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The Role of Plant Roots in Formation of Soil Humus

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ABSTRACT

The bulk volume of rhizospheric soil (soil penetrated by plant roots) under individual tree can occupy up to 3-10 m^3. However, the bulk volume of soil in immediate contact with plant roots constitutes only 1-6% of the bulk volume of a soil layer. Only a thin layer of soil, not more than 3-5-mm thick, is capable of interacting with roots. Only in this soil layer one can observe the immediate effect of plant roots on soil properties: humus formation, lower content of nutrients and some acidification of the substratum. In a larger bulk volume of rhizospheric soil, the effect of roots on soil properties is neglectable. Therefore, such soil characteristics as pH, content of humus and the sum and composition of exchangeable cations do not correlate to the mass of plant roots, including any of their fractions.
KEYWORDS: plant roots, humus formation.

INRODUCTION

Since the times of P.A. Kostychev plant roots have been considered as the primary source of soil humus. Abundant data provide evidences that soils in the rhizosphere undergo certain changes, which are often interpreted as the effect of plant roots on soil formation. Plant roots take up nutrients and water from soil. In the taiga zone, tree with their roots soak water from soil, thus decreasing water content in it. It was hypothesized that soils with thick organic horizons (deep humus soils) are formed due to penetration of root systems into deeper layers of soil. All these hypotheses and interpretations of facts reflect how we see the role of plant roots in soil formation. however, many of such theories usually remain just hypotheses.

METHODS

The research was conducted at Malinki research station (Moscow Oblast, Russia). Soil samples were collected each 15 cm along a line from one tree to another. In all samples, soil pH, humus content and root biomass were determined using standard methods.

RESULTS

The biomass of roots in soil depends on climatic conditions, the set of plants growing in this zone on particular soils and soil properties. On average, the root biomass in soil ranges from 5 to 30 t/ha, thus constituting less than 1% of soil mass (within the 0-50-cm layer). In the upper soil layer (0-20 cm), the root biomass reaches up 1-20 t/ha, which is equivalent to 0.5–5% of the mass of soil horizon. The biomass of roots, while being of the same order of magnitude as reserves of soil humus, is much less than the last. Root systems have complex architectonics: the root biomass evenly decreases downwards, it can be unevenly distributed along various directions, it has maximums not only near the surface but also in deep layers of soil, etc. While volume and biomass of roots constitute insignificant part of soil under individual tree (Table 1), the bulk volume of soil penetrated by roots (rhizosphere) is much greater (up to 3-10 m^3). When analyzing the role of plant roots, the following characteristics shall be taken into consideration: the volume

of roots, the bulk volume of rhizisoheric soil and the bulk volume of soil in immediate contact with roots. Research using ionites showed that plants are capable of taking up nutrients from the bulk volume of soil at the distance of 3 to 5 mm from the surface of active roots. A root directly contacts with small bulk volume of soil (2-5 м^3) distributed along its length. There are much more roots in a soddy horizon of soil and it is more evenly penetrated by roots. This is the horizon where resides most of biota and humus formation takes place. Under natural conditions with a probability greater than 0.7 plants maintain a certain level of humus content in their immediate vicinity. Replacement of a plant may lead to a noticeable change in humus content. There is no correlation between the biomass of various fractions of roots and the humus content in the rhizospheric soil. The plant roots promote humus formation only in the rhizosphere. The rest of superficial humus horizons become enriched with organic matter due to activity of biota that processes plant litter and mixes it in soil.

Table 1. Root biomass (g per 1500 mL of soil) of a spruce tree on Soddy–Podzolic soil (Spodosol).

