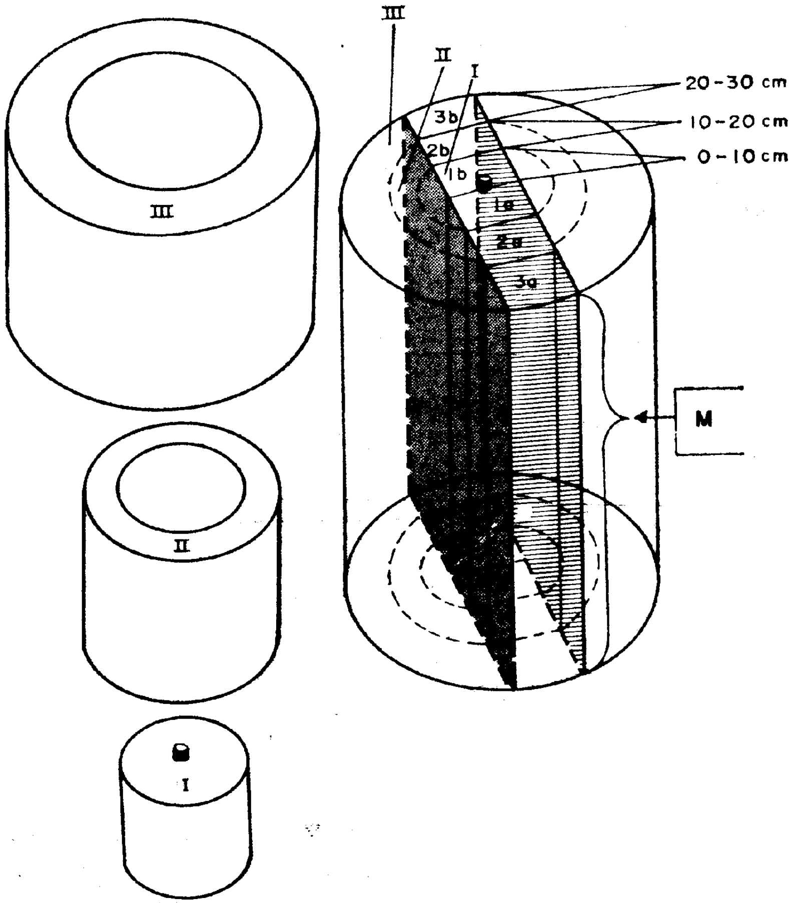

Fig. 3. Diagram of the spacial relation of the subcolumns (1 a, b; 2 a, b; 3 a, b) to their corresponding cylinders of soil (I II, III) (when the width of the column is 10 cm); M — the monolith of the soil to be investigated

intersection of the frame threads. The nails were long enough to prevent any change of their position during washing out the soil from the column (usually they were twice as large as the maximum column width). The nails were painted with 2 contrasting colors (half by half of their length). The first color delimited the width of the soil column to be investigated.

After installing the frame, the roots which were visible on the surface were registered (we do not discuss the results of this registration in the subsequent text) and afterwards the soil was gradually washed out from the volume corresponding to each square starting from the uppermost and most centrally situated ones. The situation of each root was marked on paper in the form of a map (Figs. 5-7). Roots of different thickness were registered with thin, thick or double lines. When the part of the

