Supplementary Material

Study on the causes of growth differences in three conifers after the rainy season in the Xiong'an New Area

Xin Ran1, Shenqi Qiao1, Yu Zhang1, Xiaokuan Gao 2, Yuewei Du 1, Bingxiang Liu 1,3\*, Changming Ma 1 and Hongxiang Mu 1

**\* Correspondence:** Bingxiang Liu: [proser211@126.com](mailto:proser211@126.com)

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Figure 1

**Figure S1.** Schematic diagram of root sampling: (a) Sampling top view; (b) Sample the flat view.

figure 2

**Figure S2.** Schematic diagram of root respiration determination

**Figure S1A.** Composition of soil particles at different depths(data in Figure 1A)

|  |  |  |  |
| --- | --- | --- | --- |
| [soil depth(cm)](D:\\Program Files (x86)\\Youdao\\Dict\\9.1.2.0\\resultui\\html\\index.html" \l "\\javascript:;" \o "file:///D:\\Program Files (x86)\\Youdao\\Dict\\9.1.2.0\\resultui\\html\\index.html#\\javascript:;) | Particl size composition(%) | | |
| Clay(＜0.002) | Silt(0.002-0.02) | Sand(0.02-2.00) |
| 0-20 | 5.89±1.72a | 29.88±0.66ab | 64.23±2.34ab |
| 20-40 | 4.15±0.66a | 21.38±6.07b | 74.47±6.62a |
| 40-60 | 7.25±2.20a | 35.97±3.93a | 56.78±6.07b |

**Figure S1B.** Soil water content and field water capacity(data in Figure 1B)

|  |  |  |  |
| --- | --- | --- | --- |
|  | [soil depth(cm)](D:\\Program Files (x86)\\Youdao\\Dict\\9.1.2.0\\resultui\\html\\index.html" \l "\\javascript:;" \o "file:///D:\\Program Files (x86)\\Youdao\\Dict\\9.1.2.0\\resultui\\html\\index.html#\\javascript:;) | | |
| Indicator | 0-20 | 20-40 | 40-60 |
| Soil volumetric moisture content(%) | 67.18±15.66b | 75.22±3.23b | 103.01±10.26a |
| Maximum field water capacity(%) | 96.56±3.93a | 93.87±5.44a | 103.33±3.18a |

**Figure S1C** Soil bulk density and porosity(data in Figure 1C)

|  |  |  |  |
| --- | --- | --- | --- |
|  | [soil depth(cm)](D:\\Program Files (x86)\\Youdao\\Dict\\9.1.2.0\\resultui\\html\\index.html" \l "\\javascript:;" \o "file:///D:\\Program Files (x86)\\Youdao\\Dict\\9.1.2.0\\resultui\\html\\index.html#\\javascript:;) | | |
| Indicator | 0-20 | 20-40 | 40-60 |
| [Soil bulk density](D:\\Program Files (x86)\\Youdao\\Dict\\9.1.2.0\\resultui\\html\\index.html" \l "\\javascript:;" \o "file:///D:\\Program Files (x86)\\Youdao\\Dict\\9.1.2.0\\resultui\\html\\index.html#\\javascript:;) | 1.2707±0.01308b | 1.1721±0.01423c | 1.3422±0.02086a |
| [Soil porosity](D:\\Program Files (x86)\\Youdao\\Dict\\9.1.2.0\\resultui\\html\\index.html" \l "\\javascript:;" \o "file:///D:\\Program Files (x86)\\Youdao\\Dict\\9.1.2.0\\resultui\\html\\index.html#\\javascript:;) | 52.0501±0.49344b | 55.769±0.53687a | 49.3518±0.78707c |

**FigureS1D** The correlation between soil water content and aeration(data in Figure 1D)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Water content of 0-20cm soil | Coefficient of air permeability of 0-20cm soil | Water content of 20-40cm soil | Coefficient of air permeability of 20-40cm soil | Water content of 40-60cm soil | Coefficient of air permeability of 40-60cm soil |
| 28.74 | 0.09±0.00 | 31.11 | 0.08±0.01 | 33.87 | 0.01±0.001 |
| 28.57 | 0.06±0.00 | 34.87 | 0.09±0.01 | 34.44 | 0.01±0.001 |
| 28.6 | 0.02±0.00 | 30.81 | 0.09±0.00 | 31.74 | 0.01±0.001 |
| 29.06 | 0.02±0.00 | 29.82 | 0.08±0.01 | 20.04 | 0.08±0.002 |
| 30.54 | 0.06±0.01 | 29.5 | 0.08±0.03 | 1.88 | 0.45±0.000 |
| 22.87 | 0.11±0.00 | 20.43 | 0.12±0.02 | 7.96 | 0.23±0.007 |
| 21.7 | 0.11±0.01 | 24.56 | 0.11±0.00 | 28.38 | 0.05±0.002 |
| 23.16 | 0.08±0.01 | 21.75 | 0.14±0.01 | 29.49 | 0.03±0.001 |
| 10.39 | 0.16±0.01 | 16.29 | 0.13±0.01 | 25.66 | 0.05±0.003 |
| 14.92 | 0.14±0.02 | 10.32 | 0.13±0.01 | 17.35 | 0.11±0.003 |
| 13.77 | 0.16±0.01 | 13.68 | 0.18±0.01 | 6.55 | 0.30±0.020 |
| 15.9 | 0.12±0.01 | 3.11 | 0.31±0.01 | 4.33 | 0.38±0.020 |
| 11.08 | 0.18±0.01 | 5.05 | 0.29±0.01 | 3.04 | 0.42±0.024 |
| 11.57 | 0.13±0.01 | 2.75 | 0.26±0.02 | 3.84 | 0.41±0.037 |
| 6.63 | 0.22±0.01 | 3.33 | 0.33±0.03 | 4.47 | 0.34±0.014 |
| 6.05 | 0.27±0.02 | 1.64 | 0.29±0.01 | 2.74 | 0.42±0.043 |
| 4.21 | 0.29±0.01 | 2.05 | 0.24±0.01 | 4.64 | 0.35±0.017 |
| 3.53 | 0.27±0.02 | 1.99 | 0.32±0.00 | 2.87 | 0.43±0.024 |
| 4.25 | 0.35±0.03 | 2.14 | 0.24±0.01 |  |  |
| 4.69 | 0.31±0.01 | 4.32 | 0.42±0.02 |  |  |
| 2.56 | 0.31±0.01 | 2.66 | 0.4±0.02 |  |  |
| 2.4 | 0.36±0.07 | 1.25 | 0.31±0.02 |  |  |
| 3.09 | 0.38±0.03 | 1.58 | 0.27±0.02 |  |  |
| 3.27 | 0.33±0.01 | 1.53 | 0.33±0.01 |  |  |
| 1.85 | 0.34±0.01 |  |  |  |  |
| 0.02 | 0.26±0.01 |  |  |  |  |
| 0.02 | 0.38±0.04 |  |  |  |  |
| 0.02 | 0.36±0.03 |  |  |  |  |
| 0.02 | 0.37±0.00 |  |  |  |  |

**Table.2** Changes in ground diameter and DPb-L of three coniferous species(data in Table 2)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Serial number | Ground diameter(cm) | Diameter at breast height（cm） | The height of tree(cm) | The range of tree-crown(cm) | Leaf length(cm) | The growth of shoots(cm) |
| Pa-L | 10.23±0.12a | 6.6±0.32a | 3.76±0.05a | 3.15±0.03a | 8.76±0.24a | 15.04±1.37a |
| Pa-M | 9.40±0.1b | 4.97±0.34b | 3.23±0.02b | 2.82±0.03b | 7.48±0.18b | 7.51±0.38b |
| Pa-N | 9.20±0.12b | 4.27±0.03c | 3.07±0.04c | 2.41±0.03c | 5.86±0.10c | 4.71±0.80c |
| Pb-L | 10.3±0.3a | 2.73±0.2a | 2.81±0.03a | 2.16±0.02a | 6.63±0.18a | 19.08±2.17a |
| Pb-M | 8.4±0.57b | 2.00±0.21b | 2.18±0.01b | 1.81±0.02b | 5.00±0.05b | 10.28±0.86b |
| Pb-N | 7.57±0.23c | 1.97±0.09c | 1.94±0.06c | 1.66±0.04c | 4.47±0.1c | 4.35±0.32c |
| Pt-L | 9.83±0.22a | 3.87±0.39a | 2.68±0.03a | 2.52±0.02a | 15.17±0.22a | 25.25±1.5a |
| Pt-M | 7.40±0.46b | 3.07±0.26b | 2.48±0.04b | 2.36±0.03b | 8.56±0.49b | 16.42±2.16b |
| Pt-N | 7.07±0.29c | 2.63±0.39c | 2.14±0.02c | 2.12±0.07c | 10.57±0.41c | 9.80±1.03c |

