Factors Affecting Tausch's Goatgrass (*Aegilops tauschii* Coss.) Seed Germination and Seedling Emergence

Feng Fang
Institute of Plant Protection, Chinese Academy of Agricultural Sciences
Key Laboratory of Weed and Rodent Biology and Management, CAAS
No.2 West Yuanmingyuan Road, Haidian, Beijing 100193, China
Tel: 86-10-6281-0289 E-mail: weedfang@163.com

Chaoxian Zhang (Corresponding author)
Institute of Plant Protection, Chinese Academy of Agricultural Sciences
Key Laboratory of Weed and Rodent Biology and Management, CAAS
No.2 West Yuanmingyuan Road, Haidian, Beijing 100193, China
Tel: 86-10-6281-0289 E-mail: cxzhang@wssc.org.cn

Shouhui Wei, Hongjuan Huang & Weiwei Liu
Institute of Plant Protection, Chinese Academy of Agricultural Sciences
Key Laboratory of Weed and Rodent Biology and Management, CAAS
No.2 West Yuanmingyuan Road, Haidian, Beijing 100193, China

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Abstract

Tausch's goatgrass, *Aegilops tauschii* (Coss.) is one of the most troublesome weeds in winter wheat (*Triticum aestivum* L.) producing areas of Yellow River valley of China. The effects of environmental factors affecting seed germination and seedling emergence were evaluated in laboratory and greenhouse experiments. The germination of Tausch's goatgrass seeds occurred at temperatures ranging from 0 to 40℃, with optimum germination attained between 15 and 25℃. Tausch's goatgrass seed is rather tolerant to low water potential and high salinity stress as germination was 70% and 65% at osmotic potentials of -1.7 MPa and salinity level of 400 mM, respectively. Medium pH and light have no significant effect on seed germination. Highest emergence (>80%) occurred from depths of 1 to 3cm, but no seedlings emerged when burial depth reached 8cm. Knowledge of germination biology of Tausch's goatgrass obtained in this study will be useful in predicting the potential distribution area and developing effective management strategies for this species.

Keywords: Temperature, Light, pH, Osmotic potential, Salinity stress, Burial depth

Nomenclature: Tausch's goatgrass, *Aegilops tauschii* Coss.

1. Introduction

Tausch's goatgrass, *Aegilops tauschii* Coss. (Poaceae) is one of the most economically important grass weeds in winter wheat-producing areas of the Yellow River valley of China. Tausch's goatgrass is native to temperate Asia, tropical Asia and Europe (USDA 2010). In recent years, Tausch's goatgrass infested about 330,000 ha of winter wheat in Hebei, Shanxi, Shaanxi, Shandong, Henan, Chongqing, Inner Mongolia and Jiangsu Provinces of China, and what more, the lack of adequate control measures, rapid spreading, increased damage made the grass a serious species in winter wheat producing regions (Zhang *et al*., 2007). Jointed goatgrass (*Aegilops cylindrica* Host) and winter wheat are genetically similar and have parallel growth habits. Tausch's goatgrass is prevalent in China, while jointed goatgrass is found in the United States.

It was not until 1984 when Yen et al. reported that Yili river valley in Xinjiang of China may have a natural distribution of Tausch's goatgrass. In China, Tausch's goatgrass was considered as an invasive species (Wei *et al*., 2008; Wei *et al*., 2007; Su *et al*., 2010).

Several environmental factors were known to affect weed seed germination. The optimum temperature, light, and pH conditions vary considerably depending on the species (Egley and Duke 1985; Taylorson 1987). Weed seedling could emerge from a wide range (0 to 15cm) of soil depths (Balyan and Bhan 1986; Singh and Achhireddy 1984). However, there is little published information on seed germination and seedling establishment of Tausch's goatgrass. A better understanding of seed germination and seedling emergence of Tausch's goatgrass would be helpful in predicting its potential spreading into new areas and its damage, could be useful in developing effective control measures. The objective of this study is to determine the effect of light, temperature, pH, burial depth, osmotic stress, and salt stress on Tausch's goatgrass seed germination and seedling emergence.