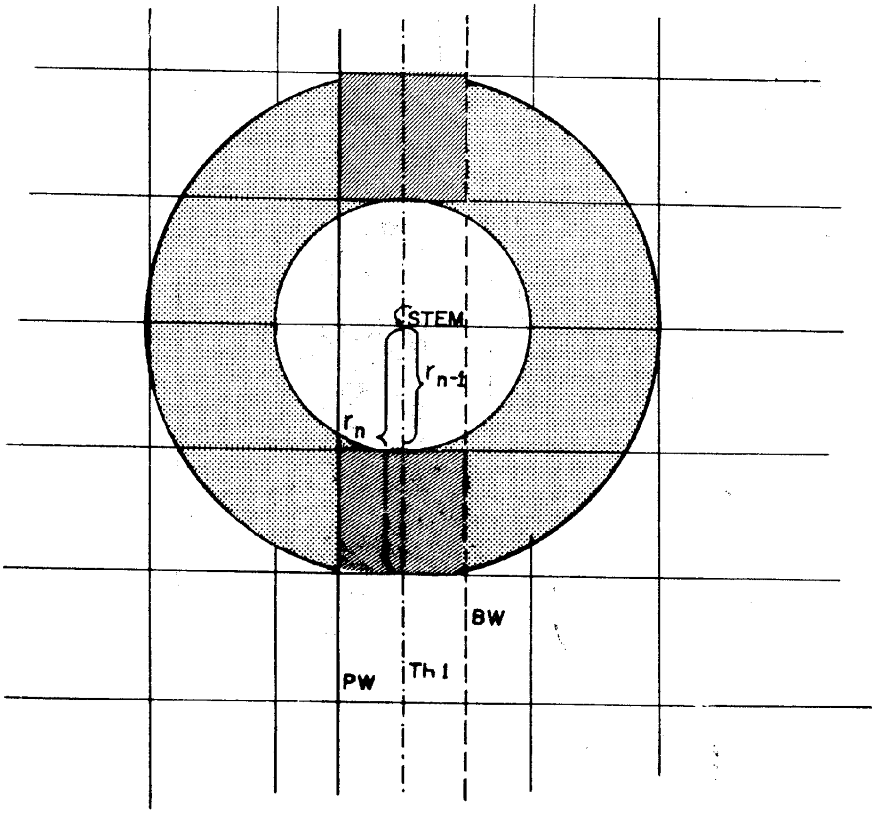

Fig. 4. Example of calculating factor "z" for a cylinder of soil (shaded) situated at distance 10-20 cm from the vertical axis passing through the stem. The area of the base of this cylinder is $\pi\left(r_n^2 - r_{n-1}^2\right) = 942\ cm^2$. The area of the bases of the 2 respective subcolumns (stripped) is 200 cm^2. therefore factor z is 942 cm^2: 200 cm^2 = 4.71; PW — profile wall; BW — back wall of the investigated column; Th1 — the longitudinal axis of the column (compare Fig. 1 and 3); $r_n = 20$ cm; $r_{n-1} = 10$ cm

root system which was contained in the column was completely uncovered, it was photographed.

The modifications introduced into the method of García Blancas and Grajeda Gómez (in print) during this study concerned the application of quantitative methods of estimation of the root system. The roots belonging to each square were cut separately, segregated into classes of thickness (in our case we have resigned from doing this), were placed into envelopes, dried in 70°C and their dry mass determined. Also, the number of apices was counted in the volume for each square.

