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Review

Smooth Brome (*Bromus inermis* L.)—A Versatile Grass: A Review

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Abstract: Smooth brome (*Bromus inermis* L.) is a species of perennial grass with growing economic importance. Initially, this species had attracted interest as a source of animal feed. Over the years, the interest in smooth brome increased significantly due to the growing knowledge about its advantages. The aim of this study was to explore the contemporary significance of smooth brome. This plant is characterized by a high tolerance to many negative environmental factors, such as periodic droughts, low temperatures and salinity, which contributes to its constant presence in the landscape of many countries. The moderate soil requirements of smooth brome, combined with the effective use of soil resources and rational nutrient utilization, contribute to high biomass yields that can reach 13 t/ha DM. The usefulness of this grass species in various management systems has been recognized in numerous research studies. Smooth brome can generate benefits in many branches of the economy. This efficient energy plant is used in paper production, and it is also recommended for the protection of fallow land or the reclamation of degraded land. Smooth brome prevents erosion, enhances biodiversity, and provides shelter for many animal species. This species fits well into the current assumptions of agricultural policy and increasingly demanding environmental standards. According to the latest guidelines, modern agriculture should pursue economic and environmental goals simultaneously. In this context, smooth brome constitutes a valuable link in sustainable development. Due to its numerous advantages, smooth brome not only provides high-quality feed and biomass but also effectively sequesters CO_2, improves soil fertility and enhances biodiversity, which makes it an important element of agriculture and environmental protection.

Keywords: grass; bromegrass; ecosystem; animal nutrition; forage grass

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1. Introduction

Smooth brome (*Bromus inermis* Leyss.), also known as bromegrass, smooth bromegrass, Austrian brome, Hungarian brome or Russian brome, is a perennial plant of the family Poaceae. The species is native to Eastern Europe and China, and at present, it is widely distributed in temperate and cool climate zones in the northern hemisphere [1,2]. Smooth brome was introduced to North America in 1884, but its significance was recognized only during the major drought events of the 1930s [1]. In the United States, sporadic breeding efforts were made at the beginning of the 20th century, but formal breeding programs were initiated only at the turn of the 1930s and 1940s. The selective breeding of smooth brome coincided with the growing popularity of Columbia brome, which was recognized for its ability to restore damaged meadows and fallow land in the Great Plains

and the Midwestern United States. Extensive research into smooth brome began only in the 1970s [3].

Smooth brome, the most popular species of perennial bromegrass in North America, is characterized by considerable ecotype diversity, and it is generally divided into northern, southern and intermediary ecotypes [3]. In North America, smooth brome is classified into two main ecotypes: the northern or meadow ecotype that thrives in valleys, humid climates of Eastern Europe and temperate Asian climates and the southern or steppe ecotype that is well adapted to dry environments. The intermediate ecotype is a cross between the northern and southern ecotypes [3,4].

Numerous smooth brome breeding and research programs have contributed to the development of its open-pollinated varieties, including 'Carlton', 'Lincoln', 'Löfar', 'Manchar' and 'Brudzyńska', as well as hybrid varieties such as AC Knowles, Sukces and K-46 [5–9]. At present, smooth brome is cultivated in many countries on several continents (Figure 1). This indicates great economic potential.