2. Materials and methods

2.1 Seed source

Mature spikelets of Tausch's goatgrass population were collected in June 2008 from a winter wheat field in Yongnian of Hebei Province (36°45′ N, 114°29′ E), China. Spikes were clipped from the dry plants and were placed in paper bags until the experiment was conducted in 2010. In the laboratory, spikes were broken apart, spikelets were cleaned by hand, and subsamples were stored dry at 25±2℃.

2.2 General germination test

Germination tests were conducted by evenly placing 25 seeds in a 9-cm-diameter Petri dish containing two layers of Whatman No. 1 filter paper moistened with 5 ml distilled water or treatment solution. All dishes were sealed with flexible, self-sealing film to reduce water loss and placed in an incubator set at 20℃, with 14-h photoperiod of 320 μmol $m^{-2}s^{-1}$. To maintain water saturation of the filter paper water was added as necessary. Germination was checked daily after sowing till fortnight. Seeds with 3-mm emerged radicles were considered as germinated. Seed viability of Tausch's goatgrass was 99%, measured by the tetrazolium chloride test (data not shown) (ISTA 1985).

2.3 Effect of temperature

Ten temperature regimes, 0, 5, 10, 15, 20, 25, 30, 35, 40 and 45℃, were employed to determine the optimum temperature for seed germination. Viable seeds were tested and germination was counted as described in 2.2 for 30 d, with various temperature set.

2.4 Effect of light

Petri dishes containing seeds were placed in incubators set at 20℃ for 7 days with 0/24, 4/20, 8/16, 10/14, 12/12, 14/10, 16/8, 20/4, and 24/0 h light/dark regimes per 24-h cycle to study the light effect on germination. Darkness treatments were achieved by wrapping the Petri dishes with double layers of aluminum foil, other treatments were left to receive light exposure (320 μmol m^{-2} s^{-1}).

2.5 Effect of pH

The effect of pH on germination was studied using buffer solutions with pH values ranging from 3.0 to 10.0 prepared as described by Chachalis and Reddy (2000). A 2-mM potassium hydrogen phthalate buffer solution was adjusted to pH 3.0 or 4.0 with 1N HCl. A 2-mM solution of MES [2-(N-morpholino) ethanesulfonic acid] was adjusted to pH 5.0 or 6.0 with 1 N NaOH. A 2-mM solution of HEPES [N-(2-hydroxymethyl) piperazine-N-(2-ethanesulfonic acid)] was adjusted to pH 7.0 or 8.0 with 1 N NaOH. A pH 9.0 or 10.0 buffer was prepared with 2-mM tricine [N-tris (hydroxymethyl) methylglycine] and adjusted with 1 N NaOH. Distilled water (pH 6.8) was used as the control. The seeds were incubated at 20℃ for 7 days with a 14-h photoperiod as described in the general germination test.

2.6 Effect of osmotic and salt stress

Aqueous solutions with osmotic potential of 0, -0.1, -0.3, -0.5, -0.7, -0.9, -1.1, -1.3, -1.5, and -1.7 MPa were prepared by dissolving 0, 72.5, 143.2, 192.6, 233.0, 268, 299.3, 327.9, 354.4, and 379.1g polyethylene glycol 6000 in 1L of distilled water, respectively (Michel and Kaufamann 1973). Salinity stress on seed germination was evaluated by placing the seeds in Petri dishes containing different concentrations (0, 20, 40, 80, 120, 160, 200, 240, 280, 320, 360, and 400 mM) of sodium chloride solutions. All sealed Petri dishes were kept in incubators set at 20℃ for 7 days with a 14-h photoperiod.

