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Compatibility between *Orychophragmus violaceus* and the plant-growing concrete

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Abstract. Planting *Orychophragmus violaceus* in light-weight green concrete is feasible by drilling method. *O. violaceus* roots can fit the plant-growing concrete and surrounding perlite. Compared with *O. violaceus* roots growing in soil, the number of lateral and fibrous roots around the taproot growing in light-weight green concrete is much more. *O. violaceus* can be selected as a plant species growing in greening concrete.

Introduction

More and more concrete buildings spring up along with urbanization; cities are confronted with many problems such as lack of green area, flat colors, large energy consumption of the building, and poor quality of environment and so on. The plant-growing concrete is a new type of material, which performance is between common concrete and arable soil, it is cemented by cementitious materials incorporating into light-weight porous rock, biological organic fertilizers, and arable soil. The plant-growing concrete was characteristic with a substantial strength, relatively light weight and a "honeycomb" space, which are beneficial to the growth of plant roots and provide storage space for the nutrients of plant growth [1], it is ideal for modern green building since it is of great significance to increase green area, air purification, noise abatement, heat insulation, and urban environment improvement. The plant-growing concrete has been widely used in ecological slope protection, road and roof greening [2,3].However, the plant species, which is able to grown in the plant-growing concrete with high pH, high calcium content, low nutrient retention, less water storage, was rare [4,5].

Orychophragmus violaceus L. Schulz, belonging to *Orychophragmus* Bunge, *Brassicaceae*, *O. violaceus* is an annual or biennial wild ornamental plant. It has been one of the important source materials used for urban afforestation in many cities due to extensive adaptation, bright-colored and diversiform flowers, and lotus-type plant shape. It is often used for those lawns on which grass is difficult to plant or maintain because of the stress resistance, barren tolerance and suitable extensive management [6]. *O. violaceus* was Karst-adaptable plant, which can grow in the Karst soil environment with high pH, high calcium content, low nutrient retention, less water storage [7]. It is possible, which *O. violaceus* in the plant-growing concrete grow up [8]. This paper dealt with the compatibility between *O. violaceus*´ roots and the plant-growing concrete by planting *O. violaceus* in the concrete.

Materials and Methods

The plant-growing concrete provided by China State Construction Engineering Corporation Limited Technical. Center. Mixture ratio was as following:10L perlite, 3.5L cement, 1L ash. The forming pressure is 37.5 Nm^{-2}. The concrete had a good water permeability and water retention. Its dimensions were 150mm×200mm×55mm with 6 holes above each block. Those holes with diameter 25 mm and depth 30-40 mm was filled with perlite.

Seeds of *O. violaceus* sowed in the holes, and the seedlings of *O. violaceus* grew up in natural conditions.

Seven months later, the natural bending length of roots was measured used a rule, and the basal diameter of the plants was measured used a vernier caliper. The biomass of *O. violaceus* underground part was obtained by weighting. The taproots of 3.6, 4.2, 6.8 and 7.2 mm diameters were used for pull-out-test, respectively. Before the pull-out-test, the perlite in the planting-hole was rinse using water. However, there is still too much perlite surrounded by the roots to wash. The stronger the plant is, the more it fixed perlite. After rinsing, there is no apparent wavering of the plant. The plant-growing concrete is fixed at one end of electronic universal testing machine workbench controlled by WDW type microcomputer (accuracy of test: 0.5%, manufactured by Changchun new testing instrument limited company) and the basal stem of *O. violaceus* is clamped at the other end, and then stretch it vertically. The maximal pull-out force was recorded automatically by computer.

Results and Discussions

Growth of *O. violaceus*. After 7 months of growth, despite of high temperatures and cold winter, *O. violaceus* still grew well (Fig. 1). From the *O. violaceus* pull out, it was found that the roots clustered together in the hole and were slenderer. Moreover, lots of fibrous roots had been found, and some fibrous roots can penetrate the concrete around 2 mm. A few fibrous roots even penetrate through the concrete. Compared with *O. violaceus* growing in the soil, the plants growing in the concrete had more and slenderer fibrous roots. It concluded that the roots of *O. violaceus* growing in the plant-growing concrete suffered large resistance from the surrounding concrete.

Fig. 1 *O. violaceus* growing on the green concrete

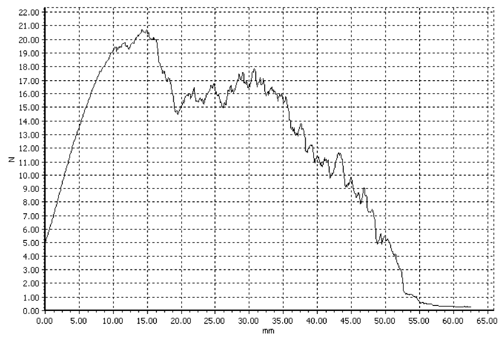

Fig. 2 Force-displacement curve from the pull-out test

O. violaceus growing in the soil had distinctly taproot. In meantime, the diameter of taproot was about 6 mm, and the taproot length reached at 22 mm. The taproot usually has 1 to 4 lateral roots with less fibrous root. The angle between lateral roots and taproot was less than 60 degrees .So was fibrous and lateral roots. *O. violaceus* growing in plant-growing concrete had lots of lateral and fibrous roots which form approximate right angles with the taproots. All roots intertwined with each other form a cylindrical shape similar to the hole, which came from the oriented-growth of roots and the resistance of the surrounding concrete. Under the influence of concrete resistance, the length of taproots was shorter than the depth of the sown-hole.