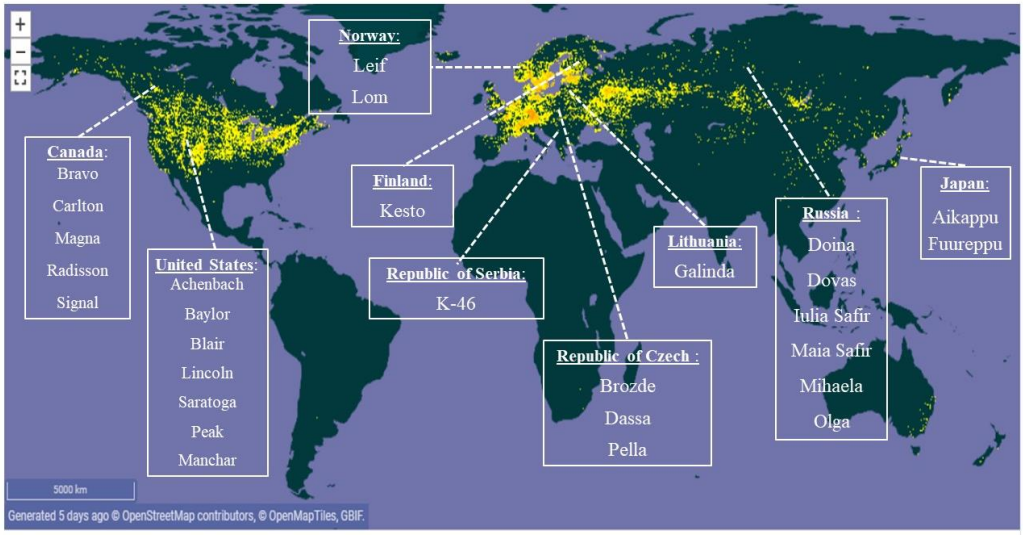

Figure 1. Geographic distribution of smooth brome and the origin of its varieties. Source: Global Biodiversity Information Facility [10,11].

According to many researchers, the broad geographic distribution of smooth brome across various habitats can be attributed mainly to its extraordinary cold resistance relative to other perennial grasses, as well as its ability to adapt to new environments [4,12–14]. Smooth brome is also highly resistant to disease [1]. It is characterized by above-average growth in cold climates and tolerance to adverse environmental conditions—in particular, low temperatures [15,16].

Smooth brome is one of the most drought-resistant species of grass [14,17]. Its extensive root system with many side branches (Figure 2) promotes adaptation to various soil types and environments, including dryland, weak and wet soils, waterlogged sites, embankments and escarpments [18]. Owing to its extensive root system, smooth brome is able to take up more water and nutrients than other grass species [14]. According to Pang et al. [19], smooth brome draws water mainly from deep soil layers below 10 cm.

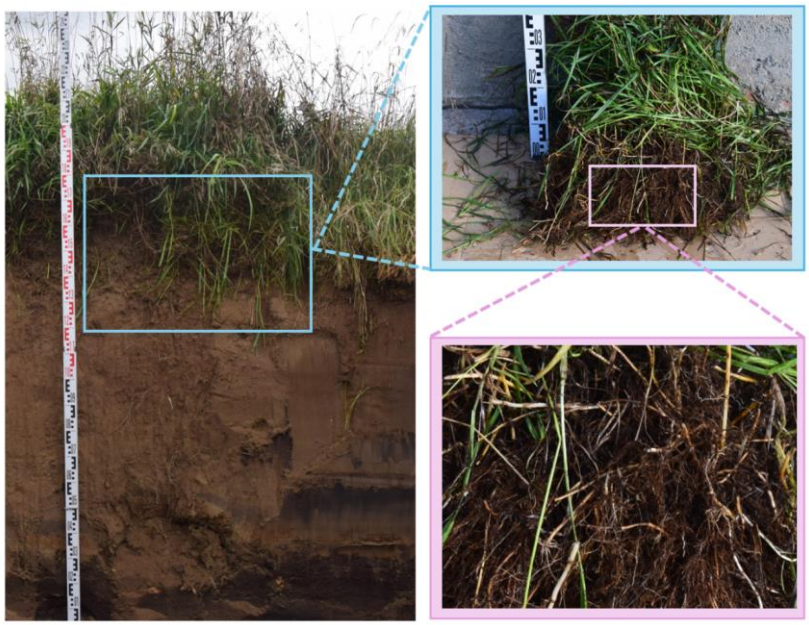

Figure 2. The root system of smooth brome at the end of the growing season.

Smooth brome effectively transports essential nutrients from mature plants to young plants, which enables the species to effectively colonize nutrient-deficient soils [20]. This process plays a key role in species survival and the development of young plants under adverse environmental conditions. Soil-dwelling microorganisms increase the availability of nutrients for smooth brome. This grass species offers a supportive environment for microbial growth, and it benefits from the minerals released by soil-dwelling microorganisms. In smooth brome, root-associated microbial communities include bacteria (63%), arbuscular mycorrhizal fungi (17%), saprophytic fungi (9%), actinobacteria (8%) and microeukaryotes (3%) [21]. This symbiotic relationship with soil-dwelling microorganisms enables smooth brome to adapt to diverse soil environments and effectively utilize nutrients (Figure 3).