|  |  |  |  |
| --- | --- | --- | --- |
| Serial number | [chlorophyll a(mg/g)](D:\\Program Files (x86)\\Youdao\\Dict\\9.1.2.0\\resultui\\html\\index.html" \l "\\javascript:;" \o "file:///D:\\Program Files (x86)\\Youdao\\Dict\\9.1.2.0\\resultui\\html\\index.html#\\javascript:;) | [chlorophyll b(mg/g)](D:\\Program Files (x86)\\Youdao\\Dict\\9.1.2.0\\resultui\\html\\index.html" \l "\\javascript:;" \o "file:///D:\\Program Files (x86)\\Youdao\\Dict\\9.1.2.0\\resultui\\html\\index.html#\\javascript:;) | [Carotenoid(mg/g)](D:\\Program Files (x86)\\Youdao\\Dict\\9.1.2.0\\resultui\\html\\index.html" \l "\\javascript:;" \o "file:///D:\\Program Files (x86)\\Youdao\\Dict\\9.1.2.0\\resultui\\html\\index.html#\\javascript:;) |
| Pa-L | 0.77±0.02a | 0.45±0.03a | 0.22±0.00a |
| Pa-M | 0.54±0.00b | 0.35±0.00b | 0.14±0.00b |
| Pa-N | 0.33±0.03c | 0.34±0.05b | 0.10±0.01c |
| Pb-L | 0.60±0.00a | 0.43±0.01a | 0.13±0.00a |
| Pb-M | 0.49±0.00b | 0.42±0.00b | 0.12±0.00b |
| Pb-N | 0.31±0.00c | 0.40±0.00c | 0.08±0.00c |
| Pt-L | 0.83±0.06a | 0.56±0.02a | 0.20±0.00a |
| Pt-M | 0.39±0.04b | 0.42±0.03b | 0.09±0.01b |
| Pt-N | 0.25±0.00c | 0.43±0.00b | 0.07±0.00c |

**Table.S3** Changes in photosynthetic pigments of three conifers under different growth states(data in Table 3)

**Figure S4A-4C.** Effects of high soil water content on the distribution of root biomass in the vertical and horizontal directions of three conifers(data in Figure 4A-4C)

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth (cm) | The horizontal distance of the soil (cm) | | | | | | | | |
| A(20-40) | B(40-60) | C(60-80) | D(80-100) | E(100-120) | F(120-140) | G(140-160) | H(160-180) | I(180-200) |
| The biomass of the root(g) | Pb-L | 0-20 | 24.62±0.09a | 26.59±0.52a | 22.62±0.92a |  |  |  |  |  |  |
| 20-40 | 20.92±0.14a | 21.77±0.29a | 10.48±0.07a |  |  |  |  |  |  |
| 40-60 | 15.27±0.34a | 18.57±0.13a | 8.42±0.1a |  |  |  |  |  |  |
| Pb-M | 0-20 | 14.58±0.21b | 16.16±0.5b | 11.56±0.09b |  |  |  |  |  |  |
| 20-40 | 10.44±0.05b | 10.57±0.24b | 8.42±0.06b |  |  |  |  |  |  |
| 40-60 | 8.55±0.26c | 8.51±0.12c | 5.23±0.10b |  |  |  |  |  |  |
| Pb-N | 0-20 | 12.03±0.23c | 13.63±0.17c | 8.25±0.09c |  |  |  |  |  |  |
| 20-40 | 6.35±0.10b | 8.59±0.16c | 4.42±0.11c |  |  |  |  |  |  |
| 40-60 | 10.31±0.14b | 11.03±0.11b | 4.85±0.23b |  |  |  |  |  |  |
| Pa-L | 0-20 | 25.4±1.19a | 25.59±0.14a | 27.86±0.29a | 22.20±0.15 | 20.95±1.08 | 18.09±0.03 | 12.75±0.06 | 10.53±0.06 | 2.097±0.06 |
| 20-40 | 19.72±0.76a | 16.74±0.07a | 21.82±0.43a | 18.31±0.04 | 11.10±0.03 | 9.26±0.05 | 5.90±0.03 | 3.07±0.02 |  |
| 40-60 | 15.19±0.49a | 13.16±0.01a | 10.26±0.1a |  |  |  |  |  |  |
| Pa-M | 0-20 | 17.32±0.2b | 13.47±0.16b | 10.60±0.26b | 6.39±0.08 |  |  |  |  |  |
| 20-40 | 10.63±0.13b | 5.57±0.11b | 3.30±0.06b | 2.1±0.05 |  |  |  |  |  |
| 40-60 | 10.63±0.13b | 8.42±0.17b | 6.68±0.17b |  |  |  |  |  |  |
| Pa-N | 0-20 | 6.47±0.08c | 4.14±0.06c | 0.76±0.03c | 0.55±0.05 |  |  |  |  |  |
| 20-40 | 7.27±0.03c | 4.56±0.20c | 1.36±0.02c |  |  |  |  |  |  |
| 40-60 | 9.32±0.03c | 6.13±0.04c | 2.13±0.03c |  |  |  |  |  |  |
| Pt-L | 0-20 | 19.18±0.06a | 21.74±0.09a | 17.14±0.73a | 11.64±0.31 | 9.46±0.05 |  |  |  |  |
| 20-40 | 16.59±0.17a | 19.68±0.08a | 12.85±0.07a | 8.16±0.03 | 6.34±0.08 |  |  |  |  |
| 40-60 | 14.29±0.10a | 10.37±0.10a | 8.5±0.09a | 6.48±0.04 |  |  |  |  |  |
| Pt-M | 0-20 | 14.13±0.15b | 17.11±0.02b | 9.6±0.08b |  |  |  |  |  |  |
| 20-40 | 7.18±0.11c | 8.42±0.12c | 5.93±0.0.03b |  |  |  |  |  |  |
| 40-60 | 10.05±0.08b | 10.32±0.04a | 6.36±0.13b |  |  |  |  |  |  |
| Pt-N | 0-20 | 8.63±0.04c | 5.34±0.12c | 3.2±0.13c |  |  |  |  |  |  |
| 20-40 | 11.29±0.10019b | 10.08±0.03b | 4.25±0.12c |  |  |  |  |  |  |
| 40-60 | 10.11±0.04b | 8.44±0.21b | 3.83±0.07c |  |  |  |  |  |  |

**Figure S4D-4F.** Effects of high soil water content on the ratio distribution of root biomass in the vertical and horizontal directions of three conifers(data in Figure 4D-4F)

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth (cm) | The horizontal distance of the soil (cm) | | | | | | | | |
| A(20-40) | B(40-60) | C(60-80) | D(80-100) | E(100-120) | F(120-140) | G(140-160) | H(160-180) | I(180-200) |
| The percentage of root biomass(%) | Pb-L | 0-20 | 0.14±0.002b | 0.16±0.004b | 0.13±0.004a |  |  |  |  |  |  |
| 20-40 | 0.12±0.002a | 0.13±0.002a | 0.06±0.001b |  |  |  |  |  |  |
| 40-60 | 0.09±0.003b | 0.11±0.002b | 0.05±0.001b |  |  |  |  |  |  |
| Pb-M | 0-20 | 0.16±0.002a | 0.17±0.005a | 0.12±0b |  |  |  |  |  |  |
| 20-40 | 0.11±0.001b | 0.11±0.002b | 0.09±0.001a |  |  |  |  |  |  |
| 40-60 | 0.09±0.003b | 0.09±0.001c | 0.06±0.001a |  |  |  |  |  |  |
| Pb-N | 0-20 | 0.15±0.003ab | 0.17±0.002a | 0.1±0.001c |  |  |  |  |  |  |
| 20-40 | 0.08±0.002c | 0.11±0.002b | 0.06±0.001c |  |  |  |  |  |  |
| 40-60 | 0.13±0.002a | 0.14±0.001a | 0.06±0.003a |  |  |  |  |  |  |
| Pa-L | 0-20 | 0.08±0.004c | 0.08±0.001c | 0.09±0.001b | 0.07±0.001a | 0.07±0.00186 | 0.06±0.00033 | 0.04±0.0004 | 0.034±0.0001 | 0.007±0.0001 |
| 20-40 | 0.06±0.003c | 0.05±0.001b | 0.07±0.001a | 0.06±0.00 | 0.04±0.00021 | 0.03±0.00001 | 0.019±0.00 | 0.01±0.0001 |  |
| 40-60 | 0.05±0.001c | 0.04±0c | 0.03±0c |  |  |  |  |  |  |
| Pa-M | 0-20 | 0.18±0.002a | 0.14±0.002a | 0.11±0.002a | 0.06±0.00b |  |  |  |  |  |
| 20-40 | 0.11±0.001b | 0.06±0.001b | 0.03±0.001b | 0.02±0.00 |  |  |  |  |  |
| 40-60 | 0.15±0.002b | 0.09±0.002b | 0.07±0.002a |  |  |  |  |  |  |
| Pa-N | 0-20 | 0.15±0.002b | 0.1±0.002b | 0.02±0.001c | 0.01±0.001c |  |  |  |  |  |
| 20-40 | 0.17±0a | 0.11±0.005a | 0.03±0.001b |  |  |  |  |  |  |
| 40-60 | 0.22±0.001a | 0.14±0.001a | 0.05±0.001b |  |  |  |  |  |  |
| Pt-L | 0-20 | 0.11±0c | 0.12±0b | 0.1±0.001b | 0.07±0.002 | 0.05±0.00033 |  |  |  |  |
| 20-40 | 0.09±0.001b | 0.11±0b | 0.07±0a | 0.04±0.00 | 0.03±0.00033 |  |  |  |  |
| 40-60 | 0.08±0.001c | 0.06±0.001c | 0.05±0.001c | 0.04±0.00033 |  |  |  |  |  |
| Pt-M | 0-20 | 0.15±0.004a | 0.19±0.005a | 0.11±0.004a |  |  |  |  |  |  |
| 20-40 | 0.08±0.003c | 0.09±0.003c | 0.07±0.002b |  |  |  |  |  |  |
| 40-60 | 0.11±0.002b | 0.11±0.003b | 0.07±0.001a |  |  |  |  |  |  |
| Pt-N | 0-20 | 0.13±0.001b | 0.08±0.003c | 0.05±0.001c |  |  |  |  |  |  |
| 20-40 | 0.17±0.003a | 0.15±0.001a | 0.06±0.002b |  |  |  |  |  |  |
| 40-60 | 0.15±0.002a | 0.13±0.003a | 0.06±0.001b |  |  |  |  |  |  |

