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Using polyaspartic acid hydro-gel as water retaining agent and its effect on plants under drought stress

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Abstract Polyaspartic acid (PASP) hydrogel is an important and widely applied water-retaining agent, thanks to its special space network structure which contains a carboxyl group attached on the side chain. In this study, the PASP hydrogel with high water absorption rate (300–350 g H_2O/g hydrogel) was developed and adopted to transplant *Xanthoceras sorbifolia* seedlings in the ecological restoration project of *Mount Daqing* National Nature Reserve. Transplantation experiments showed that the survival rate and leaf water content index for *X. sorbifolia* seedlings were increased by 8–12% and 4–16%, respectively. Additionally, compared with the counterpart without PASP hydrogel, the value of chlorophyll fluorescence that was considered as one of the most important indicators of plant physiology, was significantly improved with the addition of PASP hydrogel. The PASP hydrogel displays a promising future for the applications of increasing the survival rate and simultaneously alleviating the drought stress effects on the pioneer plants in arid and semi-arid areas.

1. Introduction

Over the past decades, accompanied by climatic change and human activities, land degradation of the biological resources and destruction of the ecological balance become more serious every day, resulting in desertification and making the soil unsuitable for plant growth (Evans and Geerken, 2004). Especially, desertification is regarded as one of the most severe ecological environment problems in the world (Xu et al., 2009; Ashraf et al., 2012). Over 2/3 of the countries and regions have suffered the damage of desertification to a certain extent, and 1/4 of the land area is under the threat of desertification. Ecological restoration is another feasible approach to prevent and cure desertification compared with other methods like mechanical or chemical dune fixation (Wang et al., 2004) and biological soil crusts (Zheng et al., 2011; Xu et al., 2013; Ashraf et al., 2013). It can effectively reduce the desertification by growing plants that possess desert adaptation properties, which gradually improve the micro climate. Actually, the versatile characteristics of non-toxicity and high water adsorption rate of PASP hydrogel indeed lead to its wide applications as a water-retaining agent for the ecological restoration in the desert area. The plants grown in the desert area need to at least

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endure the drought. Previously, it has been reported that the addition of the water-retaining agents such as poly-acrylic acid salt, denatured starch (Bai et al., 2011; Hirotama et al., 2008) and cyanobacterial polysaccharides (Xu et al., 2013; Ashraf et al., 2015) could alleviate drought stress. However, apart from the water-retaining benefits, the reduced effect for the degradation products of the utilized chemicals on the environment and plant growth is also a critical issue (Prayogo et al., 2014). For instance, degradation of poly-acrylic acid in the natural environment is so difficult that a considerable environmental risk would appear with the large-scale application of poly-acrylic acid salt (Dumas et al., 1985; Serrano et al., 2015). For denatured starch, a large quantity of denatured starch is necessary to maintain the water retention effect due to its low water absorption rate. Therefore, the performance of a certain water-retaining agent should normally involve in the biodegradability, compatibility, and water adsorption as evaluation factors.

Polyaspartic acid (PASP), a macromolecular amino acid polymer taking aspartic acid as monomer, which is found naturally in many kinds of mollusks in vivo, possesses great biodegradability and biological compatibility. The PASP hydrogel was produced by crosslinking the hydrophobic PASP backbones. The PASP hydrogel has a much higher water adsorption capacity because of (I) the large number of carboxyl groups attaching on the PASP side chain that can bind water molecules, and (II) the space structure of PASP hydrogel that has the ability to absorb the free water in the environment (Qureshi et al., 2015).

In this study, we synthesized the PASP hydrogel using the purpose-designed pilot reactor. The fabricated PASP hydrogel was subsequently adopted as the water retaining agent on planting the pioneer plant – *Xanthoceras sorbifolia*, at the *nine peak* of *Mount Daqing* National Nature Reserve that has a Semi-arid climate.

It is worth mentioning that although there are extensive and in-depth studies on the level of laboratory research related to PASP hydrogel (Tan et al., 2002), the pilot reactor and large-scale applications of the PASP hydro-gel are still scarce so far. In this work, we designed the production on the basis of the synthetic route. The PASP hydrogel was synthesized by two steps: Firstly, polysuccinimide was hydrolyzed by the "solid phase synthesis" method. Secondly, the hydrolyzed polysuccinimide was cross-linked by glycol dimethyl glycidol ether (Lu et al., 2016). Similar reaction scheme is provided in Meng et al. (2015).

In order to evaluate the effect of the PASP hydrogel, the *nine peak* of *Mount Daqing* National Nature Reserve in China was selected as the experimental base. The average annual temperature is around 7.5 °C. The frost free period is about 117 days, and sunshine time is 3095 h. The annual precipitation and evaporation is 400 mm and 1300 mm, respectively. In addition, this selected area belongs to the semi-arid continental climate such that the plants in this area are largely under drought stress. The native species *X. sorbifolia* in the base was selected as the pioneer plant for environmental restoration, and the PASP hydrogel was chosen to promote the plant growth. Three methods were used for seedling transplantation: the field seeding seedlings which are less than one year old, the slope transplantation seedlings which are less than one year old and the slope transplantation for the annual seedlings. About 15,000 seedlings were transplanted in 30 hectares, which contains transplants with and without the PASP hydrogel (Tabassum et al., 2014).

Finally, we measured the growth index of seedlings by statistical methods. The physiological index of seedlings by chlorophyll fluorescence instrument was also determined. Effects of the PASP hydrogel used as a water-retaining agent in ecological restoration were finally illustrated.

2. Materials and methods

2.1. Materials

PASP hydrogel was produced by polysuccinimide, which has a water absorption rate about 300–400 g/g (the weight of water absorbed per gram of PASP hydrogel). Two kinds of *X. sorbifolia* seedlings were cultivated by Goldenrace Co.. The height of the seedlings *less than one year old* was around 15 cm, and the corresponding height for the *annual seedling* was about 150 cm. A FluorPen FP 100 hand-held chlorophyll fluorescence instrument, and Photon Systems Instruments, Czechia, were used to collect the data.

2.2. Toxicity determination of cross-linker on plant growth

The toxicity determination was based on China national standards (GB/T3543.4-1995, 1995), with toxicity of the rape seeds as the reference standard. The experimental plants and the rape seeds were firstly immersed in cross-linking agent for 24 h respectively, then cultivated at 25 °C for 7 days. The statistical germination rate was finally obtained (Safi et al., 2015).

2.3. Application of PASP hydrogel as water-retaining agent

For field seeding of *X. sorbifolia* seedlings less than one year old a smooth zone in the mountain valley was selected. A trench was plowed 15–20 cm deep and the PASP hydrogel was applied at 250 g/m. The seedlings were transplanted, backfilled, and compacted at 10-cm intervals.

The slope transplanting seedlings less than one year old are annual seedlings: a hole was dug at about 30 cm in diameter and depth, and the PASP hydrogel was applied at 25 g/hole. The *X. sorbifolia* seedlings were transplanted, and then backfilled and compacted with soil. The plant density is about 750–1200 trees/hectare.

2.4. Determination the growth index of X. sorbifolia seedlings

The survival rate is calculated as Formula (1)

$$M = \frac{M_s}{M_t} \tag{1}$$

where M_t and M_s are the total number and survival number of the cultivated seedlings, respectively.

Leaf relative water content (RWC) was estimated by the weight ratio of the current water content of the sampled leaves tissue relative to the maximal water content they can hold at full turgidity. Firstly, about 10–20 leaves were selected randomly. Dried leaf surface weight was regarded as M_1.

Then these leaves were immersed into distilled water for 8 h in order to reach the water saturated state. The water saturated