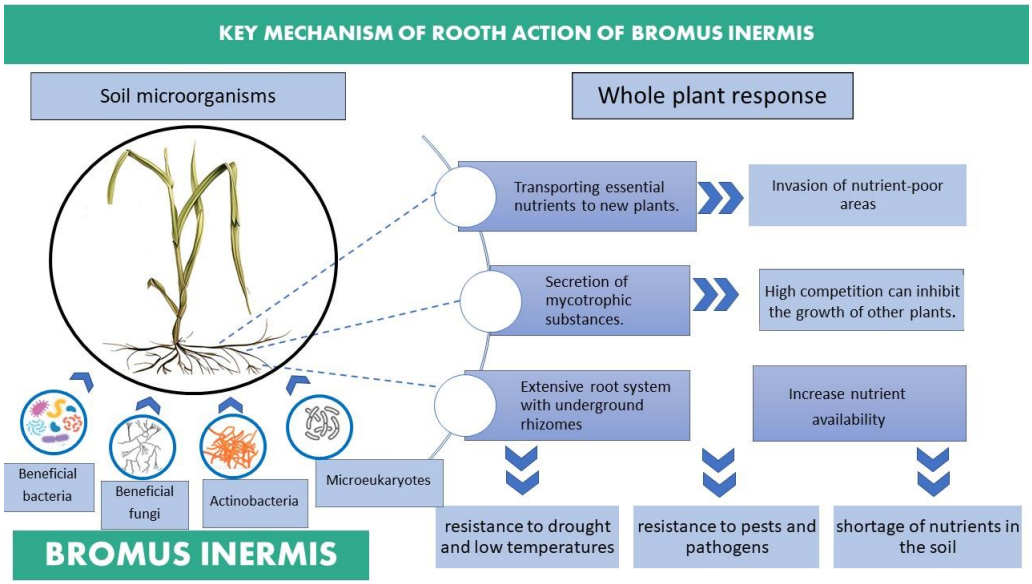

Figure 3. Root–microbe interactions in smooth brome.

Smooth brome has allelopathic effects, and it inhibits the growth of other plants by secreting mycotrophic substances that decrease competition [22]. Harkot and Lipińska

[22] demonstrated that extracts from germinating smooth brome seeds effectively inhibited the germination of Kentucky bluegrass and white clover. Benedict [23] found that smooth brome root secretions suppressed the growth of competitive plant species, thus enabling smooth brome to dominate over previously colonized habitats. Numerous studies have shown that smooth brome is a highly invasive plant that displaces native species (Figure 4). According to many researchers, smooth brome poses a significant threat to biodiversity due to its dominance. This is important in maintaining the ecological balance in nature [24–31]. Gos et al. [32] observed that smooth brome has a tendency to become the dominant species in the sward by eliminating weakly competitive species such as meadow fescue and timothy-grass.

A number of management strategies have been developed for reducing the uncontrolled spread of smooth brome. Effective methods include the introduction of rotational grazing, which helps reduce the competitive advantage of brome grass by periodically disturbing its growth. The introduction of competitive native species is also used, which can also effectively limit the development of smooth brome through natural competition [28,29,33,34]. Herbicide treatments can be effective, especially when applied selectively, reducing negative impacts on non-target species [35–39]. Good results are achieved by mechanical removal and controlled burning, which can disrupt the growth cycle of bromegrass and reduce its seed bank in the soil [29,40]. A promising method is the introduction of natural predators or pathogens specific to smooth brome, which requires further research [41].

Figure 4. Smooth brome growing on the roadside.

Initially, smooth brome had attracted interest mainly as a source of animal feed. Over the years, the interest in smooth brome increased due to the growing knowledge about its advantages. At present, the species is not only a source of forage, but it is also produced as an energy crop and used to reclaim degraded land or protect fallow land. Smooth brome is considered a pioneer plant on eroded soils and a soil stabilizer in fire-damaged areas. It provides shelter to many animal species, and it is also used in phytoremediation, the control and prevention of erosion and the enhancement of biodiversity [28,41–46]. The aim of this study was to review the existing literature on the current applications of smooth brome in agriculture and industry and its significance for the environment. This

literature review was prompted by many years of research conducted by the authors and the general scarcity of published studies on the multiple applications of this versatile grass species.

2. Methods

The following bibliometric databases were comprehensively searched to acquire data for the literature review: PubMed, Web of Science, Scopus, AGRO, MDPI, Cambridge Journals, Taylor&Francis, Science Direct and Springer. The literature was analyzed based on the following keywords: 'smooth brome', 'bromegrass', 'smooth bromegrass', 'Bromus inermis' and 'tall grasses'. Articles published in languages other than Polish and English, popular science articles and articles describing the results of research conducted at the cellular level were excluded from the analysis. The review included research papers published between 1947 and 2024. The articles selected for the review were discussed in thematically relevant sections of the manuscript.