The quantitative data for the roots are presented in 2 manners: 1) as

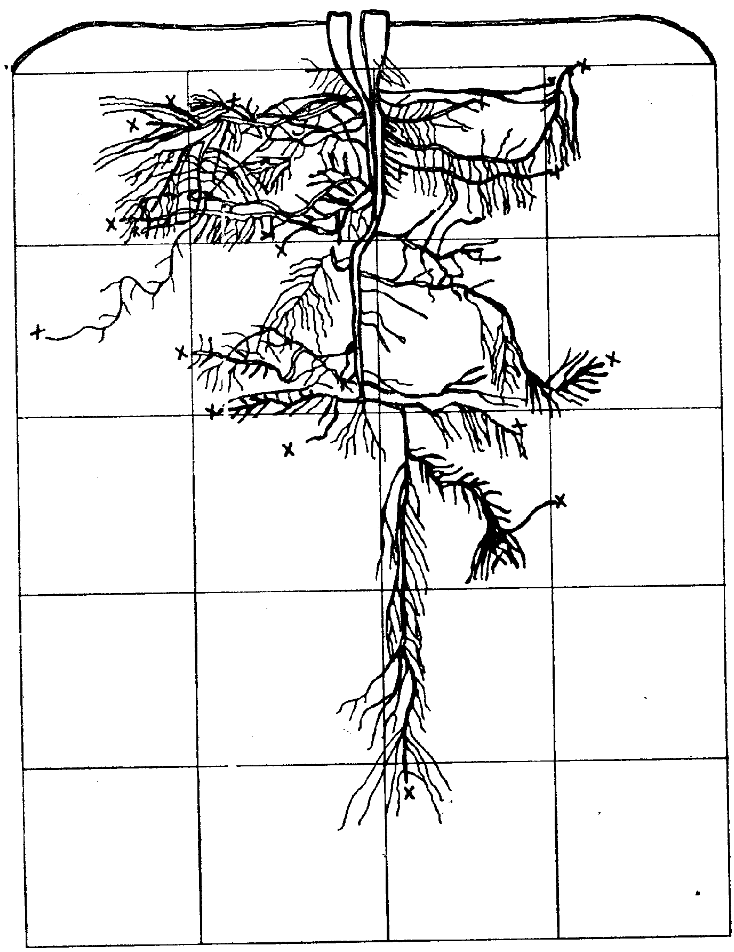

Fig. 5. The root system of a pair of plants 6 weeks after emergence; x — the root passes out of the investigated column of soil

the root dry mass (or the number of apices) in the horizontal layers of soil situated at different depths, and 2) as root dry mass (or number of apices) in the vertical cylinders of soil situated at different distances from the central axis (Fig. 3). This last point needs some explanation. Since only a part of each cylinder was investigated, for instance, in cylinder 3 only the subcolumns 3a and 3b (Fig. 3), it was necessary to multiply the mass of the roots present in the subcolumns by a factor z to obtain their approximate mass in the whole cylinder. Taking into account that the width of the investigated column changed as the plants

