

Investigation of the Characteristics of Smooth Brome (*Bromopsis inermis* Ley) Biological Traits for Cultivation Under Extreme Environmental Conditions

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Abstract—The characteristics of smooth brome biological and economic traits are examined in connection with its use under the extreme conditions of the forest steppe of West Siberia, North Buryatia, and North Kazakhstan steppe. It is shown that the species *Bromopsis inermis* Leys at the octoploid level can be one of the tolerant perennial gramineous fodder crops for cultivation under unfavorable conditions, particularly in the case of insufficient heat.

Keywords: smooth brome, climate change, polyploids, complex hybrid populations, yield, tolerance

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The climate changes observed in recent decades can threaten the stability of the production of the main animals feeds and human food products. According to an assessment by the Federal Hydrometeorological and Environmental Monitoring Service, we can expect an increase in the frequency and intensity of extreme events, such as floods and droughts, which will affect food security, particularly crop production. What is more, regional climate changes in Russia are becoming more substantial than in other countries of the world and have a strongly pronounced character. Thus, in 2012, in West Siberia in the summer the deviation from average annual surface air temperatures during 1961–1990 (°C) was the highest (2.81, probability 100%) and in the European part of the Russian Federation, respectively 1.64 and 89.5%. An increase in the average annual air temperature by 3–4°C is forecast by the middle of the century in West Siberia and by 2–3°C in northern European Russia. The great diversity of soil and climatic conditions of the country presumes the creation of different programs of adaptation of agriculture to climate changes, which in that case should be detailed and systematic [1, 2].

It takes a rather long time to create varieties adapted to new environmental conditions. Thus, it takes 15–20 years and more before a variety is included in the Register of Breeding Achievements in Perennial Crops. Furthermore, unpredictable changes in meteorological conditions can occur during the breeding process, which reduces breeding for specific soil and climatic conditions to its initial stage—the

creation of new breeding material. In the given case, by tolerance of crops we mean the ability of populations, varieties, plants to withstand the unfavorable effect of one or another environmental factor without a pronounced reduction in yield. An important role in the production of fodder under Siberian conditions is played by smooth brome, the most widespread hay and pasture grass among perennial gramineous grasses.

The purpose of the present work was to study the biological and economic characteristics of smooth brome cultivated under extreme environmental conditions.

METHOD

The investigations were conducted in the forest steppe of West Siberia (Siberian Fodder Research Institute (SibNII kormov), North Baikal district of the Republic of Buryatia (SibNII kormov experimental station), and North Kazakhstan steppe (Baraev Grain Husbandry Research and Production Center). The work began in 1979 and is presently continuing. The meteorological conditions in the years of the experiments were extremely diverse. Conventional methods were used [3]. The experimental data were treated statistically by B. Dospekhov's method with the aid of a personal computer and Snedecor application programs [4,5].

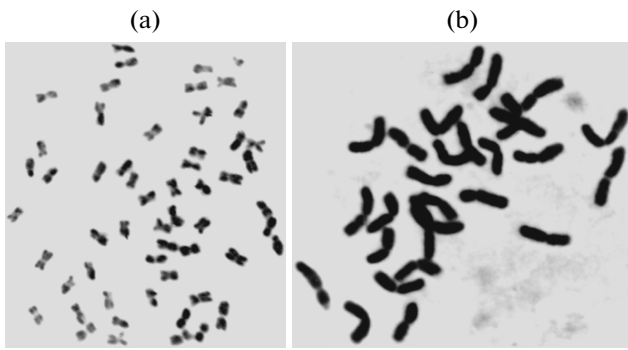


Fig. 1. Wild form from Altai krai (a): $k_{VIR} = 062530$ ($2n = 56$), magnification 140 and from Chita oblast (b): $k_{VIR} = 063385$ ($2n = 28$), magnification 2250.