Roots, mm	Near the trunk			Below the tree canopy			At the edge of tree canopy		
	0–10	10–20	20–30	0–10	10–20	20–30	0–10	10–20	20–30
<0.3	2.3	0.6	0.2	2.0	0.8	0.3	1.0	0.7	0.3
0.3–0.5	0.5	0.1	0	0.5	0.2	0.1	0.5	0.2	0.2
0.5–1	0.7	0.4	0	0.5	0.3	0.2	0.3	0.2	0.5
1–2	0.3	0	0.2	1.3	0.3	0	0.3	0	0.2
2–3	0.3	0	0	0.2	0.5	0	1.8	0.5	0
3–5	0.6	0	0	1.5	0	0	0.3	2.4	0.7
>5	0	3.3	0	0	0	0	5.8	0	0
No plants	1.8	2.0	0.3	1.3	0.5	0.4	3.1	1.7	0.3
Hazel	196	155	29	859	427	0	182	14	1
Undershrubs	437	0	0	554	0	0	297	0	0
Sedge	235	90	3	857	17	1	1189	24	3
Forbs	35	0	0	99	53	0	165	0	0

Table 2. Change in pH in loamy Soddy–Podzolic soil (Spodosol) in spruce (1), pine (2), and birch (3) forests

No. of points	Depth of sampling, cm														
	0–5			5–10			10–15			15–20			20–30		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	4.1	4.9	4.4	4.3	5.1	4.5	4.5	5.0	4.6	4.9	5.2	4.6	5.0	5.0	4.8
2	4.1	5.0	4.8	4.4	5.2	4.8	4.6	5.2	4.9	4.7	5.2	4.8	4.9	5.2	4.9
3	4.3	5.1	5.0	4.2	5.3	5.1	4.7	5.1	5.3	4.8	5.3	5.7	5.0	5.2	5.3
4	4.7	5.0	5.0	4.7	5.1	5.0	4.8	5.1	5.1	4.8	5.2	5.1	5.0	5.1	5.1
5	4.7	5.0	4.9	4.5	5.1	5.0	5.0	5.2	5.1	4.9	5.0	5.1	5.0	5.1	5.1
6	4.4	4.9	4.9	4.6	5.2	5.0	4.8	5.2	5.1	4.9	5.2	5.1	5.0	5.1	5.1
7	4.2	4.9	4.9	4.5	5.1	4.7	4.7	5.2	5.0	4.9	5.2	5.1	5.0	5.1	5.1
8	4.7	5.0	5.1	4.6	5.0	5.1	4.8	5.3	5.1	4.9	5.2	5.1	5.0	5.2	5.1
9	4.6	4.8	5.1	4.6	5.0	5.0	4.9	5.1	5.2	4.8	5.1	5.2	5.0	5.0	5.1
10	4.8	4.9	5.1	4.9	5.0	5.0	5.0	5.2	5.2	4.9	5.2	5.1	5.3	5.0	5.1
11	4.7	4.9	5.2	4.6	5.0	5.1	4.9	4.9	5.1	4.9	5.0	5.1	5.2	5.1	5.1
12	4.5	5.1	5.2	4.6	5.1	4.9	4.8	5.2	4.9	4.9	5.2	5.0	5.0	5.2	5.1
13	4.9	5.3	5.3	4.7	5.3	5.1	4.7	5.2	5.0	4.9	5.2	5.1	5.1	5.1	5.2
14	4.8		5.2	4.5		5.1	4.8		5.0	5.0	5.3	5.1	5.1		5.1
15	4.4	5.2	5.0	4.5	5.1	5.1	4.7	5.1	5.0	4.8	5.2	5.1	4.9	5.2	5.1
16	4.4	5.1	4.9	4.7	5.1	4.9	4.7	5.2	4.9	4.9	5.3	5.1	5.2	5.1	5.3
17	4.5		4.9	4.5		4.8	4.6		5.0	4.9		5.1	5.0		5.2
18	4.6			4.6			4.7			4.7			4.9		

Biomass of fine roots of herbaceous plants and undershrubs exceed those of spruce roots (Table 1), despite the fact the anisotropy of soil properties is determined by a tree (near the trunk of a spruce tree soil is noticeably more acid and contains more humus, see Tables 2 and 3).