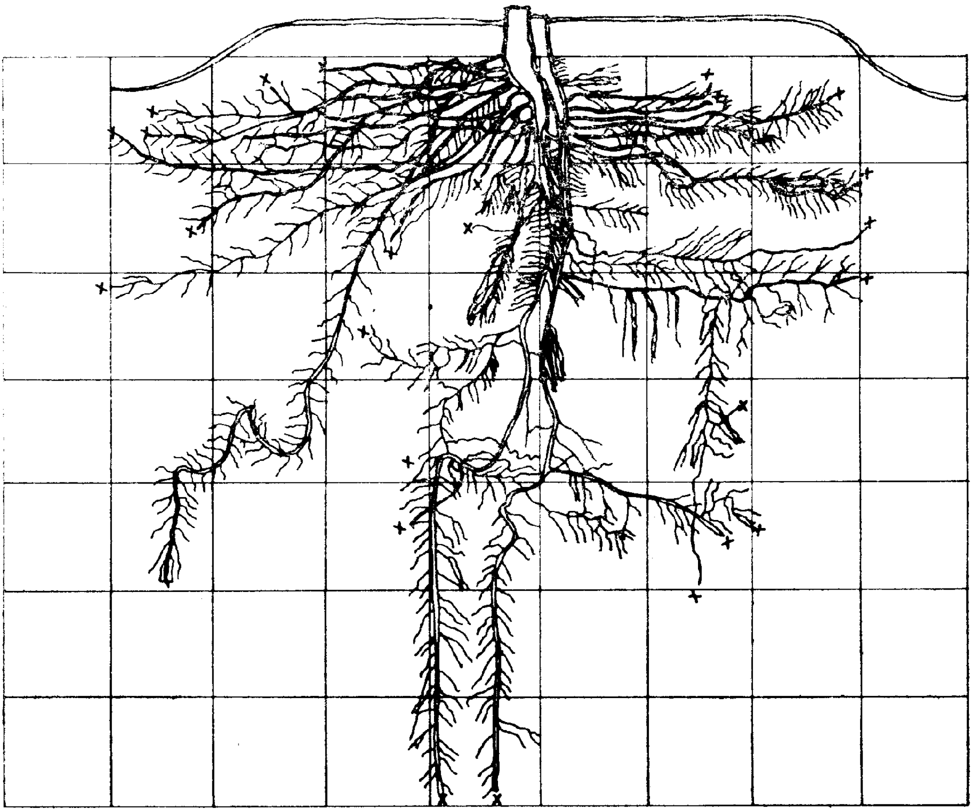

Fig. 6. The root system of the investigated plants during the 12th week after emergence (maximal development of the aerial part); x — the root passes out of the investigated column of soil

were growing, we recalculated root data from each sampling date into 2 appriopriate subcolumns with the joint base 200 cm² (10 cm×10 cm× 2)*. With this transformation, the formula for calculating z was as follows:

$$z = \pi (r_n^2 - r_{n-1}^2) : 200$$

where r_n means the larger radius, and r_{n-1} the smaller radius of the cylinder in each case (compare Fig. 4). The values of factor z used in this experiment are given in the Table 1.

* For instance when the column width was 6 cm we multiplied the results by 1.667 (=10:6), and when 14 cm — by 0.714 (=10:14).

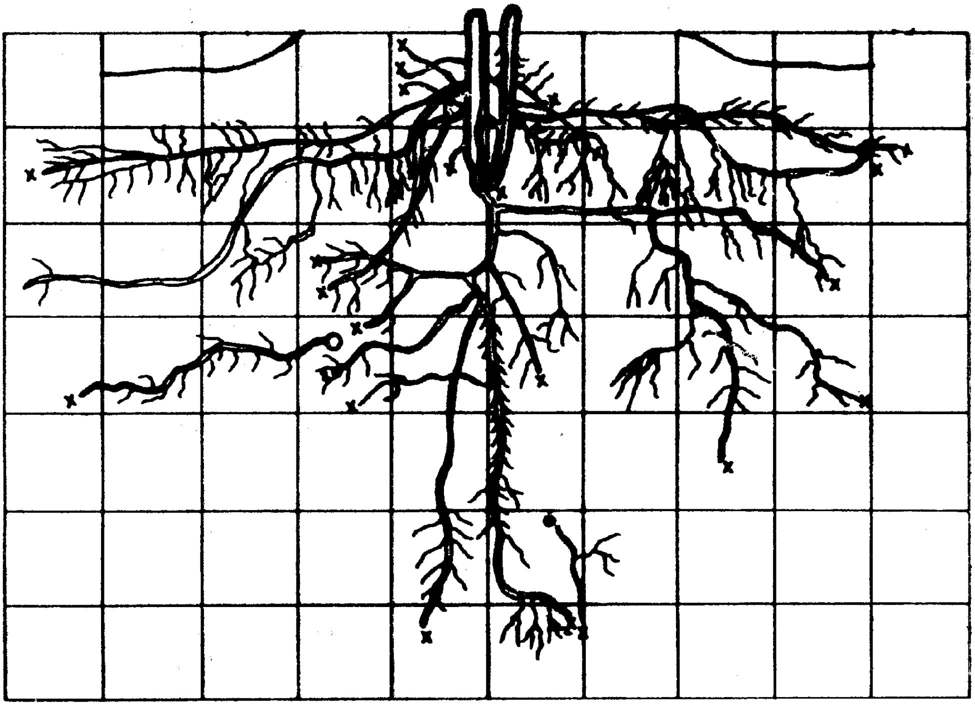

Fig. 7. The root system of the investigated plants during the 14th weeks after emergence (senescence and the decline of the plants); x — the root passes out of the investigated column of soil; o — the root which belongs to the same plants passes from the outside to the investigated column

Table 1

Values of factor *z*

Number of the subcolumns or the respective cylinder of soil	Lateral distance (cm) from the central axis (r_{n-1} and r_n)	Factor *z*
1	0-10	1.570
2	10-20	4.710
3	20-30	7.854
4	30-40	10.996
5	40-50	14.137
6	50-60	17.279
7	60-70	20.420

For explanation see the text and Fig. 4.