F**igure S4G-4I.** The percentage of root biomass in the vertical direction of soil for three conifers(data in Figure 4G-4I)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth (cm) | | |
| 0-20 | 20-40 | 40-60 |
| The percentage of root biomass(%) | Pb-L | 44.33±0.88a | 31.01±0.41a | 24.66±0.47b |
| Pb-M | 44.99±0.63a | 31.3±0.26a | 23.72±0.4b |
| Pb-N | 42.67±0.47a | 24.37±0.45b | 32.96±0.37a |
| Pa-L | 53.32±0.35a | 34.21±0.16a | 12.47±0.19c |
| Pa-M | 48.37±0.32b | 21.86±0.11c | 29.77±0.4b |
| Pa-N | 27.93±0.46c | 30.89±0.5b | 39.54±1.57a |
| Pt-L | 43.54±0.65b | 34.77±0.18b | 21.69±0.14c |
| Pt-M | 47.15±1.24a | 23.59±0.71c | 29.26±0.54b |
| Pt-N | 27.13±0.87c | 38.9±0.63a | 33.98±0.3a |

**FigureS5A-5C.** Effects of high soil water content on the horizontal and vertical distributions of root length in three coniferous species.(data in Figure 5A-5C)

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth (cm) | The horizontal distance of the soil (cm) | | | | | | | | |
| A(20-40) | B(40-60) | C(60-80) | D(80-100) | E(100-120) | F(120-140) | G(140-160) | H(160-180) | I(180-200) |
| The length of the root(cm) | Pt-L | 0-20 | 1662.31±4.52a | 1727.18±6.4a | 1442.27±13.03a | 829.86±21.69 | 259.56±9.27 |  |  |  |  |
| 20-40 | 1185.72±41.38a | 1502.84±38.68a | 1074.7±65.86a | 626.13±32.98 | 128.27±3.76 |  |  |  |  |
| 40-60 | 858.78±8.17a | 1206.22±48.49a | 678.1±6.29a | 369.34±20.69 |  |  |  |  |  |
| Pt-M | 0-20 | 851.76±2.06b | 1394.55±1.31b | 826.81±3.02b |  |  |  |  |  |  |
| 20-40 | 382.1±1.24c | 863±2.27c | 327.52±1.32b |  |  |  |  |  |  |
| 40-60 | 447.4±2.25b | 1179.07±4.74a | 464.85±0.44b |  |  |  |  |  |  |
| Pt-N | 0-20 | 289.53±4.93c | 415.47±6.39c | 76.93±1.83c |  |  |  |  |  |  |
| 20-40 | 616.27±3.11b | 940.64±3.74b | 245.97±6.55b |  |  |  |  |  |  |
| 40-60 | 353.6±1.89c | 562.38±3.74b | 129.18±5.96b |  |  |  |  |  |  |
| Pa-L | 0-20 | 2248.32±68a | 2664.18±81.14a | 4471.37±186.43a | 4153.96±29.32a | 2677.23±56.75 | 930.99±20.14 | 536.25±20.74 | 247.55±20.45 | 180.95±19.14 |
| 20-40 | 1351.64±21.8a | 2174.21±49.38a | 2662.27±18.31a | 570.61±75.38 | 334.20±17.34 | 315.38±5.13 | 241.15±18.9 | 133.54±14.34 |  |
| 40-60 | 893.54±39.85a | 1255.43±42.23a | 1706.82±55.01a |  |  |  |  |  |  |
| Pa-M | 0-20 | 768.42±3.42b | 586.89±3.48b | 540.78±4.17b | 158.75±1.04b |  |  |  |  |  |
| 20-40 | 644.24±2.62b | 490.71±4.08b | 444.61±3.91b | 111.77±2.36 |  |  |  |  |  |
| 40-60 | 719.83±3.86b | 540.55±3.84b | 465.51±1.19b |  |  |  |  |  |  |
| Pa-N | 0-20 | 359.2±12.41c | 190.48±3.27c | 156.88±3.27c | 137.21±1.99b |  |  |  |  |  |
| 20-40 | 563.43±4.53c | 291.76±7.4c | 212.97±1.43c |  |  |  |  |  |  |
| 40-60 | 768.95±9.61b | 222.73±1.4c | 171.76±5.95c | . |  |  |  |  |  |
| Pb-L | 0-20 | 2440.45±2.28a | 2543.52±4.54a | 2304.82±1.61a |  |  |  |  |  |  |
| 20-40 | 1458.75±1.02a | 1673.47±3.45a | 1301.63±4.34a |  |  |  |  |  |  |
| 40-60 | 1187.89±4.93a | 1482.4±2.21a | 1279.01±1.95a |  |  |  |  |  |  |
| Pb-M | 0-20 | 1135.5±3.22b | 1692.95±5.24b | 1146.73±2.16b |  |  |  |  |  |  |
| 20-40 | 885.13±2.38b | 1372.92±1.12b | 646.62±1.58b |  |  |  |  |  |  |
| 40-60 | 785.97±3.91b | 1112.99±4.01b | 533.5±4.85b |  |  |  |  |  |  |
| Pb-N | 0-20 | 746.07±4.19c | 933.81±2.33c | 585.78±3.5c |  |  |  |  |  |  |
| 20-40 | 554.19±2.98c | 635.63±2.86c | 405.32±2c |  |  |  |  |  |  |
| 40-60 | 578.37±3.68c | 647.03±3.13c | 468.8±2.49c |  |  |  |  |  |  |

**FigureS5D-5F.** Distribution of the length of graded roots in the vertical direction in three coniferous species(data in Figure 5D-5F)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth (cm) | Transport root (＞6mm) | Absorption root(≤6mm) |
| The length of the root(cm) | Pa-L | 0-20 | 12944.95±280.05a | 4865.56±162.99a |
| 20-40 | 6136.94±72.06a | 1646.07±71.3a |
| 40-60 | 3036.41±81.46a | 819.38±79.14a |
| Pa-M | 0-20 | 1720.96±19.75b | 333.88±19.58b |
| 20-40 | 1411.29±11.81b | 280.04±19.08b |
| 40-60 | 1409.34±36.79b | 316.55±31.15b |
| Pa-N | 0-20 | 667.63±28.96c | 176.14±27.08b |
| 20-40 | 843.5±5.59c | 224.67±16.55b |
| 40-60 | 890.48±15.85c | 272.95±12.22b |
| Pt-L | 0-20 | 4114.1±63.74a | 1807.07±61.2a |
| 20-40 | 3232.65±64.57a | 1285.01±87.4a |
| 40-60 | 2363.97±35.53a | 748.47±81.44a |
| Pt-M | 0-20 | 2394.23±44.28b | 678.89±45.5b |
| 20-40 | 1326.39±23.85b | 246.23±27.25b |
| 40-60 | 1675.26±36.85b | 416.07±37.54b |
| Pt-N | 0-20 | 589.6±8.14c | 192.33±9.64c |
| 20-40 | 1235.13±105.29b | 567.74±106.38c |
| 40-60 | 794.88±3.04c | 250.28±2.8b |
| Pb-L | 0-20 | 6279.58±396.25a | 1788.76±382.21a |
| 20-40 | 3474.52±69.18s | 957.24±75.47a |
| 40-60 | 3342.13±39.14a | 607.17±34.32a |
| Pb-M | 0-20 | 3153.65±112.56b | 821.54±109.86b |
| 20-40 | 2367.11±109.57b | 535.68±109.7b |
| 40-60 | 2065.87±64.41b | 366.6±65.38b |
| Pb-N | 0-20 | 1795.96±32.64c | 469.7±33.75b |
| 20-40 | 1250.74±55.83c | 344.4±55.83b |
| 40-60 | 1366.12±59.34c | 328.07±62.21b |

