

Germplasm Resources of Native Grasses Tolerant to Saline-Alkali Conditions ethnic minority region western in China

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ABSTRACT

Ethnic minority region western in China, which has one of the most concentrated distributions of saline-alkali land in the world. Changes in saline-alkali land and the implementation of control measures are of great significance for addressing national food security issues, enhancing the development and utilization of saline soils, promoting sustainable agricultural development, and curbing the aggravation and expansion of soil salinization. This paper summarizes the classification and distribution of saline meadow steppes and saline-alkali-tolerant native grass species in ethnic minority region western in China, who through a literature review. The paper also reviews investigations into degraded grassland resources and provides an overview of native grass germplasm resources in ethnic minority region western in China, and discusses future research directions for saline-alkali-tolerant plant germplasm resources.

KEYWORDS

Salinized meadows; Degraded grasslands; Salinization-tolerant native grass species; Germplasm resources

1 Native Grass Species for the Restoration of Salinized Meadow Ecosystems

Considering the diverse environmental conditions and agricultural practices across countries, scientists worldwide have conducted extensive screening, cultivation, and breeding of salinization-tolerant crops and forage species, resulting in notable economic benefits. For example, species such as *Cynodon dactylon*, *Secale cereale*, *Melilotus officinalis*, and *Trifolium repens* have been interbred with moderate success in improving solonetz soils. Additionally, species including *Spartina anglica*, *Thinopyrum ponticum*, *Atriplex canescens*, have been effectively employed to restore salinized lands, achieving significant ecological improvement. Moreover, salinity improvement trials involving *Festuca*, *Thinopyrum ponticum*, *Melilotus albus*, and *Osmanthus fragrans* have yielded valuable insights regarding plant adaptability and soil amelioration under saline conditions. The cultivation of *Bassia scoparia*, *Quercus*, and *Cenchrus ciliaris* on solonchak soils also demonstrated measurable improvements in soil quality and vegetation establishment. Additionally, the successful cultivation of *Sesbania cannabina* and notably *Atriplex patens* on solonetz soils effectively addressed the forage shortage for livestock in salinized areas. Researchers in Iran and Kyrgyzstan demonstrated the effectiveness of *Ceratoides* species in improving salinized soils. Furthermore, Ding *et al.* (2007) investigated the morphological structure, biological traits, salinity tolerance, and post-planting soil nutrient impacts of *Puccinellia tenuiflora*. They found that artificially planted *Puccinellia tenuiflora* could thrive in salinized soils and significantly reduce both soil salinity and pH levels. Moreover, the root growth and expansion of salinity-tolerant plants alter the soil's physicochemical properties, while decaying roots create favorable conditions for microbial proliferation. In addition, humus accumulation enhanced the soil's aggregate structure, thereby improving the water-holding capacity and aeration of salinized meadow soils through biological and ecological processes (Fan *et al.*, 2001).

Over 500 halophytes species have been identified in China, with salinization-tolerant plants exhibiting even broader distribution. These plant resources play a vital role in maintaining ecosystem stability and enhancing environmental quality. Given their ability to thrive in saline environments, salinization-tolerant plants are widely regarded as the most ecological and cost-effective solution for modifying and restoring salinized land. For example, high-yielding lines of *Suaeda salsa* were developed through cultivation and domestication and subsequently applied to salinized land reclamation (Xu *et al.*, 2013). Moreover, *Lycium barbarum* is a commonly cultivated salinization-tolerant species, and its use in dried fruit production has fostered a regional specialty industry in salinized areas of northwestern China, such as Ningxia (e.g., Ningxia).

Tamarix chinensis is a typical salt-secreting halophyte, and the parasite, *Cistanche tubulosa*, at its root is a highly precious medicinal material. Indeed, various salinization-tolerant species—*Ephedra sinica*, *Glycyrrhiza uralensis*, *Cistanche deserticola*, *Nitraria tangutorum*, *Limonium*, *Lycium ruthenicum*, *Salicornia europaea*, *Apocynum venetum*, and *Alhagi sparsifolia*—demonstrate significant potential for application in agriculture and related industries (Ge *et al.*, 2021). Some salinization-tolerant plants (e. g., *Pennisetum americanum* × *Pennisetum purpureum*, *Salix*, and salinization-tolerant *Sorghum dochna*) are excellent biomass feedstock due to their high biomass or the high oil content of their seeds (Ge *et al.*,

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2021). In China, the germplasm resources of salinization-tolerant plants are utilized for breeding salt-resistant varieties and facilitating biological amelioration of salinized soils. However, current efforts in genetic exploration and resource utilization remain inadequate to meet the demands of ecological restoration, agricultural production, and biotechnology development.