RESULTS AND DISCUSSION

According to N.I. Vavilov [6], forage plants are included in two centers of origin of cultivated plants: Middle East and Mediterranean. Smooth brome is not among them. A number of foreign researchers suggest that the center of origin of this plant is located in the territory of Russia [7–10]. In E.N. Sinskaya’s opinion [11], possibly, “the path of dispersal of many gramineous and leguminous grasses passed from Altai across

West Siberia and Urals to the north of the European part of the USSR.” The exceptional polymorphism of the biological and economic traits and properties of smooth brome in flora of West Siberia can indicate the presence of one of the possible centers of its origin in the territory of Siberia.

G.L. Stebbins [12] maintains that smooth brome is part of an old polyploid complex which is still in an active state of evolution with an insufficiently known history of origin. On the basis of our determination of the number of chromosomes in 161 wild populations and 46 domestic smooth brome cultivars of various ecological and geographic origin from the former USSR, it was shown that the most prevalent chromosome number in *B. inermis* is $2n = 56$. Of the 207 analyzed populations, 21.7% were tetraploid (Fig. 1). Domestic selected and landrace cultivars widespread in the territory of the former USSR had 56 chromosomes. Examining from a geographic viewpoint 160 wild populations investigated for chromosome number, we concluded that tetraploids are inclined to occupy more southern latitudes than octoploids (table, Fig. 2). Octoploid forms are found both in southern and northern latitudes, but the percentage of octoploids increases from the south to the north [13]. An analysis of the behavior of chromosomes in meiosis indicated instability of the genome of the given species