**Figure S5G-5I.** The ratio of graded root length to grade 1 in the vertical direction in three coniferous species(data in Figure 5G-5I)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth (cm) | Grading of root system(mm) | | | |
| I(＜2) | Ⅱ(2-4) | Ⅲ(4-6) | Ⅳ(＞6) |
| The ratio of graded root length area to grade 1 | Pb-L | 0-20 | 1±0a | 1±0a | 1±0a | 1±0a |
| 20-40 | 1±0a | 1±0a | 1±0a | 1±0a |
| 40-60 | 1±0a | 1±0a | 1±0a | 1±0a |
| Pb-M | 0-20 | 0.38±0.06b | 0.51±0.14b | 0.55±0.16b | 0.5±0.01b |
| 20-40 | 0.52±0.16b | 0.55±0.13b | 0.58±0.13b | 0.68±0.03b |
| 40-60 | 0.49±0.1b | 0.86±0.15a | 0.52±0.12b | 0.62±0.02b |
| Pb-N | 0-20 | 0.3±0.06b | 0.28±0.07b | 0.29±0.06b | 0.29±0.01c |
| 20-40 | 0.52±0.02b | 0.4±0.08b | 0.33±0.06b | 0.36±0.02c |
| 40-60 | 0.75±0.09ab | 0.81±0.22a | 0.41±0.02b | 0.41±0.01c |
| Pa-L | 0-20 | 1±0a | 1±0a | 1±0a | 1±0a |
| 20-40 | 1±0a | 1±0a | 1±0a | 1±0a |
| 40-60 | 1±0a | 1±0a | 1±0a | 1±0a |
| Pa-M | 0-20 | 0.09±0b | 0.07±0.01b | 0.07±0.01b | 0.13±0b |
| 20-40 | 0.18±0.02b | 0.18±0.01b | 0.17±0.02b | 0.23±0b |
| 40-60 | 0.33±0.02b | 0.35±0.04b | 0.44±0.08b | 0.47±0.02b |
| Pa-N | 0-20 | 0.04±0.01c | 0.04±0.01c | 0.03±0c | 0.05±0c |
| 20-40 | 0.12±0.01c | 0.14±0.02b | 0.14±0.01b | 0.14±0c |
| 40-60 | 0.34±0.06b | 0.36±0.01b | 0.33±0.04b | 0.29±0.01c |
| Pt-L | 0-20 | 1±0a | 1±0a | 1±0a | 1±0a |
| 20-40 | 1±0a | 1±0a | 1±0a | 1±0a |
| 40-60 | 1±0a | 1±0a | 1±0a | 1±0a |
| Pt-M | 0-20 | 0.45±0.09b | 0.37±0.04b | 0.37±0.01b | 0.58±0.02b |
| 20-40 | 0.17±0.01b | 0.19±0.02b | 0.2±0.03c | 0.41±0.01b |
| 40-60 | 0.67±0.16b | 0.62±0.12b | 0.54±0.09b | 0.71±0.01b |
| Pt-N | 0-20 | 0.08±0.01c | 0.09±0.01c | 0.13±0c | 0.14±0c |
| 20-40 | 0.39±0.14b | 0.47±0.14b | 0.43±0.04b | 0.38±0.03b |
| 40-60 | 0.21±0.02b | 0.32±0.03c | 0.38±0.04b | 0.34±0.01c |

**Figure S6A-6C.** Vertical distribution ratio of graded root length of three conifers(data in Figure 6A-6C)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth (cm) | The ratio of the transport root(＞6mm)(%) | The ratio of the absorption root(≤6mm)(%) |
| The ratio of the length of the root(%) | Pa-L | 0-20 | 43.96±0.99a | 16.52±0.53a |
| 20-40 | 20.84±0.33c | 5.59±0.22b |
| 40-60 | 10.31±0.24a | 2.78±0.27a |
| Pa-M | 0-20 | 31.45±0.39b | 6.1±0.35b |
| 20-40 | 25.79±0.24b | 5.12±0.34b |
| 40-60 | 25.76±0.7b | 5.78±0.56b |
| Pa-N | 0-20 | 21.71±0.89c | 5.72±0.86b |
| 20-40 | 27.44±0.39a | 7.3±0.48a |
| 40-60 | 28.96±0.55c | 8.87±0.36c |
| Pt-L | 0-20 | 30.37±0.67b | 13.33±0.36a |
| 20-40 | 23.86±0.64b | 9.48±0.58ab |
| 40-60 | 17.45±0.27c | 5.52±0.56a |
| Pt-M | 0-20 | 35.54±0.7a | 10.08±0.66b |
| 20-40 | 19.69±0.36b | 3.65±0.4b |
| 40-60 | 24.87±0.54a | 6.18±0.56a |
| Pt-N | 0-20 | 16.24±0.2c | 5.3±0.27c |
| 20-40 | 34.04±2.95a | 15.63±2.9a |
| 40-60 | 21.9±0.05b | 6.89±0.08a |
| Pb-L | 0-20 | 38.12±0.6a | 10.71±1.74a |
| 20-40 | 21.18±0.62b | 5.88±0.69a |
| 40-60 | 20.39±0.85b | 3.71±0.32a |
| Pb-M | 0-20 | 33.87±1.21b | 8.82±1.18a |
| 20-40 | 25.42±1.16a | 5.75±1.18a |
| 40-60 | 22.18±0.69ab | 3.94±0.7a |
| Pb-N | 0-20 | 32.33±0.62b | 8.45±0.6a |
| 20-40 | 22.52±1.03ab | 6.2±1a |
| 40-60 | 24.6±1.09a | 5.9±1.11a |

**Figure S6D-6F.** The percentage of root length in the vertical direction of soil for three conifers(data in Figure 6D-6F)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Indicator | Serial number |  | Soil depth (cm) |  |
| 0-20 | 20-40 | 40-60 |
| The ratio of the length of the root(%) | Pa-L | 60.48±0.47a | 26.43±0.15c | 13.09±0.4c |
| Pa-M | 37.55±0.15b | 30.91±0.12b | 31.54±0.17b |
| Pa-N | 27.43±0.17c | 34.73±0.19a | 37.83±0.21a |
| Pt-L | 43.7±0.32b | 33.34±0.19b | 22.96±0.4c |
| Pt-M | 45.62±0.04a | 23.34±0.04c | 31.04±0.04a |
| Pt-N | 21.54±0.08c | 49.67±0.17a | 28.79±0.12b |
| Pb-L | 48.83±2.32a | 27.07±1.25b | 24.11±1.07b |
| Pb-M | 42.69±0.04b | 31.19±0.03a | 26.12±0.01b |
| Pb-N | 40.79±0.04b | 28.72±0.13ab | 30.5±0.11a |

**Figure S7A-7C.** Distribution of root surface area in the vertical and horizontal directions of three coniferous species(data in Figure 7A-7C)