2.7 Effect of burial depth

Each twenty-five seeds of Tausch's goatgrass were placed on or buried in soil in 15-cm-diam, 14-cm-height plastic pots at depths of 0, 1, 3, 5, 7, 9, 11, and 13 cm to assess the effect of burial depth on seedling emergence. The soil used was a sandy clay loam with a pH of 7.4 and 1.8% organic matter. Greenhouse temperatures were 20±2℃ with a 14-h photoperiod (300 to 450 μmol m^{-2} s^{-1}). The pots were watered regularly (every 3 days). Emergence was considered when the coleoptiles were visible from the soil surface, and emerged seedlings were counted 30 d after placing.

2.8 Statistical analysis

All experiments were conducted two times using a completely randomized design with four replicates. There were no run by treatment interactions; therefore, data were pooled over runs for analysis. Seed germination was evaluated by cumulative germination percentage in 14 or 30d. Germination speed was expressed as the percentage of seeds germinated in the first 7 days. Germination index was calculated using $GI=\Sigma G_t/D_t$, where G_t is the percentage of seeds germinated for a certain day, and D_t is the number of days after seed treatment. Data were subjected to one-way analysis of variance (ANOVA) with SPSS software to evaluate the effects of set factors. Regression analysis was used to determine the effect of salinity, and osmotic potential on germination and burial depth on seedling emergence.

3. Results and discussion

3.1 Temperature

With a 14-h photoperiod, Tausch's goatgrass seed germinated from a wide range of temperature (5-35℃), the optimum temperature were between 15 to 25℃, with 92% – 97% germination (Figure 1). A marked decrease in germination occurred when temperature was lower than 10℃, or higher than 30℃, with about 15% germination after 30 d. The optimum temperatures for Tausch's goatgrass germination are similar to those reported for jointed goatgrass (Lynn *et al*., 2005; Larry *et al*., 1982).

Germination speed of Tausch's goatgrass seeds was accelerated when temperature increased from 5 to 20℃ (Figure 2). Germination index were 16, 28, 45, and 65 at constant temperatures of 15, 25, 30, and 35℃, respectively. Compared to the constant temperature, alternating temperatures did not significantly improve the germination of Tausch's goatgrass seeds. There was no significant difference ($P>0.05$) between germination at 25℃ and 30/20℃, 20℃ and 25/15℃, or 15℃ and 20/10℃ in darkness. These results indicated that Tausch's goatgrass seed germination was more related to the cumulative temperature.

3.2 Light

Tausch's goatgrass seeds germinated well under both darkness (94%) and 14-h photoperiod (98%) conditions. There was no significant difference in other regimes. Response of germination to light varied from species to species (Crisraudo *et al*., 2007; Gallagher and Cardina 1998). Seeds of some species required light to stimulate their germination (Chauhan and Johnson 2009; Chauhan and Johnson 2008b; Chauhan *et al*., 2006), but others germinated equally well in light and dark (Chauhan and Johnson 2008a; Teuton *et al*., 2004). Lynn. (2006) reported the secondary seed within jointed goatgrass dormant spikelets depended on incubation temperature and dark/light conditions. Photoperiod did not affect germination at low temperatures. Seeds germinated mostly when exposed to warm temperatures, and light only increased 6% of seed germination.

3.3 pH

Tausch's goatgrass seed germination was greater than 92% over a pH range of 3.0 to 10.0 (Figure 3). It is documented that, seed of African mustard (*Brassica tournefortii*) and American sloughgrass [*Beckmannia syzigachne* (Steud.) Fernald.] germinated in a wide range of pH (Chauhan *et al*., 2006a; Rao *et al*., 2008). In contrast, poor germination occurred at extreme pH values in trumpetcreeper (*Campis radicans* (L.) Seem. ex Bureau; Chachalis and Reddy 2000). High seed germination of Tausch's goatgrass over a broad pH range indicated that it would be able to adapt to a wide range of soil conditions. This characteristic is common for invasive weed species and will aid Tausch's goatgrass in colonizing diverse habitats (Wang *et al*., 2009).

