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Comparison of Root Development of Pear Trees on Seedling and Quince A and C Rootstocks

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Abstract

After 17 years of growing in a sod-podzolic soil root distributions of 'Byelorussian Late' pear grafted on pear seedlings and Quince A, and Quince C were determined by excavation. Tree spacing was 5 x 3 m (666 plant/ha). Cultivation system of soil management was employed. Pear seedlings had a root system made up of long, large roots, whereas the quince rootstocks had a root system made up of a large mass of fibrous roots. Quince C had a larger root system than Quince A. The majority of the roots were concentrated in a layer of 10 to 50 (60) cm. The quince rootstocks had the highest density of fibrous roots near the trunk, once was 2 to 3 times less dense in the middle of between-row spacing. The fibrous root index (= specific mass of fibrous roots/specific length of scaffold roots) of quince rootstocks was two times more as compared with seedling stock. This index for quince rootstocks was maximum at the depth of 50 to 100 cm and at the distances of 1.5 to 2.5 m from the trunk, but for pear seedlings—near thick roots.

Introduction

There have been few studies comparing root distribution of pear and quince rootstocks. Those that have been done have not completely reflected the peculiarities of root development (9, 14, 18).

Materials and Methods

The root study was carried out in the orchard of the Byelorussian Research Institute for Fruit Growing with the object of comparing root mass and distribution of pear trees, cv. 'Byelorussian Late' on rootstocks of pear seedlings *(P. communis)* from seeds obtained from wild pear trees in Western Byelorussia and Quince A and Quince C *(Cydonia oblonga)*. Quince rootstocks were grown by layering. Visual inspection of quince stool beds before removal of the rooted layers did not show any signs of virus infection. Pear tree spacing in the orchard was 5 x 3 m (666 plants/ha). Trees were trained as a hedgerow. After dormant pruning trees were 3.0 m high and 2.0 to 2.5 m across a row. Clean cultivation system of soil management at the depth of 6 to 8 cm was employed for all years. The root study was made after 17 years.

Sod-podzolic silty loam soil had the following peculiarities of its profile: the A_1 horizon = 0 to 25 cm, light-grey, lumpy-silty; the A_2B_1 horizon = 26 to 35 cm, grey-yellow with light-brown stains, moist, slightly compacted; the B_1 horizon = 36 to 50 (60) cm, light-brown with grey-yellow stains, moist, lumped or lamellar, rather compacted; the B_2 horizon = 51 (61) to 80 (90) cm, brown, moist, hard, compacted; the C horizon = 81 (91) to 100 cm, yellow-brown, loam or sandy loam, rather compacted. Bulk density of the topsoil was 1.36 and of A_2B_1 to B_2—1.50-1.57 g/cm^3. A moisture equivalent varied from 16.4 to 20.0% of soil weight, field capacity was near 22% of soil weight. Air porosity at field capacity was more than 10% of soil volume. The soil water table was deeper than 4 m from soil surface. The A_1 horizon contained 1.5 to 2.0% of humus but also held sufficient amounts of nitrates. The quantity of humus was decreased to 0.2-0.3 percent in the subsoil. The nitrate content in the A_2B_1 and B_1 horizons was by 1.5 to 2 times less than in the A_1 horizon. There were sufficient quantities of phosphorus and potassium throughout soil profile.

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Root excavations were carried out with a modified monolith method (6, 7, 13). Plots with trial pear trees were chosen in different parts of the orchard. Each plot contained two trees placed together in adjacent rows. A rectangle 4.0 x 0.5 m was laid out between these trees at the distances of 0.5 m from their trunks. This rectangle was divided into 8 squares, 0.5 m a side. Monoliths with a thickness of 0.1 m were taken out from each square to a total depth of 1.0 m. All roots were collected from each monolith, washed free of soil, surface dried and graded according to the thickness at two fractions: 1) 2.0 mm and smaller (fibrous roots); 2) 2.1 mm and greater (scaffold roots). These fractions have identical root anatomy; but fibrous roots are the main carrier of absorptive roots.

Each rootstock was excavated with 4 replications. The distance between rootstock plots did not exceed 27 m and the distance between replications did not exceed 30 m. Monoliths 0.5 x 0.5 m were considered in the bounds of replicate and were used for statistical estimation of experimental data.

Results

Seedling rootstock had the largest root mass being 231 percent of Quince A and 146 percent of Quince C (Table 1). The roots of seedling rootstock was longer and larger than Quince C and Quince A based on the proportion of scaffold and fibrous roots. The fibrous root mass was smallest for seedling rootstock, 11 percent, followed by Quince C, 23 percent, and by Quince A, 28 percent.

The specific mass of fibrous roots had a coefficient of variation (CV) for rootstocks Quince A and C and pear seedling 13%, 26% and 37%, respectively. CV for length of scaffold roots for these same rootstocks was 22, 21 and 31%, respectively, and for scaffold root mass of these rootstocks was 57, 68 and 97%, respectively.