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth (cm) | The horizontal distance of the soil (cm) | | | | | | | | |
| A(20-40) | B(40-60) | C(60-80) | D(80-100) | E(100-120) | F(120-140) | G(140-160) | H(160-180) | I(180-200) |
| The surface area of the root(cm2) | Pt-L | 0-20 | 672.48±5.54a | 776.71±6.86b | 684.08±29.35a | 383.84±19.03 | 123.21±13.56 |  |  |  |  |
| 20-40 | 592.07±3.43a | 650.29±36.16a | 508.32±40.56a | 271.29±15.49 | 67.01±5.17 |  |  |  |  |
| 40-60 | 436.11±32.5a | 559.1±1.85a | 319.33±3.3a | 178.03±23.01 |  |  |  |  |  |
| Pt-M | 0-20 | 394.38±3.56b | 818.35±1.69a | 401.48±26.66b |  |  |  |  |  |  |
| 20-40 | 234.61±2.56b | 535.94±3.33b | 70.1±12.23b |  |  |  |  |  |  |
| 40-60 | 261.29±4.28b | 617.66±2.44b | 319.45±0.68a |  |  |  |  |  |  |
| Pt-N | 0-20 | 129.59±1.86c | 141.25±2.32c | 45.96±4.88c |  |  |  |  |  |  |
| 20-40 | 337.64±3.29c | 395.38±5.98c | 128.3±2.13b |  |  |  |  |  |  |
| 40-60 | 259.94±1.67b | 189.27±4.9c | 72.29±1.91b |  |  |  |  |  |  |
| Pa-L | 0-20 | 1030.15±16.33a | 1449.16±101.58a | 1952.19±16.82a | 1794.34±97.67a | 1345.94±92.1 | 496.3±24.59 | 271.45±30.8 | 150.64±12.73 | 100.45±7.40 |
| 20-40 | 715.89±32.13a | 1056.36±88.08a | 1341.9±68.15a | 298.87±42.97 | 191.70±27.44 | 156.61±8.11 | 122.01±5.60 | 77.51±6.76 |  |
| 40-60 | 496.94±24.03a | 592.51±12.25a | 1047.15±74.48a |  |  |  |  |  |  |
| Pa-M | 0-20 | 423.51±2.7b | 357.12±2.16b | 307.41±2.36b | 80.53±5.78b |  |  |  |  |  |
| 20-40 | 338.81±2.18b | 276.06±3.05b | 246.64±2.94b | 70.50±3.45 |  |  |  |  |  |
| 40-60 | 385.16±3.82b | 293.47±2.02b | 256.22±2.4b |  |  |  |  |  |  |
| Pa-N | 0-20 | 168.88±1.78c | 101.3±3.53c | 77.26±1.48c | 64.24±1.51b |  |  |  |  |  |
| 20-40 | 206.76±2.62c | 132.32±2.99b | 84.5±1.09c |  |  |  |  |  |  |
| 40-60 | 364.83±1.79b | 158.15±1.07c | 104.5±1.59c | . |  |  |  |  |  |
| Pb-L | 0-20 | 1181.81±11.1a | 1203.18±12.92a | 1020.62±4.43a |  |  |  |  |  |  |
| 20-40 | 762.44±7.94a | 821.15±4.1a | 686.71±6.33a |  |  |  |  |  |  |
| 40-60 | 657.85±2.83a | 699.11±5.41a | 585.98±3.31a |  |  |  |  |  |  |
| Pb-M | 0-20 | 502.24±5.29b | 725.66±1.77b | 498.34±1.47b |  |  |  |  |  |  |
| 20-40 | 424.98±2.67b | 607.33±3.54b | 335.95±2.53b |  |  |  |  |  |  |
| 40-60 | 382.96±4.81b | 580.36±5.22b | 265.53±3.32b |  |  |  |  |  |  |
| Pb-N | 0-20 | 358.61±3.85c | 387.49±3.32c | 245.56±2.23c |  |  |  |  |  |  |
| 20-40 | 219.88±1.05c | 254.7±1.42c | 185.16±1.25c |  |  |  |  |  |  |
| 40-60 | 276±3.35c | 287.6±1.14c | 209.12±2.66c |  |  |  |  |  |  |

**Figure S7D-7F.** Distribution of the surface area of graded roots in the vertical direction in three coniferous species(data in Figure 7D-7F)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth(cm) | Transport root (＞6mm) | Absorption root(≤6mm) |
| The surface area of the root(cm2) | Pa-L | 0-20 | 7781.18±244.51a | 629.77±21.27a |
| 20-40 | 3747.06±118.24a | 213.79±7.59a |
| 40-60 | 2030.58±64.19a | 106.02±11.01a |
| Pa-M | 0-20 | 1125.86±10.21b | 42.7±3.16b |
| 20-40 | 887.42±4.71b | 44.6±4.47b |
| 40-60 | 893.77±10.53b | 41.08±8.72b |
| Pa-N | 0-20 | 388.62±4.86c | 23.65±2.76b |
| 20-40 | 398.93±5.35c | 24.65±1.72c |
| 40-60 | 590.45±1.75c | 37.03±2.56b |
| Pt-L | 0-20 | 2425±26.53a | 215.32±7.81a |
| 20-40 | 1926.24±55.69a | 162.75±10.17a |
| 40-60 | 1397.02±45.24a | 95.55±8.77a |
| Pt-M | 0-20 | 1272.34±141.65b | 59.25±15.38b |
| 20-40 | 864.79±17.98b | 43.38±5.44c |
| 40-60 | 974.69±84.19b | 43.58±9.6b |
| Pt-N | 0-20 | 297.7±7.85c | 19.1±2.17c |
| 20-40 | 781.6±7.58b | 79.71±12.04b |
| 40-60 | 479.93±6.14c | 41.57±3.07b |
| Pb-L | 0-20 | 3434.27±216.8a | 263.13±83.6a |
| 20-40 | 2147.64±8.82a | 122.66±8.31a |
| 40-60 | 1857.52±15.05a | 85.42±7.85a |
| Pb-M | 0-20 | 1610.7±20.15b | 115.54±20.994b |
| 20-40 | 1290.19±28.78b | 78.07±22.39ab |
| 40-60 | 1176.13±14.08b | 52.72±15.75a |
| Pb-N | 0-20 | 930.46±13.96c | 61.2±9.8b |
| 20-40 | 615.57±9.43c | 44.17±10.15b |
| 40-60 | 724.16±11.9c | 48.56±14.55a |

**Figure7G-7I.** The ratio of graded root surface area to grade 1 in the vertical direction in three coniferous species(data in Figure 7G-7I)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth(cm) | Grading of root system(mm) | | | |
| I(＜2) | Ⅱ(2-4) | Ⅲ(4-6) | Ⅳ(＞6) |
| The ratio of graded root surface area to grade 1 | Pb-L | 0-20 | 1±0a | 1±0a | 1±0a | 1±0a |
| 20-40 | 1±0a | 1±0a | 1±0a | 1±0a |
| 40-60 | 1±0a | 1±0a | 1±0a | 1±0a |
| Pb-M | 0-20 | 0.45±0.06b | 0.54±0.13b | 0.52±0.2b | 0.47±0.03b |
| 20-40 | 0.47±0.13b | 0.63±0.24b | 0.68±0.24ab | 0.6±0.02b |
| 40-60 | 0.53±0.12a | 0.87±0.19a | 0.58±0.2ab | 0.63±0.01b |
| Pb-N | 0-20 | 0.36±0.09b | 0.34±0.12b | 0.28±0.09b | 0.27±0.01c |
| 20-40 | 0.35±0.05b | 0.37±0.09b | 0.36±0.08b | 0.29±0c |
| 40-60 | 1.24±0.56a | 1.09±0.54a | 0.45±0.09b | 0.39±0.01c |
| Pa-L | 0-20 | 1±0a | 1±0a | 1±0a | 1±0a |
| 20-40 | 1±0a | 1±0a | 1±0a | 1±0a |
| 40-60 | 1±0a | 1±0a | 1±0a | 1±0a |
| Pa-M | 0-20 | 0.08±0b | 0.07±0b | 0.07±0.01b | 0.15±0.01b |
| 20-40 | 0.17±0.01b | 0.2±0.03b | 0.22±0.03b | 0.24±0.01b |
| 40-60 | 0.41±0.07b | 0.37±0.05b | 0.39±0.08b | 0.44±0.01b |
| Pa-N | 0-20 | 0.04±0.01c | 0.04±0.01c | 0.04±0c | 0.05±0c |
| 20-40 | 0.11±0.02c | 0.12±0.02c | 0.11±0.01c | 0.11±0c |
| 40-60 | 0.36±0.05b | 0.37±0.05b | 0.35±0.05b | 0.29±0.01c |
| Pt-L | 0-20 | 1±0a | 1±0a | 1±0a | 1±0a |
| 20-40 | 1±0a | 1±0a | 1±0a | 1±0a |
| 40-60 | 1±0a | 1±0a | 1±0a | 1±0a |
| Pt-M | 0-20 | 0.25±0.05b | 0.24±0.05b | 0.29±0.07b | 0.53±0.06b |
| 20-40 | 0.22±0.04b | 0.24±0.02c | 0.28±0.04c | 0.45±0.02b |
| 40-60 | 0.42±0.04b | 0.46±0.05b | 0.45±0.11b | 0.7±0.06b |
| Pt-N | 0-20 | 0.05±0c | 0.06±0c | 0.11±0.01c | 0.12±0c |
| 20-40 | 0.4±0.11b | 0.5±0.11b | 0.5±0.09b | 0.41±0.01b |
| 40-60 | 0.36±0.08b | 0.41±0.06b | 0.47±0.08b | 0.34±0.02c |