3.4 Osmotic potential

Tausch's goatgrass germination was 98, 96, and 70% at osmotic potentials of 0, -0.7, and -1.7 MPa, respectively (Figure 4). These indicated that Tausch's goatgrass seed was rather tolerant to low water potential. Similar findings were reported for hairy nightshade (Zhou *et al*., 2005), Venice mallow (Chachalis *et al*., 2008), and honeyvine milkweed [*Ampelamus albidus* (Nutt.) Britt.; Soteres and Murray 1981]. In contrast, other weed species were very sensitive to low osmotic potential, such as trumpetcreeper (*Campsis radicans* (L.) *Seem. ex Bureau*.; Chachalis and Reddy 2000), Texasweed [*Caperonia palustris* (L.) St. Hil.; Koger *et al*., 2004], American sloughgrass (Rao *et al*., 2008), and cadillo (Wang *et al*., 2009). These data suggested that Tausch's goatgrass germination and establishment remain good in poorly drained or fairly dry soil conditions and may have a competitive advantage over other weed species under water stress conditions.

3.5 Salt Stress

Germination of Tausch's goatgrass seeds inversely related to NaCl concentration (Figure 5). Germination was greater than 90% at less than 120mM NaCl, and decreased to 80% at 160mM. Even at high salinity levels of 400mM, 65% of seeds germinated. These data suggest that Tausch's goatgrass seeds were fairly tolerant to salt stress in the soil. Similar results have been reported for trumpetcreeper (Chachalis and Reddy 2000), eggplant (*Solanum melongena* L.; Akinci *et al*., 2004), American sloughgrass (Rao *et al*., 2008) and buffalobur (Wei *et al*., 2009). These data suggest that even at high soil salinity, a proportion of Tausch's goatgrass seeds may germinate.

3.6 Effect of burial depth on seedling emergence

Seedling emergence of Tausch's goatgrass was influenced by seed burial depth (Figure 6). Seed germination on the soil surface was 71%. The highest emergence (>80%) occurred from the depth of 1 – 3 cm, and emergence rate declined when seeds were buried deeper than 3 cm. No seedlings emerged from 8 cm deeper soil. Hill (1976) reported similar findings in the jointed goatgrass, although he found emergence from 8 cm. The seed on the soil surface germinated at a lower percentage than those at depths of 1 – 3cm. Morrow (1982) reported that the highest germination was found when jointed goatgrass seed were placed on the soil surface at 20℃, but no seedlings emerged from below 5 cm in greenhouse and 6 cm in laboratory studies. These plants apparently exhausted their endosperm food reserve before they could emerge from the soil.

Temperature and depth appeared to be the major controlling factors affecting Tausch's goatgrass seed germination and emergence. Higher seedling emergence was found for the seeds placed on the soil surface or for those buried 1 – 3 cm deep in soil, and no seedlings emerged when burial depth exceeded 8 cm. Tausch's goatgrass seed was rather tolerant to low osmotic potential and high salinity stress, and capable of germinating over a broad range of pH level. These results indicate that the grass could adapt to a wide range of habitats and soil conditions, the capability of wide distribution, and explain why the grass become established over the Yellow River Basin of the China. Observations in winter wheat-growing areas also indicate that Tausch's goatgrass may be a greater problem when conservation tillage systems are being practiced. The incidence of Tausch's goatgrass occurrence in China is similar to the jointed goatgrass in the United States.

Knowledge of germination biology of Tausch's goatgrass from this study could be used to predict its potential distribution in China and will aid development of effective management strategies for the species control. We recognize that ecotypes of weed species can vary in dormancy characteristics and germination behavior thus conclusions drawn from our experiments are most relevant to the Tausch's goatgrass population tested. A better understanding of weed seed germination might be further improved by studying populations gathered from fields across wider geographical regions (Chachalis *et al*., 2008).