3. Morphology

Smooth brome is a tall grass species with an extensive root system with rhizomes (Figure 5 A), which penetrates the soil to a depth of 150 cm [47,48]. The species produces long vegetative shoots with numerous leaves, as well as reproductive shoots with flowers. The leaves are folded in buds and leaf blades are flat, long and broad, with crimps in the middle (Figure 5 B). The ligule is short and incised, with a jagged margin. The leaf sheaths are usually hairless, and their edges are fused for most of their length (Figure 5 C). The inflorescence consists of a double, moderately open panicle with branches in whorls and large 3- to 10-flowered spikelets (Figure 5 D). Kernels are hulled; the lemma is nerved, sharply pointed and usually awnless, extending upward. The thousand-seed mass of smooth brome is estimated at 6.2 g [49,50]. A single plant can produce 50 to even 100,000 seeds that begin to ripen in June and August. The seeds remain viable in soil for up to ten years (Figure 6).

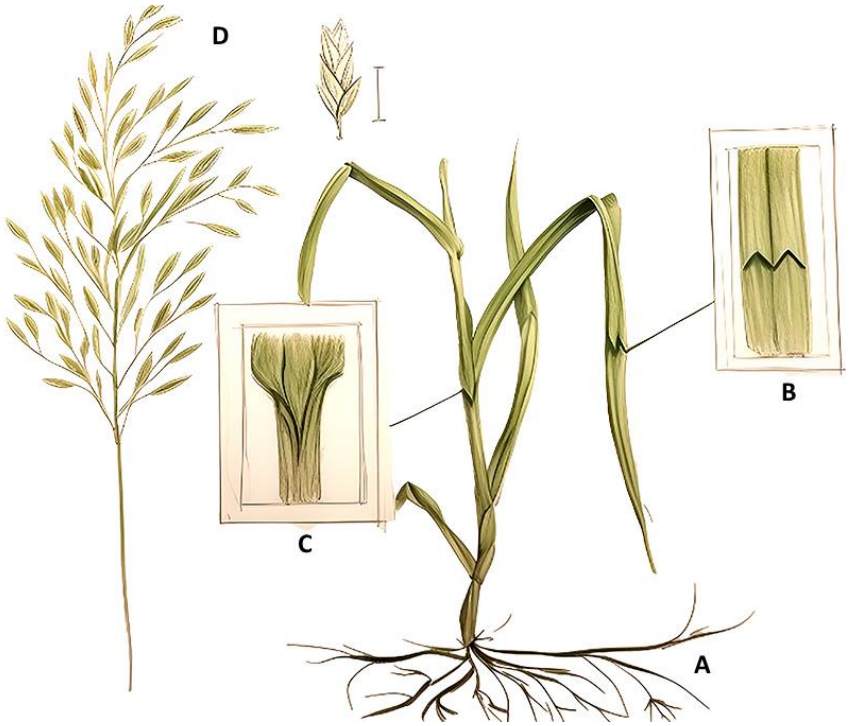

Figure 5. Morphology of smooth brome. A—root system, B—leaf blade, C—leaf sheath, D—inflorescence.

Figure 6. Seeds of smooth brome.

Smooth brome has numerous applications due to its chemical composition. The chemical composition of smooth brome during vegetative growth and flowering is presented in Table 1.

Table 1. Chemical composition of smooth brome.

Component		Content	Source
DM		27.1	[51]
ADF	g/kg DM	353.0–451.0	[8,52–55]
NDF		387.5–601.9	
ADL		572.6–618.6	
RFV		73.0–93.0	
NFE		84.0–109.0	
CP	g/kg DM	89.1–145.2	[3,52,53,55]
CF		21.7–33.2	[52,55–57]
Lignin		137.0	
Crude ash		7.7–73.0	[42,51,52,55,57]
P		1.5–1.8	[55,58,59]
K		14.5–18.9	
Ca		4.3–5.0	
Mg		2.8–5.8	[58]
Na		0.70	[42,59]
S		0.65–0.73	
Cu	mg/kg DM	4.0–5.4	[59,60]
Fe		60.0–84.1	
Zn		31.2	
Mn		66.9	
Co		0.06	

DM—Dry matter; ADF—Acid detergent fiber; NDF—Neutral detergent fiber; ADL—Acid detergent lignin; RFV—Relative feed value; NFE—Nitrogen-free extract; CP—Crude protein; CF—Crude fiber.