Underground biomass (g), aboveground biomass (g), diameter of taproot (cm), and length of roots (cm) of *O. violaceus* growing in the soil, were measured respectively. Correlations among underground biomass, aboveground biomass, diameter of taproot, and length of roots were shown in

Table 1. From the table 1, it was obvious that there was a positive correlation between underground biomass and aboveground biomass, or diameter of taproot, or length of roots. The aboveground biomass was more 5 times than the underground biomass.

Similarly, underground biomass, aboveground biomass, diameter of taproot, and length of roots of *O. violaceus* growing in the plant-growing concrete, were measured respectively (Table 1). The aboveground biomass of *O. violaceus* growing in the plant-growing concrete was lower than that in the soil. There was a good positive correlation between underground biomass and the diameter of taproot. The relationship between underground biomass and aboveground biomass was not significant. It was obvious that the aboveground parts *O. violaceus* growing in the plant-growing concrete decreased the growth due to the nutrient limitation. But the roots stretched well in the sown-hole of the plant-growing concrete.

Table 1 Correlations among underground biomass(UGB)(g), aboveground biomass(AGB)(g), diameter of taproot (D)(cm), and length of roots (L)(cm) of *O. violaceus* growing in the soil (n=8), and among underground biomass(UGBc)(g),, aboveground biomass(AGBc)(g), diameter of taproot(Dc)(cm), and length of roots (Lc)(cm) of *O. violaceus* growing in the plant-growing concrete (n=8)

	UGB	AGB	D		UGBc	AGBc	Dc
AGB	R=0.971 p=0.001			AGBc	R=0.630 p=0.094		
D	R=0.788 p=0.002	R=0.811 p=0.014		Dc	R=0.930 p=0.001	R=0.824 p=0.012	
L	R=0.834 p=0.010	R=0.828 p=0.011	R=0.614 p=0.105	Lc	R=-0.442 p=0.273	R=-0.142 p=0.736	R=-0.454 p=0.259

The compatibility between roots and the plant-growing concrete. The maximum pull-out forces were measured by pull-out test. The maximum forces of *O. violaceus*, whose diameter of taproot were 3.6, 4.2, 6.8 and 7.2 mm, respectively, were 17.2, 20.7，more than 47.6 and greater than 52.6 N, correspondingly. During the pull-out test, roots were not at all pulled out from the hole, initially; broken from the bottom of the roots, subsequently, pull off the surrounding roots, finally. The maximum pull-out force, which was shown in the curve of force versus displacement (Figure 2), was 20.7N. The curve of force versus displacement was a wavy, and the test force was 0 when the roots were broken completely.

During the test, the roots with the taproot of 3.6, or 4.2 mm diameter can be plugged out except the fibrous roots whose diameter was about 0.2 mm. In the same meantime, the plants with the taproot of 6.2, or 7.8 mm diameter were broken from the basal stem; the roots were not pulled out, and even not noticeably shaken. It showed a good compatibility between the roots of *O. violaceus* and the plant-growing concrete. The tensile strength of the roots-concrete complex was far greater than that of stem in *O. violaceus*.

The breakpoint of *O. violaceus* fibrous roots was the location that the roots contact to the concrete, and the concrete had not been destructed after the roots pulled off. The roots pulled out had showed that each taproot surrounded by many lateral roots with the diameter varied from 1 to 3 mm, and the lateral roots were surrounded by more fibrous roots. The diameter of fibrous roots penetrating the concrete was almost less than 0.8 mm. The roots of *O. violaceus* in the plant-growing concrete penetrated into the concrete not only from the vertical, but also from all directions, and more fibrous roots penetrated vertically into the bottom of the sown-hole. Although the tensile strength of a thin root was less than a thick root, the resultant force of a lot of thin roots was greater than that of a few thick roots. Therefore, the maximum pull-out force took place at the bottom of the sown-hole, and pulling out the same biomass of roots of *O. violaceus* growing in the concrete was more difficult than that in soil.

The roots and the plant-growing concrete composed of the roots-concrete organic complex. Similar to roots-soil organic complex, the roots-concrete organic complex undergone the mechanical, network linking, bonding and biochemical actions [9, 10]. The extrusion pressure, which generated from the roots penetration into the concrete, can be counteracted by the combination of tensile, shear, adsorption and bonding force. Therefore, the mechanical properties of the roots-concrete organic complex did not reduced despite of the penetration into the concrete by roots.

Conclusions and Prospect

Planting by drilling, *O. violaceus* roots can fit well with the plant-growing concrete and surrounding perlite. The plant-growing concrete was compatible with the roots of *O. violaceus*. *O. violaceus* can be selected as a plant species growing in greening concrete. The intact concrete after the roots pulled off can apply the circular plant. The small volume of the sown-hole in the plant-growing concrete limited the nutrient was limited, the application of fertilizer, and other measures should greatly increase the biomass of *O. violaceus*.

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