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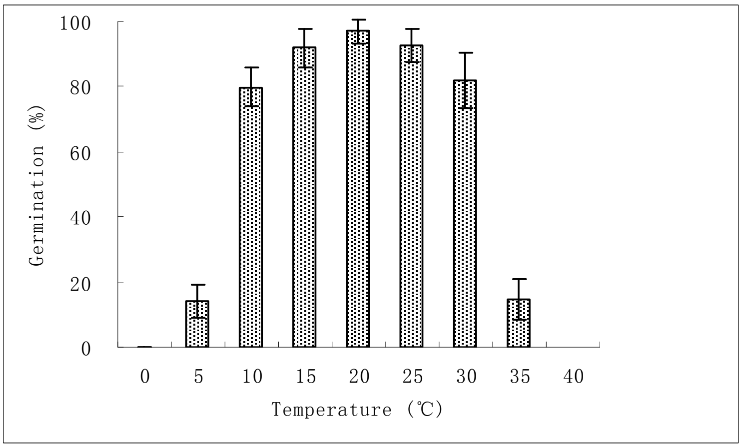

Figure 1. Effect of temperature on germination of Tausch's goatgrass seed incubated in a 14-h photoperiod with a photosynthetic photon flux density of 320 μmol m^{-2} s^{-1} for 30d. Vertical bars represent standard errors of the means

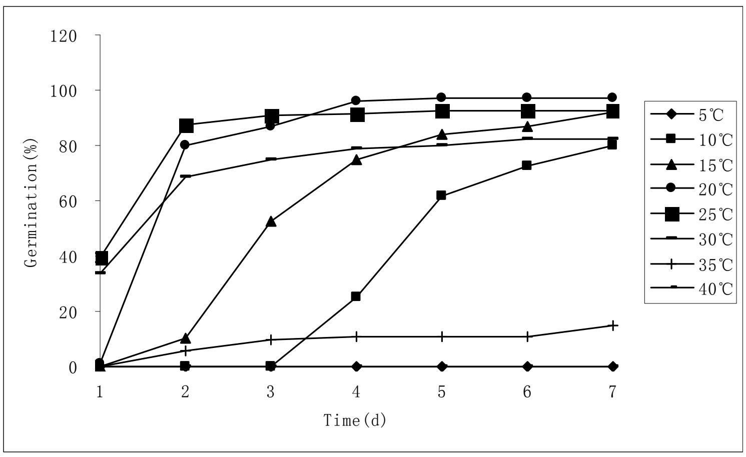

Figure 2. Effect of temperature on germination speed of Tausch's goatgrass seed incubated at 20℃ with a photosynthetic photon flux density of 320 μmol m^{-2} s^{-1} for 7d

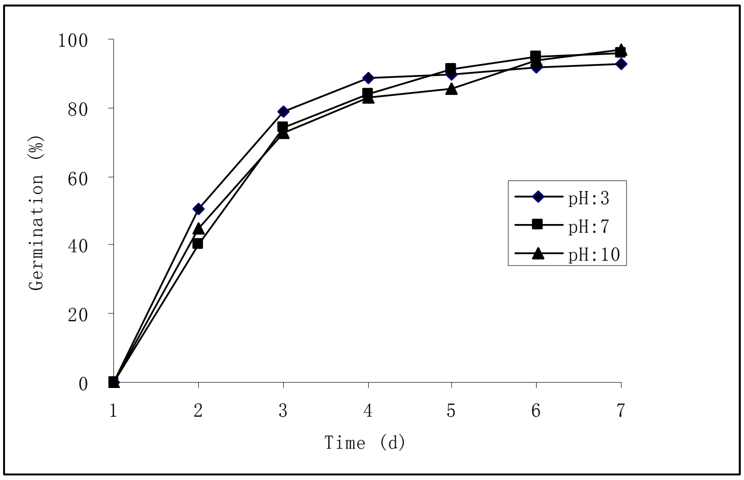

Figure 3. Effect of pH on emergence of Tausch's goatgrass seeds incubated under 14-h photoperiod with a photosynthetic photon flux density of 320μmol m^{-2} $s^{-1}$for 7d