RESULTS

In this experiment, husk tomato plants showed a prominent tap root which frequently preserved its dominant role up to the plant senescence (Figs. 5, 6, 7). The characteristic feature of the root system of the husk tomato was that the majority of the roots were concentrated in the superficial layers of soil (Fig. 8, Table 2 and 3). During the first 2 samplings (6th and 8th week after emergence) this concentration was very high 87-89% root dry mass in the 0-10 cm layer (Fig. 8). Later on, it dropped to 62-69% reflecting the tendency of the root system to spread downwards. However, it has to be taken into account that the great accumulation of the root dry mass in the superficial layer is partially due to the presence therein of the heavy uppermost part of the tap root. The number of root apices shows a less marked superficial concentration, nevertheless, the majority of them (57-89%) was always found in the 0-20 cm layer during all sampling dates (Fig. 8). The density of roots (Table 2) reflects the same tendencies. The low density of the dry mass and of the number of apices during the last sampling (14 weeks after emergence) probably reflects the progres of senescence.

The horizontal distribution of the roots was calculated on the basis of cylinders of the soil around the central axis, therefore, the original data obtained from rectangular subcolumns were multiplied by a factor z indicating how much the volume of the column differd from the volume of the corresponding vertical cylinder (see Material and methods).

The root dry mass was initially markedly concentrated (80-84%) in

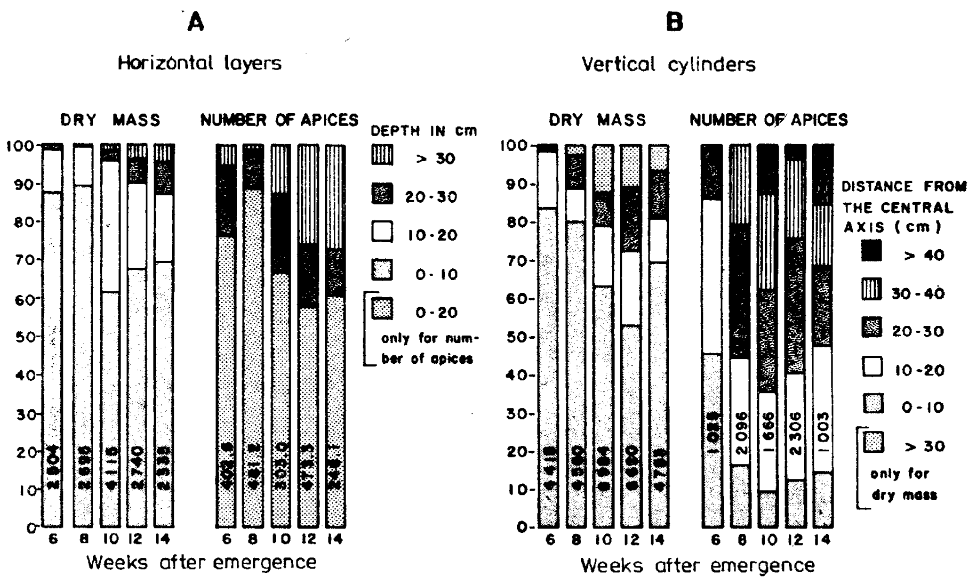

Fig. 8. Distribution of the roots in different soil levels (A) and in the cylinders of soil at different distances from the main axis (B), expressed as a per cent of the total. At the bottom of each column are marked: the total dry mass of roots (in mg) or the total number of apices (for a part investigated of the root system in A (see Fig. 3) or for a whole root system B

