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Editorial

Breeding and Genetics of Forages for Semi-Arid and Arid Rangelands

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Rangelands are the Earth's largest land type and provide the feed source for the extensive grazing of beef and dairy cattle (*Bos taurus*), sheep (*Ovis aries*), goat (*Capra aegagrus hircus*), horse (*Equus ferus caballus*), camel (*Camelus* spp.), other livestock, and wildlife [1,2]. This agriculture, which includes both subsistence and production, is the basis of the livelihood of billions of people worldwide [3]. In addition to their value for grazing agriculture, the world's rangelands provide carbon sequestration, biodiversity, water quality, aesthetics, recreation, and other ecosystem services [4]. Despite their vastness and critical importance, rangelands are fragile and vulnerable to mismanagement and disturbance [5]. Large, prolonged disturbances may result in permanent changes to the ecosystems and their supported services [6]. Thus, rangeland agriculture and associated practices must improve to maintain environmental and economic sustainability [7].

A key characteristic of rangeland agriculture is its typical lack of dependence on external inputs, such as supplemental irrigation and fertilization [8]. Rangelands are characterized by their native and naturalized plant populations that primarily consist of grasses, forbs, and shrubs [1]. Nevertheless, seeding for revegetation following disturbance or to improve the forage base and/or biodiversity is frequently done on rangelands [9]. Rangeland seedings are resource and financially expensive and often fail due to mitigating circumstances [10]. Successful rangeland seedings require correct agronomic technique, cooperative weather, and the right plant materials. Various breeding programs exist to develop and improve rangeland plant materials for establishment, persistence, and production on these harsh rangeland sites to increase the probability of successful rangeland revegetation.

This Special Issue of *Agronomy* contains nine original research articles and reviews that focus on a variety of rangeland species and topics. Articles highlight traditional plant breeding and evaluation of improved rangeland plant materials, elucidation of the effects and importance of genotype × environment interaction on rangeland plant materials, and the use of molecular biological techniques to identify genetic determinants of important traits and pursue marker-assisted selection. This Special Issue is a repository of up-to-date information documenting the current status of rangeland forage breeding and a description of future research objectives.

Sustainable rangeland agriculture requires properly adapted plant materials that not only provide feed to grazing animals, but also persist under harsh conditions to stabilize soil and compete against invasive weedy species [11]. In their native Eurasian habitats, crested wheatgrass (*Agropyron* spp.) and alfalfa (*Medicago sativa*) have long served these purposes. They produce feed and persist at semi-arid and arid locations that often have hot summers and cold winters. These are the reasons for their original exportation from Eurasia to similar rangeland locations in temperate regions worldwide. These two plant materials together stabilized millions of acres of disturbed rangelands in North America [12,13].

Extensive North American plant breeding efforts over the last 100 years resulted in the development of 18 crested wheatgrass cultivars [13]. These cultivars establish well, persist, and provide soil stabilization for disturbed sites and feed for domestic livestock and wildlife. Another approach to rangeland plant breeding is the use of natural selection to develop naturalized populations that are adapted to the target region. This approach uses the inherent characteristics of heterogeneous rangelands to develop specifically adapted populations [14]. Boe and colleagues documented this type of selection process for the development of the Smith's falcata and Grand River National Grassland alfalfa populations [12]. These populations are well-adapted to the abiotic stresses and grazing tolerances necessary to thrive in these areas. However, with a combination of in situ and ex situ management, these populations may continue to improve genetically through ongoing natural selection or serve as promising sources of germplasm for targeted plant breeding for rangeland alfalfa improvement [12].

Due to the difficulties of rangeland revegetation and the need for biodiversity, rangeland agriculture and conservation requires access to improved cultivars of a large number of species. Additional plant breeding efforts resulted in improved cultivars of both Eurasian and North American perennial Triticeae cultivars [15]. Widespread multi-location evaluations identified the species and cultivars best adapted to specific regions of the North American Intermountain and northern Great Plains regions [15]. While some species and cultivars stood out across locations, there was substantial genotype × environment interaction among the cultivars that complicates land managers' plant material choice.

Evaluations of alfalfa, forage kochia (*Bassia prostrata*), and Napier grass (*Cenchrus purpureus*) further demonstrated the effects of genotype × environment interaction for rangeland agriculture. Evaluation of the effect of alfalfa fall dormancy on forage yield in the USA southern Great Plains found that less dormant materials possessed higher yields, but that there were interactions between forage harvest and dormancy class [16]. Forage kochia is valued as a rangeland plant material for its drought and salinity tolerance, competitiveness with annual weedy species, and for its nutritional value. In the USA Southern Great Plains evaluations, the *virescens* types of forage kochia established better than *grisea* types, but between the two *virescens* types, the cv. immigrant established best in March and the Pustinny-Select population established best in May [17]. In contrast, the evaluation of Brazilian Napier grass genotypes in Ethiopia, resulted in substantial differences in forage yield and quality between wet and dry seasons, but also indicated that the genotypes with the greatest forage production were consistent across both seasons [18]. Thus, the effect of genotype × environment interaction on rangeland agriculture is species, genotype, location, and trait dependent.

Molecular biological research is still in its infancy in rangeland agriculture. Nonetheless, several studies documented the potential of this research for improving rangeland plant materials in a trait-dependent way. Larson and colleagues identified the *SH6* seed retention gene in a *Leymus* population and then discovered that homozygous recessive *sh6/sh6* genotypes exhibited greater seed retention. This trait allowed for the later harvest of these genotypes, which corresponded to greater seed viability [19]. Other important rangeland traits include drought and salinity tolerance. Seven micro RNAs (miRNAs) from *Agropyron mongolicum* Kang exhibited expression changes under drought. Three of these miRNAs resulted in genetically stable transformation in *Arabidopsis thaliana* and the same expression pattern in both species [20]. Transcriptomic and proteomic techniques resulted in the identification of a number of candidates for the molecular improvement of alfalfa salinity tolerance [21]. Finally, marker-trait associations in Napier grass identified polymorphisms with potential utility for identifying genotypes with high agronomic performance [18]. Although the potential for marker-assisted and genomic selection is still untapped, these techniques show great promise as the efforts increase and receive more emphasis.

Rangeland agriculture has greatly benefited from concentrated plant breeding efforts in a number of species. These plant breeding efforts have provided land managers with a number of both widely and narrowly adapted cultivars that serve to revegetate disturbed sites, stabilize soil resources, and provide feed for domestic livestock and wildlife. Due to ongoing disturbances and climate change, there is a critical need for ongoing rangeland plant breeding efforts. Traditional approaches must be complemented and supplemented with new and advancing molecular biological and genomic technologies. This Special Issue of *Agronomy* addresses a number of historical and current research topics that document the importance of this research and the potential for further genetic gains in the future.

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