For Res (2006) 11:319-328
DOT 10.1007/s10310-006-0214-y

ORIGINAL ARTICLE

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Effects of drought stresses induced by polyethylene glycol on germination of *Pinus sylvestris* var. *mongolica* seeds from natural and plantation forests on sandy land

Received: June 7. 2005 / Accepted: April 10, 2006

Abstract Effects of drought stresses induced by polyethylene glycol (PEG) (0.0%, 10%, 15%, 20%, 25%, and 30%, with four replicates) on germination of Mongolian pine *(Pinus sylvestris* var. *mongolica)* seeds produced in plantations (southern Keerqin sandy land) and natural forests (Hulunbeier sandy plain) were observed. The results indicated that the seeds from both provenances did not germinate when PEG concentration was more than 25%. The time of initial germination and that of its completion of stressed seeds from both provenances were delayed when compared with the unstressed seeds. The germination capacity and germination rate of natural seeds were significantly higher than those of plantation seeds for all treatment levels ($P < 0.05$). The mean growth rates of radicle and hypocotyl from natural seeds were significantly higher than those from plantation seeds at all treatment levels below 20% PEG treatment ($P < 0.05$). The ratios of radicle to hypocotyl of 20% PEG treatment were significant higher than those of the corresponding controls for both provenances ($P < 0.05$). These results suggested that Mongolian pine seeds/seedlings had stronger resistance to PEG drought stresses: 10% PGE stress did not significantly influence germination. Natural seeds exhibited more resistance to PEG stress than plantation seeds. It was concluded that drought stress on seed germination might he one cause of obstructed natural regeneration of Mongolian pine plantations on sandy land. It is recommended that natural seeds he used for afforestation. and light drought stress (e.g., 10% PEG stress) may be useful in improving seed germination and the growth of radicles and hvpocotyls.

Key words Water stress • Sandy land • *Pinus sylvestris* var. *mongolica* seed • Germination • Provenance

Introduction

Mongolian pine *(Pinus sylvestris* var. *mongolica),* a geographical variety species of Scots pine *(Pinus sylvestris),* is naturally distributed in Honghuaerji, on the Hulunbeier sandy plain of China (47°35'-48°36' N, 118°58'-120°32' E), and is an important tree species of afforestation in the "three north" areas of China (the north, northeast, and northwest of China), especially in sandy areas (Zheng 1983; Jiao 1989; Wang and Huang 1996; Zhu et al. 2003a; Kang et al. 2004). After successful introduction of the tree species on sandy land in the 1950s, the area of Mongolian pine plantation forests on sandy land reached more than 30000 ha in northern China (Kang et al. 2004). However, there have been many problems such as withered top, low growth rate, and no regeneration from the earliest Mongolian pine plantations on sandy land. These problems have been considered as decline of the plantations (Chang and Zhao 1990; Jiao 2001; Liu et al. 2002; Zeng et al. 2002a; Zhu et al. 2003a). There have been many assumptions introduced to explain the causes of the decline (Jiao 1989, 2001; Zeng et al. 1996; Wang et al. 1999; Liu et al. 2002; Zhu et al. 2005), but until now no specific theories could successfully

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