Table 2

Density of roots at different soil depths

Weeks after emergence	Soil layer located at the depths (cm)				
	0-10	10-20	20-30	30-40	>40
			Dry mass, mg · dcm^{-3}		
6	363.8	70.2	8.0	8.3	
8	400.9	39.3	4.4	0.9	
10	361.4	156.1	19.3	11.9	2.9
12	265.3	67.9	19.7	9.1	5.4
14	202.3	41.2	21.7	7.7	6.4
			Number of apices · dcm^{-3}		
6	28.1	34.4	18.5	7.9	3.3
8	31.0	30.0	8.0	3.1	
10	14.6	11.1	9.1	3.6	3.2
12	16.7	15.2	9.0	7.2	6.4
14	5.8	9.6	5.5	3.8	2.8

Table 3

Density of roots in the cylinders of soil located at different distances from the central axis (cm)

Weeks after emergence	0-10	10-20	20-30	30-40	40 >
			Dry mass, mg · dcm^{-3}		
6	294.7	23.5	3.2		
8	316.7	16.6	12.8	4.2	
10	301.6	30.2	15.9	10.8	3.1
12	161.6	27.0	14.3	5.9	3.0
14	151.3	14.1	7.9	3.0	1.2
			Number of apices · dcm^{-3}		
6	29.7	14.6	8.8	0.4	
8	28.3	20.4	15.5	9.8	
10	8.5	9.2	6.9	4.8	3.8
12	13.2	9.7	10.4	4.4	1.5
14	6.7	7.0	3.4	1.8	1.3

the cylinder adjacent to the central axis (0-10 cm), (Fig. 8), but afterwards spread wider, so that during the last 3 samplings, only 53-69% of the root dry mass was found in this cylinder. The number of apices showed a similar distribution only during the first sampling (6th week after emergence: 45.5% of apices in the cylinder 0-10 cm). Thereafter, the apices were rather evenly distributed in the cylinders 10-40 cm.

The root density in the particular cylinders (Table 3) showed similar tendencies of distribution as the data in Fig. 8.

The total dry mass of the root system showd a sharp maximum at the 10th week (Fig. 9). It may be interesting that the number of apices temporarily dropped at that time.

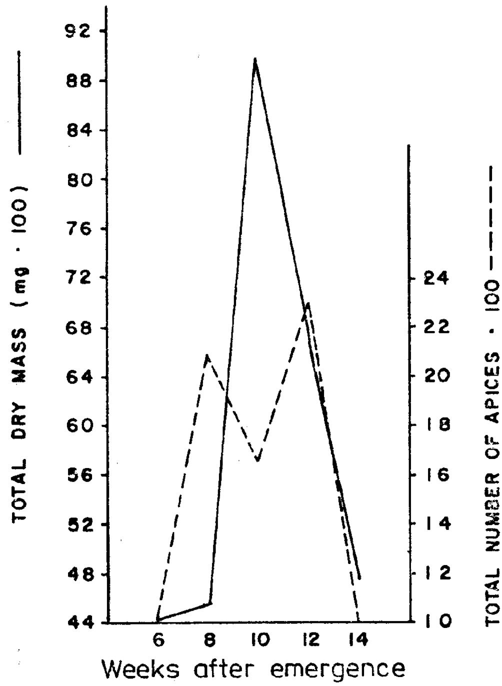

Fig. 9. Total dry mass and the total number of apices of the root system (the averages for the pairs of plants) during consecutive sampling

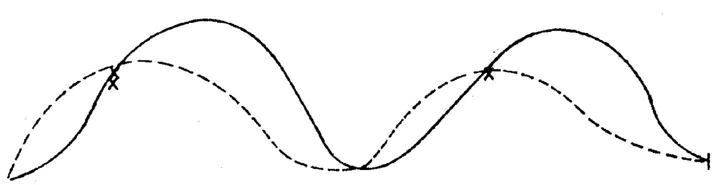

Fig. 10. The plants were sown asymmetrically in the middle of one side of the furrow (see x) to facilitate the access of water. After the establishment of the plants, the shape of the furrows was changed (broken line).