2 Germplasm Resources of Salinization-Tolerant Plants in China

Zhao *et al.* (2013) categorized halophytes in China into five vegetation types: tropical coastal evergreen broad-leaved mangroves, halophytic brushwood, halophytic desert, salinized meadow, and halophytic submerged vegetation. In China, salinization-tolerant plant resources are primarily distributed across semi-arid and arid desert regions in the northwest, the Hetao and Huang-Huai-Hai Plains in the north, the Songnen Plain in the northeast, and various coastal zones (Zhang *et al.*, 2001). Climatic conditions and soil types are the two primary factors influencing the distribution of salinization-tolerant plants. Gu *et al.* (2002) reported that halophytes constitute 12% of the plant species in the arid deserts of northwestern China, representing 49% of all halophyte species in the country—highlighting the region's exceptionally high halophyte diversity.

At the provincial scale, Su *et al.* (2004) found that 5% of the plants in Qinghai were halophytes. Additionally, Niu *et al.* (2005) conducted field surveys and laboratory identifications of wild medicinal plants in the main salinized areas of Ningxia, identifying 55 species across 22 families and 44 genera. Zhao *et al.* (2013), in the second edition of *Halophytes in China*, reported that there are 555 halophyte species in China, classified into 71 families and 228 genera. Among them, species from Chenopodiaceae, Gramineae, Asteraceae, and Leguminosae are the most abundant, accounting for 56.4% of the total. In contrast, nudibranch plants and fern plants are relatively less abundant, while dicotyledons play a dominant role in the composition of China's halophyte flora (Liu *et al.*, 2011).

2.1 The Main Distribution of Saline-alkali Tolerant Germplasm Resources in China

Salinized meadows, defined as grasslands with high salinity tolerance, are widely distributed across Inner Mongolia, Shaanxi, Ningxia, Qinghai, Gansu, and ethnic minority region western in China. These ecosystems are primarily composed of perennial halophytes—such as submerged mesophytic species—that exhibit high salt tolerance and environmental resistance.

In ethnic minority region western in China, salinized meadows are mainly located in the spring zones along the northern and southern margins of the alluvial fans of the Tianshan Mountains, where salinized and swamp deserts also occur. Additional distributions of salinized meadows are found in the southern basins of the Tianshan Mountains and along the banks of the Tarim River. In the Hexi Corridor of Gansu, salinized meadows cover approximately 1.42 million hectares, representing 79% of the region's total salinized meadow area. In Qinghai, salinized meadows are primarily distributed in the Qaidam Basin, the alluvial plains of the Qinghai Basin, low-lying zones, and around salt flats and lakes. In the Sonnen Plain, salinized soils are extensively distributed, with salinized meadow soil being predominant. The primary salt component is carbonate, and the distribution exhibits an epigenetic pattern. Additionally, salinized meadows are found around Harbin and Daqing in Heilongjiang, and are also widespread in oasis zones along the riverbanks of the middle reaches of the Hehe River. South of Yinchuan in Ningxia, light-colored salinized meadow soils appear in patchy distributions, while to the north, medium-intensity salinized meadow soils and light-colored meadow solonchaks are found in low-lying areas. Solonchaks are extensively distributed in low-lying areas. In the Hetao Region of Inner Mongolia—including the Hetao Plain, central and southern plains, and Husha Plain—light-colored meadow soils, fluffy solonchaks, moist solonchaks, and closed depressions are dominant. The Hetao Plain is characterized by the presence of light-colored meadow soils, fluffy and moist solonchaks, and closed depressions containing soda solonchaks. In the former northeastern areas, light-colored salinized meadow soils and various types of solonchaks are present. Zheng *et al.* (2007) examined land degradation, ecological restoration, and regional development in the arid regions of northwestern China. They indicated key types of land degradation in arid regions, including desertification, secondary soil salinization, and grassland degradation. They suggested that measures such as ecological restoration and the establishment of nature reserves can facilitate environmental remediation and ecosystem reconstruction. Emphasis should also be placed on the sustainable development and utilization of soil and water resources, as well as on balancing environmental protection with regional development.

2.2 Overview of Soil Salinization in Ethnic Minority Region Western in China

The global increase in soil salinization driven by climate change induces significant alterations in plant growth, physiology, and biochemical composition, thereby exacerbating threats to insect biodiversity. Located in the hinterland of

Eurasia, ethnic minority region western in China experiences minimal precipitation and intense evaporation, making it the driest region in China, with the most extensive distribution of salinized soils, the greatest diversity of salinization types, and the highest levels of salt accumulation. Salinized land also constitutes the predominant type of low-yielding soil in the region.