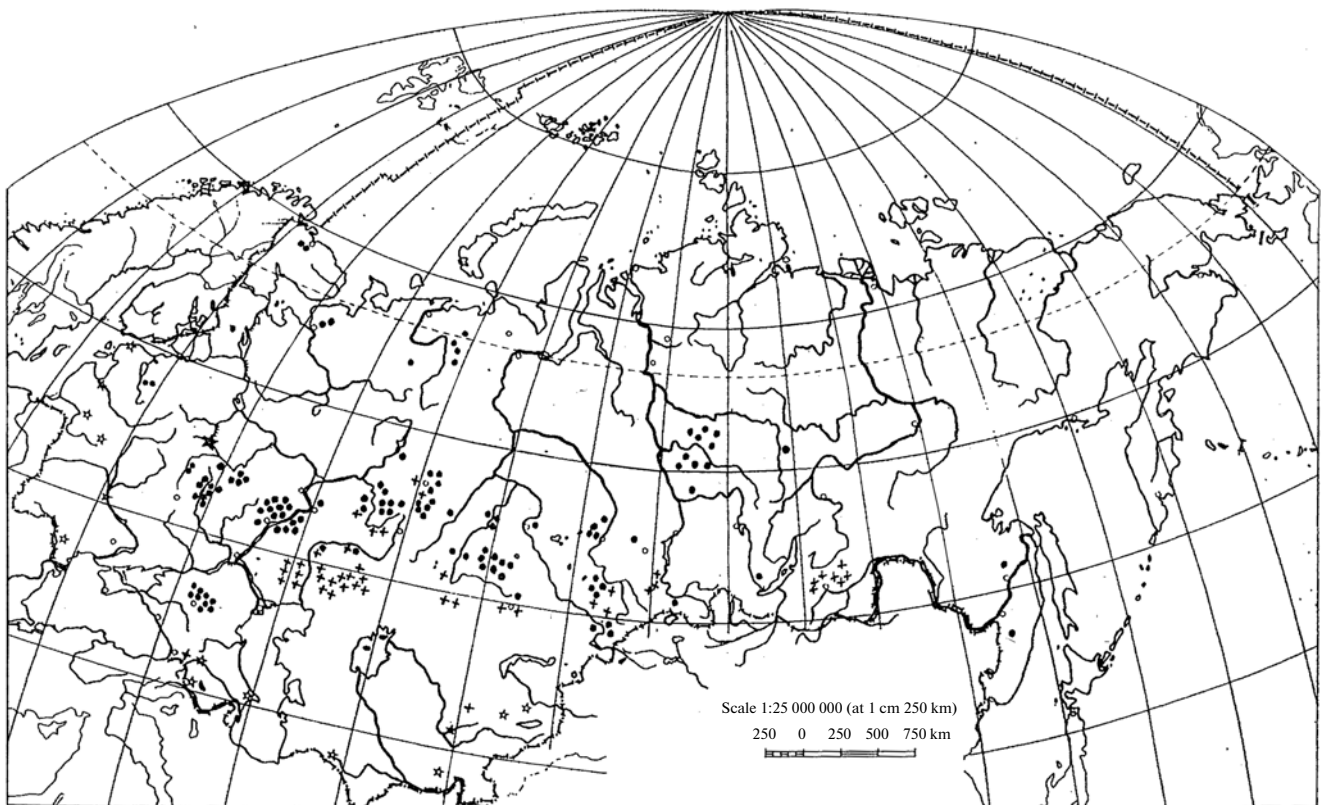


Fig. 2. Geographic distribution of polyploid forms of smooth brome in territory of the former USSR; legend: +, $2n = 28$; ●, $2n = 56$.

