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Differentially improved soil microenvironment and seedling growth of *Amorpha fruticosa* by plastic, sand and straw mulching in a saline wasteland in northwest China

Tao Liu[a], Baitian Wang[a,b], Huijie Xiao[a,b,*], Ruoshui Wang[a,b,*], Benman Yang[a], Qiqi Cao[a], Yuanbo Cao[c]

[a] School of Soil and Water Conservation, Beijing Forestry University, Beijing, China
[b] Key Laboratory of Soil and Water Conservation & Desertification Combating, Ministry of Education, Beijing Forestry University, Beijing, China
[c] National Hulunber Grassland Ecosystem Observation and Research Station, Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing, China

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ABSTRACT

Amorpha fruticosa is often used to revegetate saline wasteland in the YinNan Irrigation Area, northwest China. However, the survival rate of transplanted *A. fruticosa* seedlings is constrained by its low tolerance to high soil salinity, drought, and low soil temperatures (T_{soil}) at the early transplanting stage. This study aimed to evaluate the effects of three different mulches, including plastic mulch (PM), sand mulch (SM) and rice straw mulch (RSM), and control (CK) on the soil microenvironment and *A. fruticosa* seedling growth. The results indicated that PM (19.1–26.2 °C), followed by SM (18.6–26.1 °C), provided the highest T_{soil} at 0–20 cm depth during the whole growing period, while RSM (16.5–21.5 °C) exhibited lower T_{soil} than CK (15.8–22.0 °C) at all time except the later growing stage. RSM (7.1%–26.4%) retained soil water most effectively as compared to CK, followed by SM (3.2%–22.5%), and then PM (-0.6%–19.7%). PM (11.4%–18.5%) had the best performance in reduction of EC_e at 0–80 cm depth, followed by RSM (10.5%–15.5%), and then SM (3.7%–7.4%). Still, PM exhibited the greatest improvement in soil structure. *A. fruticosa* seedlings grown in PM achieved the best stand establishment and growth characteristics, in which its root reached to 40–60 cm depth, while the counterparts in RSM showed the poorest performance in three mulching treatments. The results above suggest that PM is a promising strategy to promote the growth of transplanted halophytes in saline wasteland of the YinNan Irrigation Area and other areas with similar ecologies.

1. Introduction

The Yinchuan Plain, as one of the most productive agriculture areas in China (Zhou et al., 2013), consists of the TaoLe, HeDong, YinBei, and YinNan Irrigation Areas (Fig. 1a). The area of saline wasteland in the Yinchuan Plain is increasing because of poor irrigation management, the high evaporation rate (1825 mm/year), limited precipitation (185 mm/year), and the shallow groundwater table (-1 to -4 m) (Zhou et al., 2013). Recently, the area of salt-affected wasteland in the plain reached 55,667 hm^2 (He et al., 2010). This large area seriously affects the ecological security of the local environment. Therefore, revegetation of the saline wasteland is vital for the sustainable development of agriculture in this semiarid region. *Amorpha fruticosa* is one of the most important halophytes for revegetation of salt-affected wasteland because of its strong adaptability to harsh environments and its ability to restore soil physicochemical properties (Wei et al., 2016). Nevertheless, the salt tolerance of *A. fruticosa* varies with its growth and development. It is more sensitive to salinity at its early transplanting stage (i.e. recovering stage) when suddenly subjected to osmotic effects, ion toxicity (Na^+, Cl^-), and nutrient imbalances than at other growth stages (Läuchli and Grattan, 2007). Accumulated salts in the root zone cause growth retardation at the seedling stage. In addition, *A. fruticosa* is often exposed to low soil temperature (T_{soil}), low soil moisture, and strong wind (Table 2: mean wind/gust speed in May, 1.4–9.6 m/s) during the early transplanting period. Low T_{soil} combined with soil salinity can further affect normal root development, induce cell damage, and even decrease the stand establishment of *A. fruticosa*.

In recent decades, various studies have tested different practices to

* Corresponding authors at: School of Soil and Water Conservation, Beijing Forestry University, Qinghua East Road 35, Beijing 100083, China.
E-mail addresses: lukeinbeijing@bjfu.edu.cn (T. Liu), wbaitian@bjfu.edu.cn (B. Wang), soilandwater2006@hotmail.com (H. Xiao), wrsily_2002@163.com (R. Wang), yangbenman@bjfu.edu.cn (B. Yang), caoyuanbo@caas.cn (Y. Cao).

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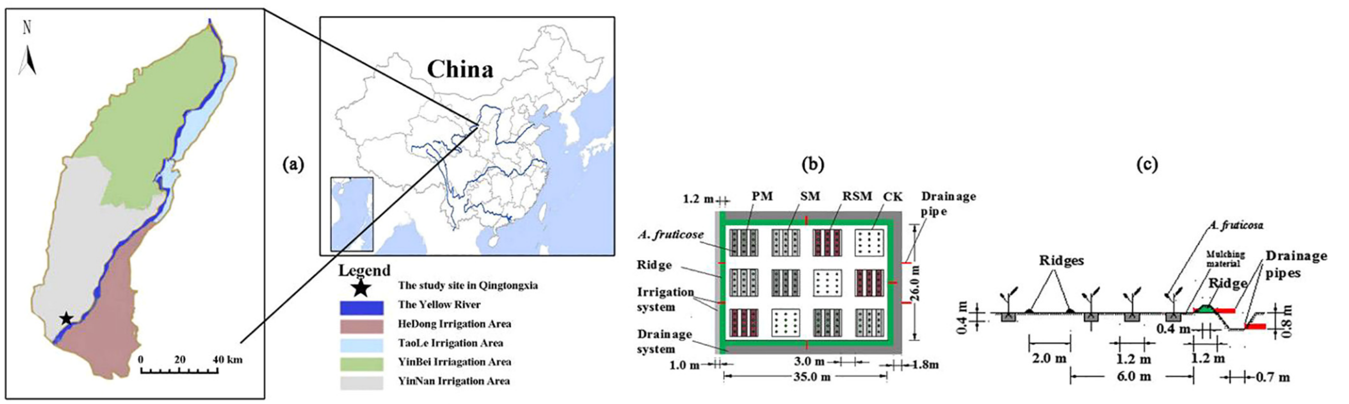