4. Soil Requirements

Smooth brome thrives on various types of soil—both fertile soils that are abundant in humic substances and nutrients and nutrient-deficient soils [12,14]. According to research, this grass species easily adapts to different environments and exhibits tolerance to salinity and low pH [12,14,61]. It is recommended for reclaiming eroded and fire-damaged soils [28,44]. Smooth brome is also resilient to intense sunlight and can be planted within a broad elevation range [18,23]. This species can tolerate short-term spring flooding for up to 45–50

days, and it is well suited for floodplain meadows [62,63]. Smooth brome can also be cultivated on dry and highly decomposed organic soils [49].

5. Agronomic Management

To maximize smooth brome yields and performance, the analyzed grass should be grown after small-seeded legumes and root vegetables. Smooth brome plantations should not be established in fields where grasses were grown in the past two years. The field should be plowed after the preceding crop has been harvested. The first spring treatments involve shallow cultivation (drag harrow) and fertilization. Fertilizers should be thoroughly mixed with soil, and the field should be adequately prepared for sowing. The optimal rates of phosphorus and potassium fertilizers should be determined based on the concentrations of these nutrients in soil. Fertilizers are generally applied at 60–80 kg/ha P_2O_5 and 80–100 K_2O kg/ha [20,49]. Nitrogen can be applied before sowing, depending on the preceding crop, soil nutrient levels and the intended use of smooth brome [17].

When produced for forage, smooth brome should be sown at a density of 30–52 seeds/ha [41,64]. According to Mahli and Foster [65], barley should be sown at 30 kg seeds/ha as a cover crop in the seeding year to maximize the herbage yields of smooth brome. In turn, Ou et al. [66] found that smooth brome should be sown at a density of 35 kg/ha with a row spacing of 45 cm to optimize seed production. The recommended seeding rate for the protection and restoration of fallow land is around 30 kg/ha. A 1:1 seeding ratio should be applied when smooth brome is sown with other plant species, such as fodder galega or hybrid alfalfa. The seed mix should be sown at a density of around 40 kg/ha [67,68]. According to Liu [69], smooth brome should be sown (undersown) at approximately 400 seeds/m^2 to restore grasslands. Seeds should be planted at a depth of 1–2 cm, and the field should be rolled after seeding. Plants generally emerge 12–14 days after sowing [17,18].

Initial growth is slow, which is why optimal nitrogen fertilization plays an important role in the production of smooth brome. Slow-release fertilizers such as urea and calcium nitrate applied at 40–60 kg N/ha before the first cut are recommended to increase forage yields. Similar fertilizer rates are applied before the second and the third cuts, totaling 120 kg N/ha per growing season [17]. According to Kang et al. [70], moderate nitrogen rates (120 kg/ha) combined with a mild water deficit not only promote high yields in smooth brome but also prevent nitrogen leaching through the soil profile. Türk et al. [53] reported that the yields and quality of smooth bromegrass forage can be optimized when nitrogen is supplied at 120 to 160 kg/ha. Smooth brome effectively utilizes nutrients from organic waste fertilizers such as sewage sludge and fly ash [43,71]. Dried and wet distiller grains with solubles have also been found to increase smooth brome yields in meadows and pastures [72]. However, numerous studies have demonstrated that high yields of smooth brome can also be achieved without nitrogen fertilizer, which makes this species suitable for organic farming [67,73].

Agronomic treatments, particularly weed management, play a key role in the first year of smooth brome cultivation. Monocotyledonous weeds, such as plants of the genera *Apera* and *Alopecurus myosuroides*, are sensitive to fenoxaprop-P-ethyl at the recommended dose of around 69 g/ha. Dicotyledonous weeds should be controlled with MCPA sprayed at a dose of 1200 g/ha. Herbicides should be applied in the appropriate growth stage when smooth brome plants have developed at least six to eight leaves.

The first harvest takes place when smooth brome reaches a height of 8–10 cm. The harvested herbage can be used directly as forage or ensiled. To stimulate plant growth, smooth brome should not be cut too low in the first year of production [17]. The analyzed species grows slowly in the first year, and the highest yields are generally reported in the third and fourth years of cultivation [18]. Seed yields generally range from 600 to 1800 kg/ha [74]. The number of generative shoots and the number of seeds per panicle are the main yield components in smooth brome [75].

Smooth brome continues to attract growing interest as a valuable fodder crop, particularly in permanent grasslands. In the past, smooth brome was not regarded as an economically important plant, but water scarcity and the search for plant species and varieties that

easily adapt to adverse environmental conditions have increased the popularity of smooth brome among crop breeders [15,72]. The discussed species is characterized by stable yields due to its high tolerance to drought and its ability to adapt to novel environments [14].