**Figure S8A-8C.** Vertical distribution ratio of graded root surface area of three conifers(data in Figure 8A-8C)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth (cm) | The ratio of the transport root(＞6mm)(%) | The ratio of the absorption root(≤6mm)(%) |
| The ratio of the surface area of the root(%) | Pa-L | 0-20 | 53.61±1.04a | 4.35±0.2a |
| 20-40 | 25.84±0.89b | 1.48±0.07a |
| 40-60 | 14±0.52c | 0.73±0.08b |
| Pa-M | 0-20 | 37.09±0.28b | 1.41±0.11b |
| 20-40 | 29.24±0.16b | 1.47±0.15a |
| 40-60 | 29.44±0.3b | 1.35±0.29b |
| Pa-N | 0-20 | 26.56±0.41c | 1.62±0.19b |
| 20-40 | 27.26±0.26a | 1.68±0.11a |
| 40-60 | 40.35±0.12a | 2.53±0.18a |
| Pt-L | 0-20 | 38.97±0.31a | 3.46±0.14a |
| 20-40 | 30.95±0.76b | 2.62±0.18b |
| 40-60 | 22.46±0.75b | 1.54±0.15b |
| Pt-M | 0-20 | 38.84±1.6a | 1.78±0.33b |
| 20-40 | 26.85±2.23b | 1.36±0.24b |
| 40-60 | 29.85±0.57a | 1.33±0.29b |
| Pt-N | 0-20 | 17.51±0.4b | 1.12±0.13b |
| 20-40 | 46±0.76a | 4.68±0.68a |
| 40-60 | 28.24±0.23a | 2.45±0.19a |
| Pb-L | 0-20 | 43.33±1.11a | 3.26±0.9a |
| 20-40 | 27.21±0.87b | 1.56±0.15a |
| 40-60 | 23.55±0.96c | 1.08±0.1a |
| Pb-M | 0-20 | 37.26±0.46b | 2.67±0.49a |
| 20-40 | 29.84±0.65a | 1.81±0.52a |
| 40-60 | 27.2±0.31b | 1.22±0.36a |
| Pb-N | 0-20 | 38.38±0.56b | 2.52±0.41a |
| 20-40 | 25.39±0.38b | 1.82±0.42a |
| 40-60 | 29.87±0.48a | 2±0.6a |

**Figure S8D-8F.** The percentage of root surface area in the vertical direction of soil for three conifers(data in Figure 8D-8F)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth(cm) | | |
| 0-20 | 20-40 | 40-60 |
| The ratio of the surface area of the root(%) | Pa-L | 57.95±0.84a | 27.31±0.9b | 14.73±0.48c |
| Pa-M | 38.5±0.24b | 30.71±0.14a | 30.8±0.16b |
| Pa-N | 28.18±0.24c | 28.94±0.34ab | 42.88±0.14a |
| Pt-L | 42.44±0.22a | 33.57±0.67b | 23.99±0.84b |
| Pt-M | 40.61±1.91a | 28.21±2.45c | 31.18±0.54a |
| Pt-N | 18.64±0.3b | 50.68±0.1a | 30.68±0.31a |
| Pb-L | 46.59±1.97a | 28.78±1.02a | 24.63±0.96c |
| Pb-M | 39.93±0.16b | 31.65±0.14b | 28.42±0.13b |
| Pb-N | 40.91±0.19b | 27.22±0.07b | 31.88±0.2c |

**Figure S9A-11C.** Distribution of root volume in the vertical and horizontal directions of three coniferous species(data in Figure 9A-11C)

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth(cm) | The horizontal distance of the soil (cm） | | | | | | | | |
| A(20-40) | B(40-60) | C(60-80) | D(80-100) | E(100-120) | F(120-140) | G(140-160) | H(160-180) | I(180-200) |
| The volume of the root(cm3) | Pt-L | 0-20 | 31.55±0.75a | 36.57±0.56a | 26.68±2.02a | 14.48±0.1 | 4.72±0.86 |  |  |  |  |
| 20-40 | 22.33±1.57a | 22.9±1.96a | 18.5±0.1a | 10.5±0.69 | 2.84±0.48 |  |  |  |  |
| 40-60 | 18.45±0.24a | 19.38±0.44b | 12.04±0.21a | 6.91±1.42 |  |  |  |  |  |
| Pt-M | 0-20 | 16.32±0.64b | 26.4±1.79b | 17.19±0.87b |  |  |  |  |  |  |
| 20-40 | 11.8±0.28b | 22.3±0.92a | 9.71±1.57b |  |  |  |  |  |  |
| 40-60 | 12.63±2.82b | 23.04±0.88a | 12.17±0.09a |  |  |  |  |  |  |
| Pt-N | 0-20 | 4.46±0.52c | 4.92±0.79c | 1.91±1.06c |  |  |  |  |  |  |
| 20-40 | 9.12±0.29b | 10.52±0.4b | 7.17±0.06b |  |  |  |  |  |  |
| 40-60 | 7.89±0.26b | 12.64±0.92c | 5.93±0.48b |  |  |  |  |  |  |
| Pa-L | 0-20 | 38.84±0.02a | 65.98±7.34a | 69.74±4.21a | 71.99±0.68a | 54.84±1.08 | 22.39±0.83 | 11.2±1.19 | 7.3±0.64 | 4.53±1.13 |
| 20-40 | 30.82±3.37a | 41.4±6.04a | 55.28±4.61a | 56.9±0.63 | 27.89±1.13 | 6.22±0.61 | 5.01±0.63 | 3.59±0.29 |  |
| 40-60 | 22±1.15a | 22.65±1.63a | 21.71±0.85a |  |  |  |  |  |  |
| Pa-M | 0-20 | 18.69±0.3b | 17.22±0.91b | 12.37±0.46b | 6.91±1.75b |  |  |  |  |  |
| 20-40 | 13.55±0.32b | 10.83±0.23b | 9.64±0.45b | 5.12±0.35 |  |  |  |  |  |
| 40-60 | 14.41±0.22b | 13.42±0.55b | 10.86±0.23b |  |  |  |  |  |  |
| Pa-N | 0-20 | 6.35±0.02c | 4.63±0.13b | 3.79±0.25c | 3.77±0.4c |  |  |  |  |  |
| 20-40 | 7.22±0.53b | 5.73±0.08b | 4.46±0.15b |  |  |  |  |  |  |
| 40-60 | 13.82±0.12b | 7.03±0.27c | 5.59±0.21c |  |  |  |  |  |  |
| Pb-L | 0-20 | 55.19±2.4a | 59.92±6.01a | 37.17±0.23a |  |  |  |  |  |  |
| 20-40 | 35.57±0.83a | 44.36±2.99a | 28.88±0.88a |  |  |  |  |  |  |
| 40-60 | 27.34±0.9a | 22.61±0.03a | 15.73±0.2a |  |  |  |  |  |  |
| Pb-M | 0-20 | 18.17±0.51b | 23.96±0.5b | 17.02±0.63b |  |  |  |  |  |  |
| 20-40 | 15.2±0.58b | 20.47±0.33b | 11.18±0.45b |  |  |  |  |  |  |
| 40-60 | 14.54±1.11b | 18.84±0.72b | 10.95±0.29b |  |  |  |  |  |  |
| Pb-N | 0-20 | 10.99±0.42c | 11.56±0.77b | 7.92±0.31c |  |  |  |  |  |  |
| 20-40 | 12.09±1c | 13.29±0.36c | 8.86±0.54c |  |  |  |  |  |  |
| 40-60 | 12.55±0.69b | 12.29±0.23c | 8.07±0.02c |  |  |  |  |  |  |