The root system of husk tomato showed asymmetry related to unilateral application of fertilizers and to non-equal water supply (due to asymmetrical sowing — see Fig. 10) only during the first weeks after emergence. Thereafter, asymmetry was sometimes observed, but was rather of accidental character, because it occurred in different directions.

DISCUSSION

The investigated husk tomato plants had a well-developed tap root. Also, in other species of cultivated plants, a well developed tap root is frequently observed, especially, if they are sown directly to the soil, without transplantation (Hartman and Kester, 1975). As it was mentioned, the plants in our experiment were grown without transplantation.

The pattern of husk tomato root distribution in the soil is similar to that of the soybean (Raper and Barber, 1970), or sunflower (Weaver, 1926), in that the main lateral roots grow predominantly superficially and perpendicularly to the main axis. There are, however, some differences: in the soybean, the main lateral roots initially grow horizontally, and after reaching 35-40 cm, they change their direction of growth, penetrating downward (Mitchell and Russell, 1971). Such a phenomenon was not observed in the husk tomato.

Several of the soybean (Mitchell and Russell, 1971) and sunflower roots (Weaver, 1926), similarly as those of the husk tomato, penetrate obliquely in the deper soil layers. An other phenomenon observed in the soybean, which we have also found in the husk tomato, is that some roots of higher order penetrate vertically downwards (Raper and Barber, 1970). This last phenomenon also occurs frequently in fruit trees (Kolesnikov, 1971).

The superficial distribution of husk tomato roots finds its analogy in the behaviour of soybean (Raper and Barber, 1970; Mitchell and Russell, 1971; Mayaky et al., 1976) and sunfluwer roots (Weaver, 1926), as well as in other cultivated plants (Spencer, 1951; Goodman and Greenwood, 1976). Nevertheless, in some other cultivated and wild plants, the root system is very deep, for instance in alfalfa and in *Aster multiflora* (Weaver, 1926).

The tendency of husk tomato roots to have their dry mass concentrated near the central axis finds analogy in the behaviour of other cultivated plants, as cabbage (Goodman and Greenwood, 1976) and soybean (Raper and Barber, 1970; Böhm et al., 1977).

The presence of a relatively high number of apices in the soil cylinders 10-40 cm which was observed in sampling weeks 8-14, reflects the dynamic spreading of the root system of this plant and should be taken into account in planning cultivation practices.

It is characteristic that our results, based on the dry mass of the roots, are very similar to those of other authors who used the same criterion or fresh mass to evaluate root system distribution (Raper and Barber, 1970; Mitchell and Russell, 1971). On the other hand, our results based on the number of apices were similar to those of the authors which used the length or the number of roots as a criterion (Spencer, 1951; Böhm et al., 1977).

As it was mentioned, using dry mass for evaluating the root system, one obtains data relatively elevated for the concentration of roots in the most superficial layers, due to the presence of the roots base in this layer. On the other hand, the concentration of the dry mass in the central cylinder of the soil results from the presence of the whole tap root in it. Therefore, it should be advisable to treat the tap root as a separate unit, at least up to a certain depth (for instance 20 cm). It seems also necessary to use at least 2 characteristics for evaluating root systems. Root dry (or fresh) mass may indicate how large are the expected losses of assimilates caused by the respiration of the root system. This is important from the point of view of root/shoot equilibrium (Szaniawski, 1981). The number of root apices or any analogical characteristic (see Atkinson, 1974) may indicate how active the root system is at a given moment. The youngest parts of the root system are very active in absorption, in production of hormones etc. (Russell and Sanderson, 1967).

Root density is frequently used for characterizing root systems. It is a useful criterion which relates the mass of the roots or the number of apices to the volume of the soil. This makes possible better localization of the regions of greatest activity of the root system, which may be important from the practical point of view.

Several authors have found great differences in the root system among particular varieties of the same species (Zobel,, 1975; Raper and Barber, 1970). It was also found that the characteristics of the root system are inherited (Surma et al., 1978). In the present experiment, we have not found any difference in the root systems between the prostrated and erect forms of husk tomato. Possibly, many more plants should be investigated to find such differences.