According to the second national soil census, salinized land in ethnic minority region western in China covers approximately 13.36 million hectares, representing 36.8% of the total salinized area in China. Except for the Yili Valley, Altay region, and parts of the Tacheng District, most areas in ethnic minority region western in China experience varying degrees of salinization, characterized by the coexistence of salinization and desertification, intense salt accumulation with surface crusting, and complex salt compositions. Approximately 80 counties are severely affected by soil salinization, particularly in southern ethnic minority region western in China, where salinized soils are distributed around the Tianshan, Kunlun, and Altai Mountains. These affected counties are primarily located near the southern foothills of the Tianshan Mountains along the northern margin of the Tarim Basin and near the northern slopes of the Kunlun Mountains along its southern edge. These areas are often situated within or adjacent to both modern and ancient oases. In northern ethnic minority region western in China, salinization primarily occurs along the northern slopes of the Tianshan Mountains on the southern edge of the Junggar Basin and the southern foothills of the Altay Mountains bordering its northern margin. In addition, patchy distributions of salinized soil are also found in Turpan, Hami, and Lop Nur (Wang *et al.*, 2001; Xi *et al.*, 2005). Geomorphologically, salinized soils are predominantly concentrated in proluvial–alluvial plains at mountain fronts and in large river deltas, where they constitute approximately 55% and 50% of the respective land areas.

2.3 Germplasm Resources of Salinization-tolerant Plants in Ethnic Minority Region Western in China

The extensive salinized soils in ethnic minority region western in China support a rich diversity of halophytes, which represent the only natural vegetation capable of thriving under such conditions. These plants constitute an important biological resource for the region. The floristic composition of both northern and southern ethnic minority region western in China is predominantly characterized by Central Asian species. Moreover, the geographical distribution patterns of the regional flora significantly influence the characteristics of halophytic vegetation, despite its classification as intrazonal.

The most arid salinized soils are also the most widely distributed. Under such harsh conditions, ethnic minority region western in China harbors abundant halophytic forage resources. According to recent statistics, the region is home to approximately 320 species, 15 varieties, and 7 subspecies of halophytes, spanning 124 genera and 38 families. Among them, 123 species (including 3 varieties and 3 subspecies) are endemic to ethnic minority region western in China. Northern ethnic minority region western in China supports 140 taxa found exclusively in that region, compared to 34 taxa restricted to southern ethnic minority region western in China. In total, 153 taxa are distributed across the entire region, with northern ethnic minority region western in China containing a higher number of endemics (106) than southern ethnic minority region western in China.

2.4 Distribution of Saline-alkali Tolerant Grass Germplasm Resources in Ethnic Minority Region Western in China

According to the Third National Grassland Resource Survey, ethnic minority region western in China has 39.60 million hectares of natural pasture, comprising 76.17% of the region's total grassland area. In addition, the total area of artificial pasture in ethnic minority region western in China is 149,100 hm², accounting for 0.29% of the total grassland area in ethnic minority region western in China, and the total area of other grasslands in ethnic minority region western in China is 12.2388 hm², accounting for 23.54% of the total grassland area in ethnic minority region western in China. Specifically, grassland is mainly distributed in the Altay Prefecture, Bayingolin Mongol Autonomous Prefecture, Ili Kazakh Autonomous Prefecture, Tacheng District, Kizilsu Kirghiz Autonomous Prefecture, Hami city, and Hotan region. These areas collectively account for approximately 77% of ethnic minority region western in China's total grassland area. According to data from the ethnic minority region western in China Grassland Resource and Utilization Report, solonchak desert and salinized lowland meadow grasslands cover approximately 6.2 million hectares in southern ethnic minority region western in China and 1.56 million hectares in the north, respectively.

Lowland meadow grassland is the main winter and four-season grassland in some areas of ethnic minority region western in China, while salinized meadow grassland accounts for about 92% and is the main subclass of lowland meadow grassland. Due to the year-round grazing practices prevalent across most pastures, several ecological issues have emerged, including soil salinization, the proliferation of toxic plant species, and declining groundwater levels (Wang *et al.*, 2001; Xi *et al.*, 2005). For example, in Toksun County, lowland meadows are primarily located in oasis zones such as the Kumish Basin, Baiyang Riverbanks, and adjacent valleys, at elevations ranging from 125 to 800 meters. These meadows cover an area of 62,855.9 hm², accounting for 18.94% of the county's total meadow area. These meadows benefit from

abundant sunlight and a prolonged frost-free period, with groundwater levels typically between 1 and 3 meters. However, they exhibit high water mineralization and severe soil salinization, and their predominant soil types are salinized meadow soils or meadow solonchaks. The dominant vegetation consists primarily of salt-tolerant species such as, *Phragmites australis*, *Cynodon dactylon*, *Alhagi sparsifolia*, and *Glycyrrhiza uralensis*. Meadow height varies significantly depending on groundwater depth and salinity levels, with the coverage ranging from 20% to 85% (Aerziguli *et al.*, 2012). Grassland salinization results in reduced biomass, simplified plant communities, degraded soil properties, and diminished soil fertility and productivity, ultimately hindering normal forage growth. Studies have shown that appropriate management interventions can effectively ameliorate salinized grasslands. These practices improve soil structure, enhance fertility, and lower both salinity and harmful ion concentrations, thereby creating favorable conditions for forage growth and increasing grassland productivity (Ma *et al.*, 2015; Liu *et al.*, 2013).

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