Root mass was decreased with soil depth in all plots, especially when the B_2 horizon was compacted (bulk density = 1.49-1.51 g/cm^3). There is little difference between quince and seedling rootstocks in amount of root formation in the dense horizons.

The specific mass of fibrous roots of quince rootstocks was significantly higher than seedling rootstock (Table 1). Quince C had a greater root mass than Quince A. On the other hand, specific length of scaffold roots of pear seedlings was greater by 86% and 36% than of Quince A and Quince C, respectively.

The main part of the root systems of all rootstocks was concentrated in the lower part of the A_1 horizon and in the A_2B_1 horizon (Figure 1). The 10-30 cm layer contained the greatest total mass of roots for all rootstocks. Quince A contained a greater amount of fibrous roots in this layer, 52 percent, compared to 47 percent for seedling and 45 percent for Quince C. Only 19 to 28 percent of fibrous roots were located at a depth of 50 to 100 cm.

Table 1. Specific root mass and specific root length of pear trees on different rootstocks in the monoliths 0.5 x 0.5 x 1.0.

	Mass of fibrous roots		Scaffold roots		
	g	% of total	mass (g)	length (cm)	Total root mass (g)
Pear seedling	42	11	351a	788a	393
Quince A	47	28	123b	422c	170
Quince C	62	23	207b	576b	269
LSD_{05}	4.7		140	117	

[1]The means within columns followed by unlike letters are significantly different by Student's test at the 5% level.

Table 2. Distribution of specific mass and length of roots in horizontal direction (% of total). Soil monoliths 0.5 x 0.5 x 1.0.

Rootstock	Distance from trunk, m			
	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5
	Specific mass of fibrous roots			
Pear seedlings	34	32	22	12
Quince A	38	23	24	15
Quince C	32	27	26	15
	Specific length of scaffold roots			
Pear seedlings	32	24	18	26
Quince A	40	32	20	8
Quince C	39	30	18	13
	Specific mass of scaffold roots			
Pear seedlings	50	25	14	11
Quince A	62	26	9	3
Quince C	58	25	14	3

Significant differences in the relative amount of fibrous root mass with depth was not found among rootstocks. But a difference in location of scaffold roots was apparent. Thirty percent of the total length of seedling scaffold roots and only 14 to 16 percent of quince scaffold roots were found in layers at a depth of 50 to 100 cm. Sixty percent of the total length of quince scaffold roots in comparison to forty percent of total length of seedling roots was concentrated in 10-30 cm layer. This was not a result of a larger root system because of the same depth of excavation of all treatments.

Root distribution in horizontal direction was related to the high density of planting and narrow row spacing. Maximum density of fibrous roots for all rootstocks was noted near the tree trunk (Table 2). It was 2 to 3 times less in the middle of between-row spacing. The relative amount of fibrous roots at different distances from the trunk was not related to rootstock.

Specific root extension of quince rootstocks in the middle of the orchard alleys was 3 to 5 times less than near the trunk. Relative root mass of seedling scaffold roots in the middle of alleys was somewhat greater because there was close contact of root systems from adjacent rows. (Figure 1).

No suckers were found in horizontal roots.

An index of root branching (fibrous index) was used in this study for estimation of fibroid properties of rootstocks, which was calculated by dividing specific fibrous mass by specific scaffold root length. The index of root branching for quince rootstocks was two times more than for seedling rootstock (Table 3).

Maximum branching occurred for all rootstocks in the 0-10 cm layer. This index for seedlings was decreased from topsoil towards subsoil. Branching of quince rootstocks was less at the depth of 10 to 40 cm, but increased towards the bottom of soil profile. A difference of root branching variations in the horizontal direction was noted. The index of root branching of seedling rootstock in the middle of between-row alleys was lower than for quince rootstocks.

Discussion

The root system of *P. communis* as rootstock grows deeper in soil than of an apple (2, 5, 17). Shallow location and fibrous branching is characteristic of root systems of quince rootstocks in comparison with pear seedlings (4, 10, 14, 17-19). The shallow scaffold root location of quince rootstocks by contrast to pear seedling was confirmed

Table 3. Indexes of root branching for pear rootstocks at different distances from trunk, g/m.

Rootstock	Distance from trunk, m				
	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	0.5-2.5[1]
Pear seedlings	5.4	7.9	7.2	3.6	6.0a
Quince A	11.7	7.9	14.0	25.3	14.7c
Quince C	8.1	8.8	15.5	16.3	12.2b

[1]Calculated from plot data for each replicate.