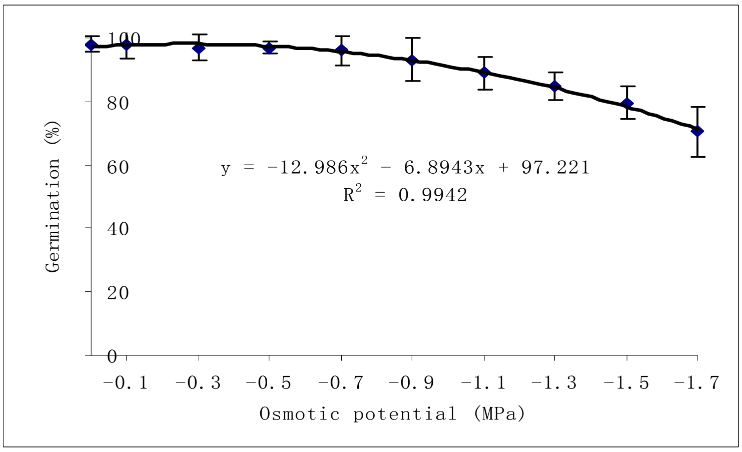

Figure 4. Effect of osmotic potential on germination of Tausch's goatgrass seeds incubated under 14-h photoperiod with a photosynthetic photon flux density of 320μmol m^{-2} $s^{-1}$for 7d. Vertical bars represent standard errors of the means

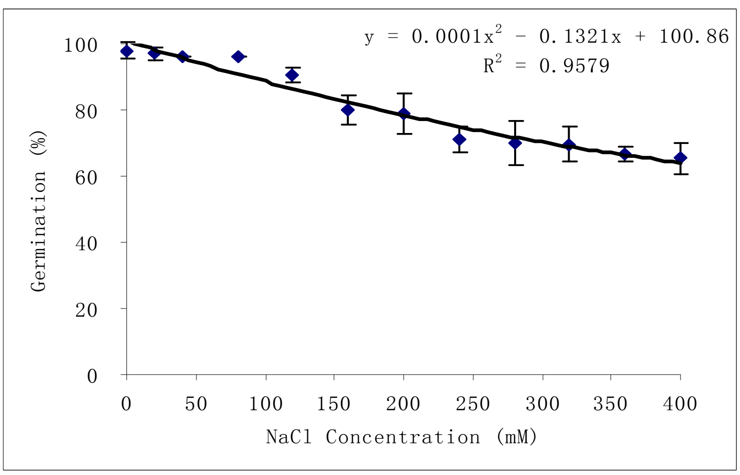

Figure 5. Effect of NaCl concentration on germination of Tausch's goatgrass seeds placed under 14-h photoperiod with a photosynthetic photon flux density of 320μmol m^{-2} $s^{-1}$for 7d. Vertical bars represent standard errors of the means

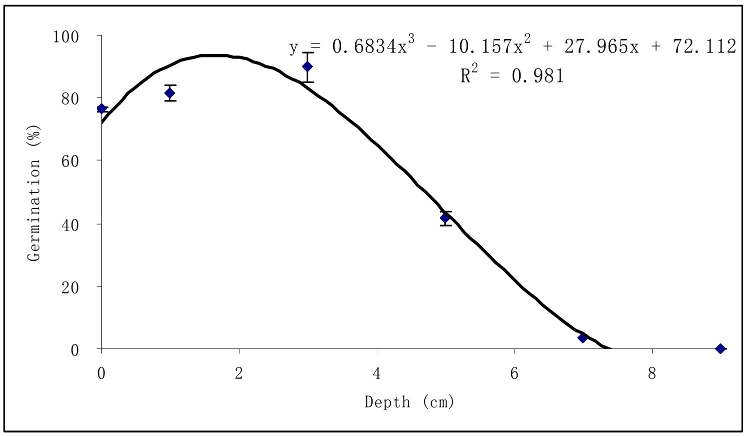

Figure 6. Effect of seed burial depths on emergence of Tausch's goatgrass seedlings under a sandy clay loam soil at 20℃ and a 14-h photoperiod in the greenhouse for 30d. Vertical bars represent standard errors of the means