In the group of cultivated grasses, smooth brome is characterized by a unique morphology of aerial biomass. Vegetative shoots are predominant in smooth brome stands, and similar to generative flowering shoots, they feature many leaves, which contributes to the high yields and high quality of the resulting forage [76]. Smooth brome can be cut several times per season, and it easily regrows after harvest, which is why it is often produced as a fodder crop on arable land [64,77,78]. According to Vasylenko et al. [20], the annual yields (three harvests) of smooth brome can reach 13 t DM. High yields have also been reported when smooth brome was grown intercropped with legumes [64,67]. The forage yields were even twice as high, and the nutritional quality of the forage improved considerably when smooth brome was grown in a mixture with small-seeded legumes [79]. When intercropped with smooth brome, alfalfa fixed twice as much nitrogen as alfalfa grown alone [80]. Research has also shown that greenhouse gas emissions were considerably lower in alfalfa and smooth brome mixtures than in alfalfa monocultures. Alfalfa and bromegrass mixtures also increased the carbon and nitrogen pool in soil relative to alfalfa monocultures [81]. The search for effective approaches to increasing carbon and nitrogen sequestration by crops poses one of the greatest challenges for contemporary agriculture. Various incentives have been introduced around the world to encourage the production of crops that fix atmospheric nitrogen and sequester large amounts of CO_2 [82–85].

6. Roles in Animal Nutrition

Smooth brome can be grown for hay, silage or grazing. Cattle, particularly beef cattle and small ruminants, as well as other herbivorous animals (horses and camelids), are frequently grazed on pasture. Grazing also plays an important role in dairy cattle production systems. Green forage has a high nutritional value, and it is cheap and easy to produce. In addition, grazed animals are physically active, have unlimited access to forage and are exposed to sun and fresh air, which improves their health and well-being [86,87]. The optimal pasture mix should offer well-matched grass species and varieties that are tailored to the animals' nutritional needs. Pasture grasses should have a high nutritional value; they should be palatable and resistant to trampling and frequent grazing. Forage grasses should efficiently utilize soil nutrients and be capable of rapid regrowth. Smooth brome is characterized by high palatability and digestibility, and it is willingly consumed by animals, particularly ruminants. It has a low content of crude fiber, a higher content of fat and protein of high biological value [79,80,88]. Smooth brome is a key component of pasture mixes due to its rapid spring growth, considerable persistence on pastures and a long life cycle [81,82]. It is also highly resistant to cutting and grazing [12,89].

Pastures with a predominance of smooth bromegrass are an excellent source of forage for cattle during the entire growing season. Daily weight gains are similar in cattle grazed on smooth bromegrass and other grass species [90]. In the tillering stage, the protein content of smooth bromegrass ranges from 230 to 244 g/kg. The protein content decreases in the second and third cuts, but smooth bromegrass remains an important source of protein in the animals' diets [20].

Smooth brome accumulates lipids, phosphatidylcholine and fatty acids. These compounds play an important role in the diet of Yakutian horses, especially in the fall, when these animals accumulate fat reserves. High levels of lipids in muscle tissues enable Yakutian horses to withstand extremely low winter temperatures [56].

During winter dormancy, smooth brome is an important source of forage for llamas. Smooth brome is characterized by higher biomass yields than those of other grass species, and it retains its high nutritional value in winter. Animals readily graze on this grass species during difficult winter conditions [91].

7. Protection of Fallow Land

Smooth brome is recommended for restoring fallow land. Bromegrass monocultures effectively protect valuable farmland. Cultivation does not lead to the depletion of soil nutrients [45,92,93]. This sod-forming grass densely covers soil and effectively inhibits the growth and germination of annual weeds [94]. Smooth brome tends to dominate over other plant species on fallow land, and it offers protection against weeds for many years [67] (Figure 7). Smooth brome does not require fertilization, and it can protect soil against nutrient leaching, which can be largely attributed to its extensive root system [47,92]. Smooth brome roots are able to draw water and nutrients from much deeper soil layers than other grass species, and nutrients are accumulated in roots to nourish young plants [29]. Fallow land should be optimally seeded with a mixture of smooth brome, fodder galega or hybrid alfalfa. On fallow land, smooth brome and legume mixtures should be established at a 1:1 ratio, which increases biomass yields relative to grass monocultures and eliminates the need for fertilization [95]. Smooth brome and fodder galega mixtures on fallow land are effective preceding crops in the production of cereals and rapeseed. The positive impact of these mixtures persists for three years after the plantation has been terminated [96]. On fallow land and in extensive crop farming, smooth brome grown alone or in mixtures with fodder galega and hybrid alfalfa also enhances biodiversity. Smooth brome is a tall grass species that offers shelter to many animal species, including larger animals such as hares and roe deer [95].