**Figure S9D-9F.** Distribution of the volume of graded roots in the vertical direction in three coniferous species(data in Figure 9D-9F)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth(cm) | Transport root (＞6mm) | Absorption root(≤6mm) |
| The volume of the root(cm3) | Pa-L | 0-20 | 329.91±5.85a | 7.54±0.49a |
| 20-40 | 223.85±8.11a | 3.26±0.22a |
| 40-60 | 65.4±2.04a | 0.96±0.11a |
| Pa-M | 0-20 | 54.67±1.47b | 0.51±0.05b |
| 20-40 | 38.69±0.18b | 0.45±0.07b |
| 40-60 | 38.06±0.27b | 0.63±0.11a |
| Pa-N | 0-20 | 18.26±0.42c | 0.27±0.05b |
| 20-40 | 17.17±0.31c | 0.24±0.07b |
| 40-60 | 25.74±0.32c | 0.69±0.26a |
| Pt-L | 0-20 | 111.27±1.42a | 2.72±0.14a |
| 20-40 | 75.25±0.98a | 1.84±0.19a |
| 40-60 | 55.71±1.82a | 1.07±0.1a |
| Pt-M | 0-20 | 58.88±2.77b | 1.03±0.22b |
| 20-40 | 43.37±2.06b | 0.45±0.13b |
| 40-60 | 47.69±2.93b | 0.54±0.12b |
| Pt-N | 0-20 | 11.03±1.23c | 0.26±0.02c |
| 20-40 | 26.04±0.69c | 0.77±0.04b |
| 40-60 | 25.86±0.97c | 0.6±0.06c |
| Pb-L | 0-20 | 149.65±8.67a | 2.63±0.28a |
| 20-40 | 107.09±3.53a | 1.73±0.24a |
| 40-60 | 64.67±1.01a | 1.01±0.01a |
| Pb-M | 0-20 | 57.76±1.66b | 1.39±0.29b |
| 20-40 | 45.91±0.17b | 0.93±0.35a |
| 40-60 | 43.11±1.78b | 0.59±0.23a |
| Pb-N | 0-20 | 32.26±2.2c | 0.67±0.1b |
| 20-40 | 30.65±1.38c | 0.82±0.36a |
| 40-60 | 31.79±0.66c | 0.67±0.11a |

**Figure S9G-9I.** The ratio of graded root volume to grade 1 in the vertical direction in three coniferous species(data in Figure 9G-9I)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth(cm) | Grading of root system(mm) | | | |
| I(＜2) | Ⅱ(2-4) | Ⅲ(4-6) | Ⅳ(＞6) |
| The ratio of graded root volume to grade 1 | Pb-L | 0-20 | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a |
| 20-40 | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a |
| 40-60 | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a |
| Pb-M | 0-20 | 0.46±0.07b | 0.63±0.16b | 0.55±0.17b | 0.39±0.03b |
| 20-40 | 0.36±0.10a | 0.51±0.19a | 0.56±0.21a | 0.43±0.01b |
| 40-60 | 0.45±0.09a | 0.84±0.23a | 0.55±0.23a | 0.67±0.04b |
| Pb-N | 0-20 | 0.31±0.05b | 0.29±0.03b | 0.25±0.01b | 0.22±0.01c |
| 20-40 | 0.74±0.32a | 0.79±0.50a | 0.5±0.27a | 0.29±0.01c |
| 40-60 | 0.94±0.39a | 1.00±0.36a | 0.62±0.10a | 0.49±0.02c |
| Pa-L | 0-20 | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a |
| 20-40 | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a |
| 40-60 | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a |
| Pa-M | 0-20 | 0.09±0.01b | 0.07±0.00b | 0.07±0.00b | 0.17±0.00b |
| 20-40 | 0.15±0.01b | 0.15±0.01b | 0.14±0.02b | 0.17±0.01b |
| 40-60 | 0.55±0.03a | 0.58±0.11a | 0.71±0.16a | 0.58±0.01b |
| Pa-N | 0-20 | 0.04±0.01c | 0.04±0.01b | 0.04±0.01c | 0.06±0.00c |
| 20-40 | 0.06±0.01c | 0.07±0.01c | 0.07±0.03b | 0.08±0.00c |
| 40-60 | 0.99±0.51a | 0.96±0.51a | 0.73±0.30a | 0.39±0.02c |
| Pt-L | 0-20 | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a |
| 20-40 | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a |
| 40-60 | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a | 1.00±0.00a |
| Pt-M | 0-20 | 0.39±0.16b | 0.35±0.09b | 0.4±0.11b | 0.53±0.02b |
| 20-40 | 0.31±0.14b | 0.26±0.09b | 0.26±0.09b | 0.58±0.03b |
| 40-60 | 0.6±0.16ab | 0.61±0.14b | 0.5±0.15ab | 0.86±0.04b |
| Pt-N | 0-20 | 0.05±0.01b | 0.07±0.00c | 0.11±0.00c | 0.1±0.01c |
| 20-40 | 0.40±0.13b | 0.46±0.12b | 0.42±0.02b | 0.35±0.01b |
| 40-60 | 0.40±0.10b | 0.48±0.1b | 0.62±0.12b | 0.47±0.03c |

**Figure S10A-10C.** Vertical distribution ratio of graded root volume of three conifers(data in Figure 10A-10C)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth(cm) | Transport root (＞6mm) | Absorption root(≤6mm) |
| The ratio of the volume of the root(%) | Pa-L | 0-20 | 52.3±0.91a | 1.20±0.09a |
| 20-40 | 35.47±1.02a | 0.52±0.04a |
| 40-60 | 10.36±0.2c | 0.14±0.01b |
| Pa-M | 0-20 | 41.09±0.59b | 0.38±0.04b |
| 20-40 | 29.09±0.22b | 0.34±0.05a |
| 40-60 | 28.62±0.28b | 0.48±0.09ab |
| Pa-N | 0-20 | 29.27±0.58c | 0.44±0.08b |
| 20-40 | 27.52±0.41b | 0.38±0.11a |
| 40-60 | 41.28±0.71a | 1.11±0.40a |
| Pt-L | 0-20 | 44.89±0.45a | 1.1±0.05a |
| 20-40 | 30.36±0.45b | 0.74±0.08b |
| 40-60 | 22.48±0.70c | 0.43±0.04b |
| Pt-M | 0-20 | 38.73±1.17b | 0.69±0.17b |
| 20-40 | 28.52±0.70b | 0.30±0.08c |
| 40-60 | 31.42±1.88b | 0.35±0.07b |
| Pt-N | 0-20 | 17.00±1.28c | 0.41±0.04b |
| 20-40 | 40.4±1.22a | 1.21±0.1a |
| 40-60 | 40.06±0.22a | 0.93±0.09a |
| Pb-L | 0-20 | 45.75±1.9a | 0.81±0.1a |
| 20-40 | 32.8±1.36a | 0.53±0.07a |
| 40-60 | 19.8±0.44c | 0.31±0a |
| Pb-M | 0-20 | 38.44±1.27b | 0.92±0.2a |
| 20-40 | 30.54±0.19a | 0.62±0.23a |
| 40-60 | 28.67±0.98b | 0.40±0.15a |
| Pb-N | 0-20 | 32.82±1.87b | 0.69±0.11a |
| 20-40 | 31.20±1.06a | 0.85±0.38a |
| 40-60 | 32.41±1.05a | 0.68±0.12a |

**Figure S10D-10F.** The percentage of root volume in the vertical direction of soil for three conifers(data in Figure 10D-10F)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth(cm) | | |
| 0-20 | 20-40 | 40-60 |
| The ratio of the volume of the root(%) | Pa-L | 53.5±0.96a | 35.99±1.01a | 10.51±0.20c |
| Pa-M | 41.47±0.57b | 29.43±0.28b | 29.1±0.31b |
| Pa-N | 29.71±0.51c | 27.91±0.36b | 42.39±0.41a |
| Pt-L | 45.99±0.42a | 31.1±0.41b | 22.91±0.73c |
| Pt-M | 39.42±1.11b | 28.81±0.75b | 31.77±1.83b |
| Pt-N | 17.4±1.26c | 41.61±1.29a | 40.99±0.14a |
| Pb-L | 46.56±1.84a | 33.33±1.40a | 20.11±0.44c |
| Pb-M | 39.36±1.25b | 31.16±0.35a | 29.48±1.19b |
| Pb-N | 34.86±0.53b | 32.05±0.69a | 33.1±1.17a |