The content of humus, the sum and composition of exchangeable cations and pH do not correlate to any fractions of plant roots. The similar pattern can be observed for birch and pine trees.

Soil samples were collected along the line between trees. Points 1 and 18 are located near tree trunks. In these points, spruce and pine are characterized by the lowest values of pH. Upper layers of soils below the tree canopy have the greatest values of pH. Humus content and soil pH correlate to location of pit within the forest, but do not to the content of any fraction of roots in a particular soil sample.

The humus content to a greater degree correlates to a greater volume of litterfall near the tree trunk. It can be concluded that plant roots do not exert significant effect on chemical properties of soil. The latter are more affected by aboveground parts of plants and by the way it redistributes precipitation, litterfall and biota.

Table 3. Humus content (% of soil mass) at different depths, cm, under spruce (1), pine (2) and birch (3) trees.

No.	0-5			5-10			10-15			15-20			20-25		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	8.1	7.2	7.2	4.1	3.7	1.6	2.9	2.9	1.4	1.2	1.5	1.3	0.6	0.8	0.6
2	9.5	4.2	3.1	4.7	2.9	2.4	2.9	2.1	1.7	1.3	1.3	1.2	0.7	0.6	0.6
3	8.9	7.0	3.3	3.4	4.5	2.3	2.5	2.9	1.8	1.4	2.1	1.8	0.8	1.1	0.7
4	7.0	6.3	3.9	3.9	3.5	2.8	2.1	3.4	1.8	1.2	2.0	1.5	0.9	1.0	0.7
5	9.2	7.6	2.7	3.6	4.8	2.2	1.2	3.1	1.6	1.6	1.1	1.2	0.8	0.4	0.5
6	7.8	7.2	1.9	2.9	5.1	3.2	1.7	1.8	1.5	1.2	2.0	1.0	0.8	0.8	0.5
7	4.9	7.0	3.4	2.2	4.2	2.3	1.7	2.9	1.4	1.0	1.4	1.0	0.8	0.6	0.3
8	5.4	6.2	4.6	2.1	3.9	2.7	1.4	3.1	1.4	1.0	1.8	1.9	0.6	0.4	0.6
9	6.2	7.3	3.9	2.3	4.3	1.5	1.2	2.8	1.1	1.5	1.1	0.8	0.6	0.7	0.6
10	6.9	8.2	3.5	1.7	5.4	2.0	1.2	4.1	1.2	0.8	1.8	1.0	0.4	1.1	0.5
11	4.2	6.3	3.9	1.9	3.4	1.5	1.3	3.9	0.9	1.1	2.7	0.4	0.5	0.7	0.4
12	5.2	8.5	4.4	2.2	6.4	2.8	1.2	2.7	2.4	1.0	3.9	0.8	1.1	9.4	1.2
13	4.1	6.4	4.1	7.1	4.8	2.4	2.2	2.6	1.8	1.7	1.4	1.3	1.1	-	0.7
14	9.1	-	3.2	2.4	-	1.4	1.4	-	2.3	1.1	1.3	1.1	0.5	0.9	0.6
15	3.8	9.0	2.9	1.9	4.8	1.8	1.3	3.8	1.6	1.3	2.8	1.5	0.4	0.9	0.7
16	8.4	7.9	2.9	1.9	4.7	1.9	1.1	3.7	1.5	1.0	0.6	0.8	0.6	-	0.5
17	7.3	-	4.0	2.2	-	2.2	1.2	-	1.6	0.6	-	0.9	0.6	-	0.4
18	10.3	7.1	-	3.2	-	-	1.8	-	-	1.3		-	0.7	0.7	-
Average	7.0	7.2	3.4	3.0	4.4	2.2	1.7	3.1	1.6	1.2	1.9	1.1	0.6	0.7	0.6

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