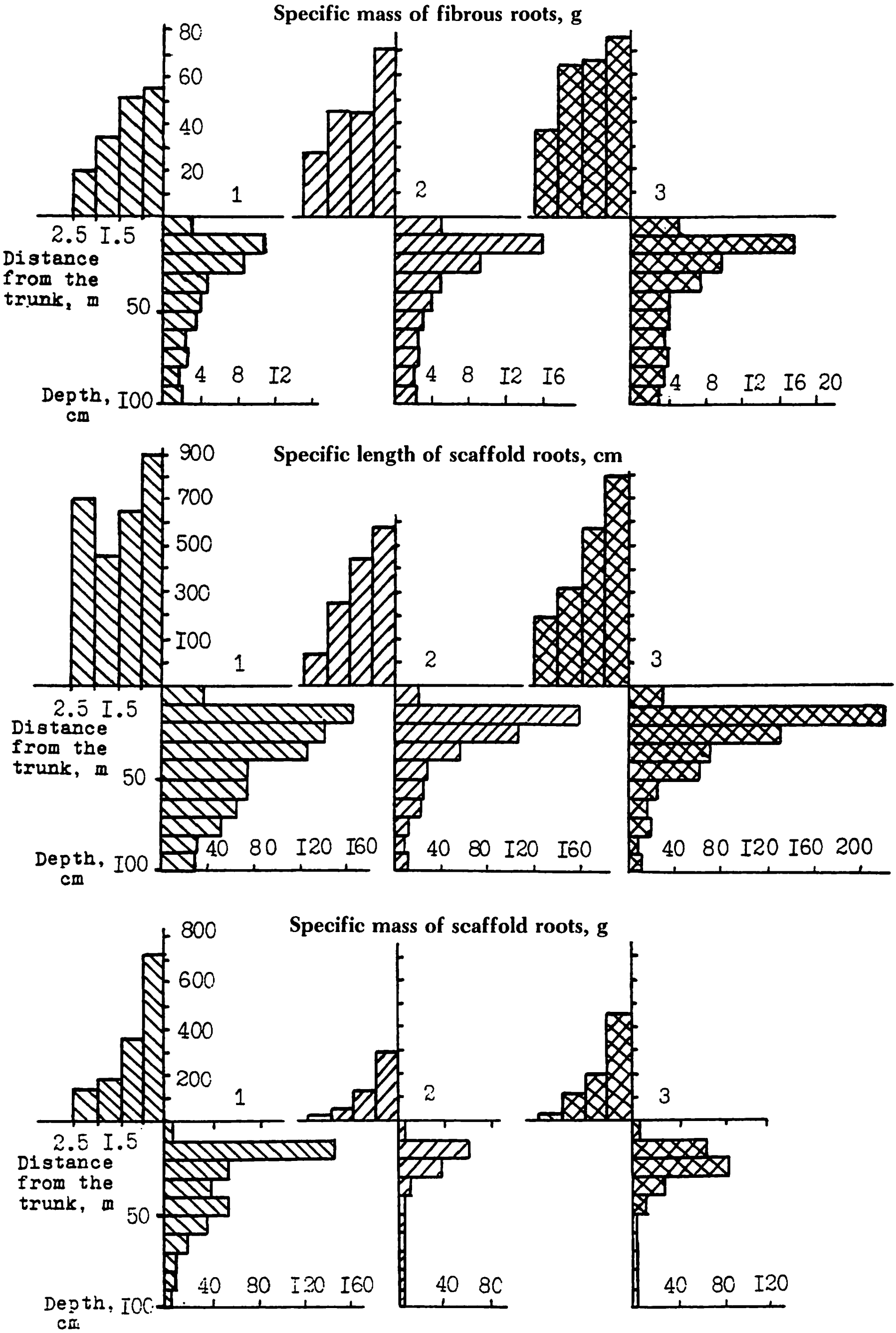

Figure 1. Distribution of specific fibrous root mass, scaffold root length and mass along the profile of sod-podzolic soil and in horizontal direction from the tree trunk to the middle of between-row spacing. Rootstocks: 1-pear seedlings; 2—Quince A; 3—Quince C.

in this study. On the other hand the decrease of specific mass of the fibrous roots from topsoil towards subsoil did not depend on rootstock species. Root systems of all rootstocks had the same susceptibility to low soil acidity that correspond to (10). There is an American information that the pear seedling and quince rootstocks have the moderate hardiness to soil pH 4.0 (10). In accordance to German sources the most desirable soil pH for fruit trees is 6.0 to 6.5 (12) or 5.5 to 7.5 (4). According to Byelorussian researchers the best growth of young pear seedlings and grafted trees was observed when soil pH_{KCl} was 4.2 to 4.9 (15). Apparently the main reasons of the very intense decrease of specific fibrous mass in the subsoil were the little content of humus and nitrate and the soil compactions.

The rooting depth of seedling and quince rootstocks observed in the sod-podzolic soil was similar to that observed in the Moscow region (11).

A report on yield data on this study is in press (3). A correlation between pear tree yield and specific fibrous root mass or index of root branching was low. It is known that pear trees on quince are considerably higher in uptake of magnesium and lower in nitrogen, iron and boron (1). Apparently higher yield of pear trees on quince rootstocks in our trial can be as a result of metabolism of the aerial part and roots in conditions of density orchard with compact crowns of trees.

Summary

Quince rootstock had weaker ability to form scaffold roots in comparison with seedling rootstock but sufficiently greater in production of fibrous ones particularly in upper horizons of sod-podzolic soil under conditions of close planting with compact tree crowns and clean cultivation of soil. Index of root branching for quince rootstocks was two times more than for pear seedling.

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