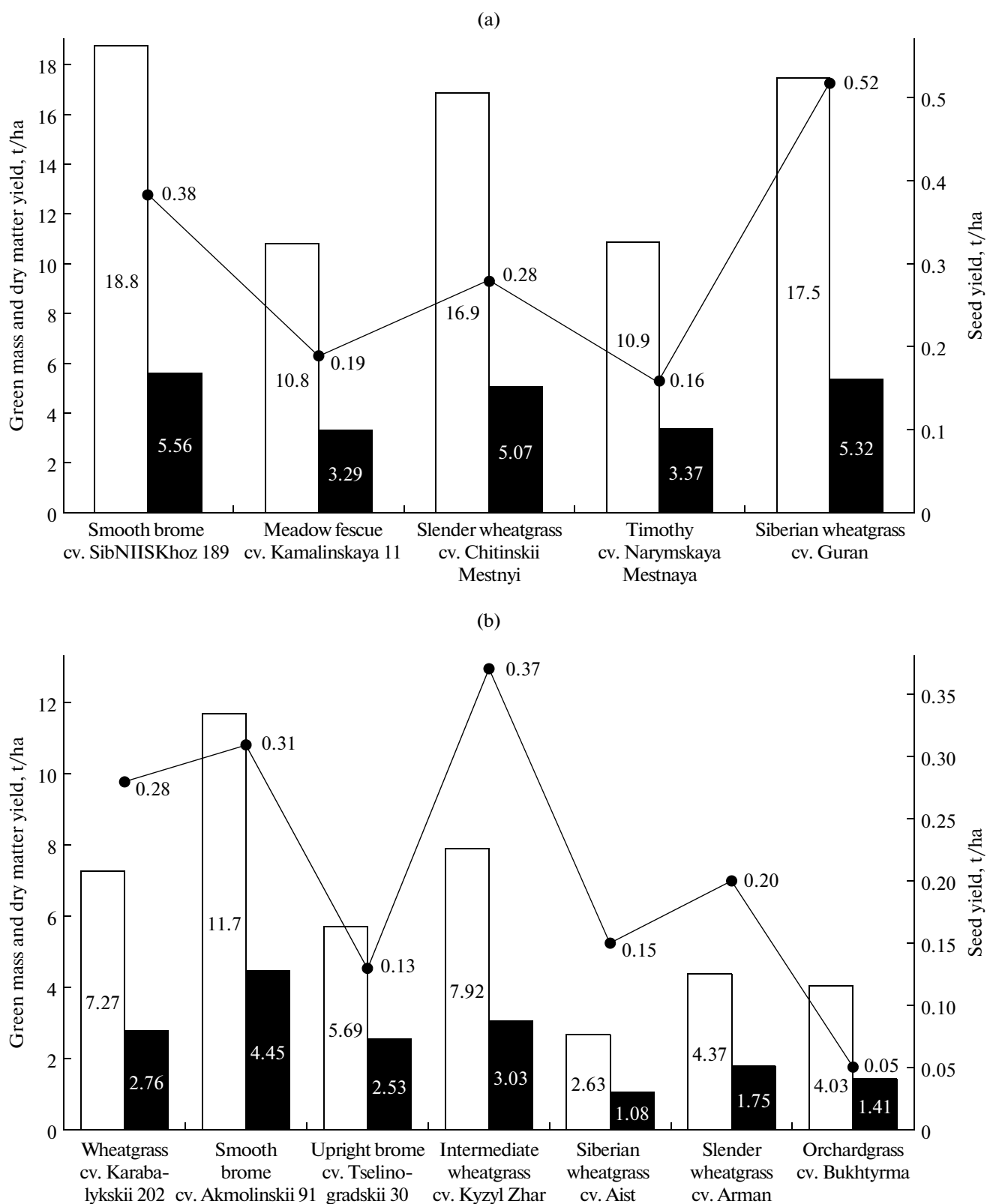


Fig. 3. Yield (t/ha) of green mass (first column), dry matter (second), and seeds (third) of various species of perennial gramineous grasses: (a) in North Buryatia (1992–1995); (b) in North Kazakhstan steppe (2011–2013).

at a higher ploidy level ($2n = 56$), which confirms Stebbins' viewpoint. Cytomixis and pyknotic formations were found in octoploid forms rather often (up to 20% of the analyzed plants) [13].

Since smooth brome is a strictly anemophilous species with high heterozygosity and cultivars are complex hybrid populations, and meiotic imbalance leads to an increase of genetic variability, we can assume that this species has extensive epigenetic mechanisms regulating gene expression. Ecologically determined epigenetic mechanisms enable it to adapt quickly to new conditions by a change in gene expression. The presence of a reserve of natural phenotypic variability in existing smooth brome cultivars allows distinguishing tolerant high-yielding populations since for cultivated plants it is important to solve the problem of their ability not only to survive stress but also to form a high yield under stress conditions. According to our data, specimens with high yield indices are found more often among octoploid populations than among tetraploid. With consideration that octoploids (Fig. 2) occupy more northern latitudes, they can be cultivated under extreme conditions with insufficient heat.

A study of smooth brome cultivar SibNIISKhoz 189 at the octoploid level ($2n = 56$) compared with other perennial gramineous grasses in the North Baikal district of the Republic of Buryatia, equated to the Far North, in years with sharp drops of average daily air temperatures and nighttime frosts showed its advantage in yield of green mass, dry matter, and seeds (Fig. 3a).

In 2011–2013, a comparative study of seven species of perennial gramineous grasses was conducted in the North Kazakhstan steppe. This zone with a pronounced continental climate characterized by a variable hydrothermal regime over the years and during the growing season, in which case conditions typical both for a desert and the northern taiga zone and temperate climate belt are created. During those years the hydrothermal coefficient (HTC) from April through August varied from 0.42 to 0.94. Smooth brome also had the highest green mass and dry matter yield: on average during the 3 years, it was respectively 11.7 and 4.45 t/ha. In the other species of perennial gramineous grasses, it varied from 2.63 and 1.08 (Siberian wheatgrass) to 7.92 and 3.03 (intermediate wheatgrass) t/ha, Fig. 3b. Intermediate wheatgrass and smooth brome were notable for seed yield, respectively 0.37 and 0.31 t/ha.

Thus, on the basis of our investigations smooth brome can be recommended as one of the tolerant perennial gramineous fodder crops in case of the occurrence of extreme conditions, particularly insufficient heat.

Distribution of wild octoploid and tetraploid populations within the species *Bromopsis inermis* Leys according to geographic latitudes in the territory of the former USSR

Boundaries of middle geographic latitudes, degrees	Octoploids, $2n = 8x = 56$		Tetraploids, $2n = 4x = 28$	
	number	%	number	%
40–50	13	36.12	23	63.88
51–60	83	79.05	22	20.95
61–70	20	100.0	0	0

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SPELL: 1. Sinskaya's