Fig. 1. Location of experimental site in Qingtongxia, northwest China (a), plus the horizontal (b) and vertical (c) designs of study treatments. PM: plastic mulching; SM: sand mulching; RSM: rice straw mulching; CK: control.

increase the survival and growth of transplanted seedlings in saline wastelands (Dan et al., 1994; Li et al., 2015). Among these practices, irrigation with fresh water pumped from the Yellow River was one of the most available countermeasures to reduce salinity in the root zone (Feng et al., 2005; Li et al., 2016). However, this practice had to be carefully integrated with adequate drainage to avoid raising the depth of the groundwater table (Houk et al., 2006). In addition, the water from the Yellow River was polluted and sometimes in short supply, and salts were more likely to re-accumulate on bare soil because of the high evaporation in this region. As a promising strategy, mulching provides various benefits to manage the harsh soil environment (Dong et al., 2009; Fernández and Vega, 2016). Compared with bare soil, which is exposed to heat, wind, and compacting forces, mulched soil was shown to retain more moisture because of reduced evaporation. Especially in saline soil, mulches could reduce the effects of salt stress on plant seedlings with low salinity tolerance or seedlings at transplanting survival stage (Sedaghati et al., 2016). Mulches can also help maintain optimal soil temperatures for seedling development (Wang et al., 2017). Such conditions can improve root establishment, transplanted seedling survival, and plant growth (Sun et al., 1994). Hence, a suitable combination of flood irrigation and mulching may give better seedling establishment and later growth than individual use of irrigation or normal mulching (Dong et al., 2010).

Previous studies on mulches have focused mainly on economic crops such as cotton, maize, wheat, soybean, and potato. Currently, some of the most common types of mulching materials are straw (rice, wheat, and maize), plastic film, and sand. However, the effects of mulching materials on the soil microenvironment and plant growth are poorly understood. Little field work has been undertaken in the Yinchuan Plain, particularly in the YinNan Irrigation Area. The secondary salinized land in this area represents a special hydrological, geographical, and soil environment. It is of the importance to evaluate different mulching materials' performance to optimize the revegetation of saline wastelands in this region. The objectives of this 1-year experiment were as follows: to determine the effects of three different mulches on the soil microenvironment, the stand establishment and growth of *A. fruticosa*; and to select the best mulching practice for *A. fruticosa* seedlings to successfully revegetate the saline wasteland in the YinNan Irrigation Area.

2. Materials and methods

2.1. Study site and climate

The experiment was carried out from April to October in 2016 at the Shuxin Forestry Station (Fig. 1a, 38°1′ N, 105°56′ E, ca. 1139.8 m a.s.l.) in Qingtongxia, YinNan Irrigation Area, northwest China. The site has a typical arid inland climate with average annual rainfall of 175.9 mm, about 60.8% of which falls between June and August. The mean annual evaporation is approximately 1864.5 mm, more than 10 times annual precipitation. The average annual temperature is approximately 9.2 °C with extreme winter and summer temperatures of −25.0 and 37.7 °C, respectively. The mean annual wind speed is 2.6 m/s and the maximum wind speed is 26 m/s. The groundwater table at the site ranged from −0.9 to −2.1 m, with salts concentration ranging from 1.4 to 15.0 g/L. The soil texture is clay with moderate salinization. Table 1 summarizes the main properties of soils at the site.

2.2. Experimental design

We used three mulching materials commonly used by local farmers; plastic mulch (PM, 0.08 mm thick), rice straw mulch (RSM, 4 cm thick), and sand mulch (SM, 4 cm thick). These mulches were fully covered to 1-year-old *A. fruticosa* seedlings in plots from May to October in 2016. The *A. fruticosa* seedlings once were raised in the nursery garden. The transplanted seedlings had a mean ground diameter of 1.08 cm and were cut to 1.0 m in height. Before transplanting, red paint was brushed on the top end of trunks to reduce invalid transpiration. The treatments were designed as 6 m × 6 m plots with 3 m spacing between plots. All treatments were arranged in a completely randomized block design with three replicates. Each plot contained 12 manually transplanted *A. fruticosa* seedlings. The planting density was 2.0 m × 1.3 m (12

Table 1
Basic properties of soils at experimental site.

Depth/cm	Soil texture in % (USDA)			Soil texture	Bulk density/(g/cm^3)	EC$_e$/(dS/m)	pH$_e$	SAR$_e$/(mmol$_c$/L)$^{0.5}$
	Clay	Silt	Sand					
0–20	0.80	30.48	68.72	SL	1.70	7.40	8.46	7.19
20–40	0.88	37.29	61.82	SL	1.72	7.09	8.54	7.20
40–60	2.83	35.77	61.40	SL	1.72	7.18	8.41	7.19
60–80	1.84	30.48	67.68	SL	1.64	7.27	8.42	7.19

Note: SL = sandy loam.