Figure 7. Set-aside land protected with smooth brome in the eighth year after sowing (May/June).

8. Reclamation of Degraded Areas

Smooth brome is recommended for reclaiming open-pit mines and landfills and for stabilizing soil in fire-damaged areas [28,44]. Bromegrass monocultures are also effective in reclaiming fly ash landfills enriched with sewage sludge from municipal wastewater. Sewage sludge overgrown by smooth brome triggers microbial activity in inert fly ash, and the produced organic matter acts as a sorbent that promotes the storage of nutrients and water [44]. Microorganisms play a significant role in the restoration of plant life in degraded ecosystems. Smooth brome promotes microbial growth and significantly increases the diversity of fungal and bacterial communities colonizing the soil surface, which are directly responsible for the availability of nitrogen, phosphorus and potassium. When sown in degraded areas, smooth brome quickly restores the ecosystems of many microbial species. The size and stability of microbial communities, particularly soil fungi, increase rapidly [97].

Pure-sown smooth brome thrives on fly ash, both deprived of organic matter and enriched with sewage sludge. In these conditions, generative shoots can grow to a height of 130 cm. The proportion of this grass species in the stand can reach 95%, and cover abundance is estimated at 8.3 on a 9-point scale. Other plant species are very rarely noted in smooth brome stands [44].

According to Antoniadis et al. [98], smooth brome can be effectively used in the phytoremediation of soils that are strongly contaminated with heavy metals. Majtkowski et al. [99] reported that smooth brome roots can accumulate significant quantities of heavy metals. Similar observations were made by Shi et al. [100], who found that smooth brome is exceptionally useful for removing aromatic hydrocarbons from soil. Smooth brome removes these pollutants more rapidly and effectively than other perennial plants, such as hybrid alfalfa. According to Shi et al. [101], smooth brome can decompose polycyclic aromatic hydrocarbons (PAHs) with four to six rings. This grass species significantly increases the activity of catalase and lignin peroxidase enzymes, which play a key role in the removal of high-molecular-weight PAHs (HMW-PAHs). Smooth brome has an extensive root system that penetrates soil to a depth of 1.4 m, which increases the effectiveness of phytoremediation, including the elimination of HMW-PAHs [47].

Due to its specific morphology, smooth brome can also act as an effective phytosanitary barrier. Davidson et al. [102] found that smooth brome can decrease the recovery of infective rotavirus particles in surface runoffs by 73% on average and delay the time to peak recovery by impeding surface flow and increasing the potential for infiltration into the soil profile.

9. Energy Generation

Tall perennial grasses, including smooth brome, meet the criteria for energy crops and can be used as renewable energy sources [89,90,103]. In comparison with other perennial grasses, smooth brome is more abundant in polysaccharides with a low degree of polymerization, and its biomass can be readily used as feedstock in biogas plants [43,104]. According to Martyniak and Żurek [105], the methane yield of smooth brome exceeds 6000 m^3/ha and is comparable with maize grown in the same area. Żurek and Martyniak [106] found that ensiled smooth brome is characterized by a much higher fermentation rate than maize, which speeds up biogas production. Smooth brome biomass has a high carbon content, and its calorific value and heat of combustion can reach 17.35 MJ/kg and 18.26 MJ/kg, respectively. These results indicate that smooth brome is highly suitable for energy generation [42,43]. The greenhouse gas emissions associated with the production of perennial energy crops, including smooth brome, are 3–13 times lower in comparison with those of fossil fuels or annual energy crops. These plants sequester more CO_2 to develop extensive root systems. The roots of perennial grasses accumulate significant amounts of organic carbon [82,107].

Waliszewska et al. [43] demonstrated that smooth brome has a higher ash content than other grasses, which does not undermine its energy value, and the obtained ash can be used as fertilizer. In turn, Bałuch-Małecka et al. [42] found that smooth brome, compared with other perennial grasses, was characterized by a low ash content and very low sulfur content after energy recovery. In perennial grasses, dry biomass can be obtained during harvest, which significantly decreases production costs in renewable energy generation. Smooth brome biomass can be converted to solid fuel (briquettes, pellets), and it is a good source of heating fuel. Biomass-based heating systems offer a promising solution on the bioenergy market [108–111]. Perennial energy crops, including smooth brome, also deliver important ecosystem services. These plants generate greater benefits for wildlife than annual crops such as maize. Plants that are harvested in smaller quantities several times during the growing season are less disruptive for animal ecosystems than crops that are harvested only once [46].