The method of García Blancas and Grajeda Gómez (in print) of investigating root systems shows some advantages in relation to the pinboard method. The whole investigation is made in situ, therefore without moving the blocks of soil containing the roots to the laboratory. Böhm et al. (1977) mention that such blocks fraquently break in the light soils causing trouble to the researcher. With the method of García Blancas one needs few tools: a spade, pins, a frame with threads, a hammer for knocking the pins and a sprayer with water. Usually one has to water the plants well the day before. Taking this into account, this method can be used in places where more sophisticated utensils and apparatus are lacking. Washing the root system in situ permits preserving the roots better in the original position. One can also observe the roots which overpass the dimentions of the investigated column. This helps the maximal, vertical and lateral extension of the root system to be fixed better.

The method of García Blancas and Grajeda Gómez (in print) proved to be somewhat laborious (7.5-9 hours for 2 persons for one pair of plants). This number of hours can be lowered by half if one can automatize the work of the sprayer. In this method, similarly as in the modified method of the profile wall (Böhm et al., 1977), there exists the possibility of overlooking the thinnest roots since they frequently adhere to the wet, thicker roots. This difficulty may be avoided by cutting the roots belonging to each 10×10 cm square after mapping them or photographing, and by placing them into water to float. In such a way one can see well the small roots, and they can be counted.

In developing the original method of García Blancas and Grajeda Gómez (in print), we have introduced into it the quantitative estimation of root systems. Among other things, we have introduced to this method transformation of the data obtained for the subcolumns of the soil investigated, multiplying them by the appropriate factor to obtain the data which represents the whole vertical cylinder of the soil around the central axis. With respect to such a transformation it is obvious that the data for the more distant cylinders are burdened with a higher error than those for the cylinders situated more centrally. On the other hand, it would be advisable to divide the central 0-10 cm cylinder into 2 parts because the density of the roots is quite different in the immediate proximity of the axis, than 5-10 cm from it. The cylinders may therefore be arranged as follows: 0-5 cm, 5-10 cm, 10-20 cm, 20-30 cm, 30-40 cm etc. As already mentioned, the central root may be cut out and treated as a separate unit. This is especially important in plants which form large storage roots, like the carrot.

Acknowledgments

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System korzeniowy miechunki pomidorowej (*Physalis ixocarpa* Brot.)

Streszczenie

Miechunka pomidorowa jest powszechnie uprawiana w środkowym Meksyku i nadaje się do uprawy w krajach o klimacie umiarkowanym. Doświadczenia z odmianą 'Rendidora' założono w suchej porze roku w stanie Morelos, w Meksyku, w okresie gdy średnia temperatura tygodniowa wynosiła 17-22°C. Pole doświadczalne było nawadniane systemem bruzdowym co tydzień. Systemy korzeniowe badano metodą García Blancas i Grajeda Gómez, która jest modyfikacją metody „tablicy z gwoździami". Badano systemy korzeniowe 2 roślin lub 2 par roślin co 2 tygodnie. Metodę García Blancas i Grajeda Gómez przystosowano do ilościowego określania suchej masy korzeni w warstwach poziomych gleby i w cylindrach gleby wokół osi pionowej systemu korzeniowego. Miechunka pomidorowa miała dobrze rozwinięty korzeń palowy. Większa część korzeni zalegała w powierzchniowej warstwie gleby: 0-20 cm. Sucha masa korzeni była także zgromadzona w pobliżu osi głównej. Większość wierzchołków korzeni występowała w odległości 10-40 cm od osi głównej. W czasie starzenia się rośliny (14 tygodni po wzejściu) wystąpiło zamieranie znacznej części drobnych korzeni. Metoda García Blancas i Grajeda Gómez pozwala badać korzenie bardzo prostymi środkami, na miejscu, bez przenoszenia monolitu gleby z korzeniami do laboratorium.