**Figure S11A-11C.** Effects of high soil water content on root activity of three coniferous species with graded roots (data in Figure S11A-11C)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Indicator | Soil depth(cm) | Serial number | Grading of root system(mm) | | | |
| I(＜2) | Ⅱ(2-4) | Ⅲ(4-6) | Ⅳ(＞6) |
| The root activity(ug/(kg·h)) | 0-20 | Pb-L | 35.49±0.39a | 24.53±0.27a | 20.31±0.18a | 18.15±0.37a |
| Pb-M | 22.19±0.34b | 20.3±0.12b | 18.22±0.39b | 16.13±0.37b |
| Pb-N | 16.46±3.17c | 13.34±0.25c | 11.21±0.21c | 10.03±0.3c |
| 20-40 | Pb-L | 37.34±0.15a | 29.06±0.13a | 22.25±0.24a | 20.17±0.43a |
| Pb-M | 23.77±0.21b | 21.1±0.24b | 19.4±0.18b | 15.31±0.18b |
| Pb-N | 17.35±0.28c | 15.97±0.23c | 13.64±0.25c | 11.69±0.25c |
| 40-60 | Pb-L | 21.04±0.21a | 19.75±0.19a | 16.14±0.42a | 11.83±0.32a |
| Pb-M | 21.97±0.57b | 17.33±0.22b | 13.78±0.18b | 10.17±0.32b |
| Pb-N | 13.43±0.96c | 5.58±0.24c | 4.26±0.5c | 2.53±0.18c |
| 0-20 | Pa-L | 36.96±0.14a | 29.49±0.3a | 33.37±0.14a | 28.29±0.25a |
| Pa-M | 32.54±0.24b | 24.8±0.42b | 22.89±0.47b | 16.7±0.28b |
| Pa-N | 26.28±0.42c | 20.79±0.27c | 18.94±0.29c | 13.57±0.42c |
| 20-40 | Pa-L | 38.57±0.21a | 34.67±0.24a | 28.84±0.17a | 26.86±0.23a |
| Pa-M | 31.00±0.53b | 26±0.12b | 24.47±0.5b | 21.9±0.18b |
| Pa-N | 30.78±0.55c | 23.17±0.84c | 19.56±0.23c | 15.35±1.12c |
| 40-60 | Pa-L | 28.48±0.36a | 25.65±0.25a | 24.98±0.13a | 19.7±0.51a |
| Pa-M | 18.78±0.32b | 14.68±0.19b | 13.58±0.31b | 13.31±0.25b |
| Pa-N | 20.57±0.15c | 13.57±0.24c | 9.33±0.12c | 6.14±0.25c |
| 0-20 | Pt-L | 37.46±0.32a | 35.73±0.42a | 34.92±0.5a | 32.81±1.35a |
| Pt-M | 30.68±0.27b | 28.39±0.76b | 27.62±0.31b | 25.54±0.23b |
| Pt-N | 19.75±0.35c | 18.05±0.53c | 17.44±0.9c | 15.05±0.34c |
| 20-40 | Pt-L | 39.06±0.30a | 36.70±0.44a | 33.62±0.39a | 32.71±0.15a |
| Pt-M | 31.89±0.35b | 29.40±0.32b | 28.27±0.2b | 27.37±0.33b |
| Pt-N | 21.02±0.23c | 19.84±0.32c | 18.38±0.2c | 13.43±0.27c |
| 40-60 | Pt-L | 27.27±1.92a | 23.41±2.39a | 18.90±0.34a | 15.44±0.43a |
| Pt-M | 23.38±0.14b | 17.20±0.42b | 15.21±0.17b | 11.69±0.40b |
| Pt-N | 14.57±0.72c | 12.11±1.42b | 9.40±0.33c | 8.13±0.22c |

**Figure S11D-11F.** Root activity of the three conifer root classes varied in the vertical direction of soil(data in Figure 11D-11F)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Indicator | Serial number | Soil depth(cm) | | |
| 0-20 | 20-40 | 40-60 |
| The root activity(ug/(kg·h)) | Pa-L | 32.35±0.41a | 33.51±0.52a | 25.91±0.39a |
| Pa-M | 27.66±0.77b | 29.30±1.05b | 16.40±0.6b |
| Pa-N | 21.11±0.63c | 22.89±0.91c | 15.20±0.72b |
| Pt-L | 35.36±0.38a | 36.70±0.35a | 21.71±1.10a |
| Pt-M | 28.76±0.35b | 29.46±0.38b | 16.87±0.73b |
| Pt-N | 18.05±0.31c | 19.19±0.34c | 11.47±0.52c |
| Pb-L | 28.66±0.94a | 29.62±1.02a | 19.38±0.56a |
| Pb-M | 20.74±0.29b | 21.96±0.42b | 17.48±0.59a |
| Pb-N | 13.78±1.11c | 16.14±0.41c | 8.32±1.02b |

**Figure S12A-12C.** Effects of high soil water content on root respiration of three coniferous species with graded roots(data in Figure 12A-12C)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Indicator | Soil depth(cm) | Serial number | Grading of root system(mm) | | | |
| I(＜2) | Ⅱ(2-4) | Ⅲ(4-6) | Ⅳ(＞6) |
| The root respiration(mg/kg·h) | 0-20 | Pa-L | 2102.22±12.93a | 1598.67±29.09a | 1566.07±30.41a | 1223.62±29.13a |
| Pa-M | 1354.22±46.64b | 1315.11±40.02b | 1266.83±9.97b | 1065.78±21.86b |
| Pa-N | 1212.44±138.8c | 1144.±30.53c | 1111.41±13.99c | 898.86±27.29c |
| 20-40 | Pa-L | 2366.22±25.87a | 2278.22±17.63a | 1749.00±19.35a | 1408.00±10.71a |
| Pa-M | 1719.67±34.98b | 1683.00±16.80b | 1549.78±39.66b | 1300.44±36.06b |
| Pa-N | 1280.89±40.02c | 1075.56±29.74c | 968.00±37.39c | 909.33±54.88c |
| 40-60 | Pa-L | 2107.13±48.15a | 1984.891±9.56a | 1334.67±81.88a | 1148.89±27.74a |
| Pa-M | 1300.4±56.38b | 1207.56±24.44b | 1102.1±21.09b | 987.56±36.85b |
| Pa-N | 1114.67±25.40c | 1036.45±43.45c | 914.22±29.5c | 815.83±50.19c |
| 0-20 | Pb-L | 1584.00±55.53a | 1544.89±25.87a | 1410.1±31.10a | 1259.5±13.70a |
| Pb-M | 1403.11±39.11b | 1378.67±38.8b | 1301.67±27.12b | 1095.11±14.98b |
| Pb-N | 1160.76±27.48c | 1068.57±29.03 | 987.56±27.17c | 834.37±24.50c |
| 20-40 | Pb-L | 1852.89±19.56a | 1760.00±33.87a | 1499.67±33.35a | 1349.33±31.36a |
| Pb-M | 1628.00±50.81b | 1427.56±46.64b | 1287.733±32.93b | 1214.4±33.25b |
| Pb-N | 1339.56±12.93c | 1256.44±42.62c | 1188.00±13.61c | 1047.85±17.30 |
| 40-60 | Pb-L | 1324.89±21.31a | 1236.89±29.74a | 1126.4±38.92a | 953.33±33.26a |
| Pb-M | 1227.11±12.93b | 1114.67±36.91b | 947.14±40.58 | 809.11±43.92b |
| Pb-N | 1056.00±22.4c | 928.89±29.73c | 829.48±26.49c | 697.48±132.63c |
| 0-20 | Pt-L | 2112.00±25.12a | 1826.00±12.7a | 1659.42±31.27a | 1478.07±37.53a |
| Pt-M | 1760.00±55.53b | 1628.00±8.47b | 1225.48±12.73b | 989.190±19.26b |
| Pt-N | 1188.00±33.87c | 1056.00±22.4c | 917.48±16.60c | 749.63±105.27c |
| 20-40 | Pt-L | 2361.33±8.47a | 2244.00±8.47a | 2009.3±18.93a | 1811.33±26.87 |
| Pt-M | 1823.56±40.02b | 1745.33±59.27b | 1549.78±29.74b | 1063.3±25.61b |
| Pt-N | 1549.78±25.87c | 1412.89±25.87c | 1357.71±20.71c | 875.11±80.74c |
| 40-60 | Pt-L | 1271.11±21.31a | 1153.78±51.04a | 1009.56±34.17a | 862.89±35a |
| Pt-M | 1065.78±29.74b | 928.89±43.45b | 865.33±52.88b | 718.67±46.69b |
| Pt-N | 938.67±25.40c | 738.22±48.15c | 689.3±49.74c | 575.26±27.74c |

**Figure S12D-12.** Root respiration of the three conifer root classes varied in the vertical direction of soil (data in Figure 12D-12F)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Indicator |  | Soil depth(cm) | | |
| Serial number | 0-20 | 20-40 | 40-60 |
| The root respiration(mg/kg·h) | Pa-L | 1542.35±54.84a | 1878.61±79.18a | 1484.83±88.83a |
| Pa-M | 1205.86±27.07b | 1517.19±43.87b | 1126.67±27.39b |
| Pa-N | 1062.00±27.49c | 1028.5±36.49c | 923.27±33.39c |
| Pt-L | 1726.72±50.86a | 2019.11±54.06a | 1028.3±39.63a |
| Pt-M | 1254.00±58.41b | 1465.85±74.74b | 859.47±40.53b |
| Pt-N | 905.67±49.54c | 1194.00±67.77c | 682.73±33.74c |
| Pb-L | 1396.83±30.73a | 1528.67±43.31a | 1102.32±37.61a |
| Pb-M | 1266.47±30.18b | 1354.83±42.48b | 971.63±32.84b |
| Pb-N | 961.89±27.29c | 1162.94±22.98c | 820.72±30.55c |