10. Prevention of Erosion and Buffer Zone Management

Smooth brome easily adapts to new environments, tends to dominate over other plant species in the sward, is more persistent than other grasses and has an extensive root system, which is why it is recommended for stabilizing slopes and protecting areas at a high risk of water and wind erosion [14,62,112]. In practice, smooth brome is frequently used to establish grass cover on embankments, escarpments, ditches and other earth structures [50].

Smooth brome has a very strong and dense root system. It produces dense roots, especially in the 0–10 cm horizon, which are characterized by a higher tensile strength than the roots of other grass species and increase the soil resistance to extreme loading [113,114]. These properties play a key role in controlling soil erosion. Smooth brome has fibrous roots that are strongly attached to soil, which increases sward stability and resistance, particularly to intensive surface runoffs [28,41]. According to Łyszczarz et al. [115], smooth brome is highly recommended for stabilizing escarpments and flood embankments. The cited authors noted that smooth brome is most effective in preventing soil erosion when sown in a mixture with legumes. Smooth brome is particularly useful for reinforcing the embankment base, which does not offer a supportive environment for plant growth. Cao et al. [116] have also suggested that smooth brome can be used to prevent soil erosion on unpaved roads where the traffic load does not exceed 300 vehicles per year. According to the cited authors, smooth brome offers a much cheaper and environmentally friendly solution for controlling road erosion than unbound aggregates.

Smooth brome can also be used to create buffer zones [41]. This grass species is very well suited for this purpose due to its ability to produce a thick ground cover that persists throughout the year, various tillering systems that promote the formation of strong and thick sod and dense turf and a long growing season that lasts from early spring to the late form, its ability to take up large amounts of nutrients utilized for tillering and biomass production and its ability to produce a fibrous root system that stabilizes plants in soil, increases turf resistance to surface runoffs and prevents erosion [41,117].

11. Paper Production

Smooth brome is also a highly promising resource for the paper industry. Paper is produced from lignocellulosic biomass that is derived mainly from trees, but due to limited wood resources, the biomass of rapidly growing plants, including perennial grasses, is increasingly often used in paper production [61,118]. According to many researchers, smooth brome is a good source of cellulose [118,119]. Various plants species that are a rich source of lignocellulosic biomass are being researched to decrease production costs and minimize the environmental impact of cellulose and paper production [120,121]. Smooth brome is considered as a cheap source of lignocellulosic biomass that can be processed into paper [118].

12. Directions for Further Research on Smooth Brome

- Improving the nutritional value of green fodder through breeding efforts by increasing the protein content and decreasing the fiber content of smooth bromegrass;
- The production of biomass for energy generation, particularly on weak and dryland soils;
- The development of low-input technologies for the production of smooth brome biomass with a minimal carbon footprint;
- The development of meadow and pasture swards composed of several plant species, including smooth brome, to enhance biodiversity;
- Expanding the geographic range of smooth brome based on its ability to adapt to difficult soil conditions and dominate over other plant species;
- The development of low-input, sustainable and energy-efficient technologies for the production of smooth brome biomass for the paper industry.

13. Summary

Smooth brome has been researched extensively in recent decades, which increased the number of potential applications of this grass species. Smooth brome is very well suited for sustainable farming and environmental protection. This grass species is an excellent source of green forage produced in both conventional and organic farming systems. Smooth brome is also a highly promising energy crop that can be processed in biomass incineration facilities and biogas plants, and the obtained ash and digestate can be used as agricultural fertilizers. In the future, smooth brome can largely replace wood pulp as an eco-friendly resource in paper production.

Despite the fact that smooth brome is an invasive species of perennial grass, it does not lead to the depletion of soil nutrients. In contrast, the long-term cultivation of smooth brome, particularly in mixtures with legumes, improves soil fertility and can promote the achievement of sustainable development goals.

Smooth brome fully meets the recommendations for the sustainable production of animal feed and bioresources, nutrient management and the protection of soils and atmospheric air. In line with the sustainable development paradigm, various eco-friendly technologies should be combined to produce high-quality feed and energy crops to effectively sequester CO_2 and improve soil fertility. Smooth brome can significantly contribute to the achievement of these goals in agriculture and environmental protection.

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