Phytodiversity and bioproductivity of the *Leymus chinensis* steppes in eastern Transbaikalia

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**Abstract.** The research objective is caused by wide spread of leymus communities in the southeastern Transbaikalia and gaps in studying their species composition, structure, and phytomass accumulation; it is to give a phytocenotic characteristics of leymus communities in the steppe zone of eastern Transbaikalia, and to determine the level of their biological productivity using standard geobotanical, agrochemical and soil methods. The paper studies monodominant *Leymus chinensis* communities growing on various soil types of meadow steppe, steppe floodplain meadows and haloxerophytic steppe of the south-eastern Transbaikalia. The species composition of communities is represented by 21 families, 45 genera, 62 species. Halophytes account for 11.3 % (7 species), halotolerant – 29 % (18 species), glycophytes – 59.7 % (37 species). The species of the families Asteraceae – 30.6 %, Poaceae – 17.7 %, Rosaceae – 8 % form the largest share in the projective cover of communities. The rest families are of 1–2 species. The species composition of Leymus is represented mainly by the steppe complex with xerophytes different variants belonging to the Asian type of area. The main part belongs to rhizome species in the biomorph composition, and the share of annuals and biennials is significant as well. The similarity between communities is within the range from low to medium, which is due to the great participation of single-species families and genera. The authors have assessed the contribution to aboveground phytomass of a dominant species, *Leymus chinensis*, other species and died grass. The greatest contribution of ears to the aboveground phytomass is marked only in Descriptions 4 and 5. The primary production of *Leymus chinensis* communities is estimated as high, 2105–3189 g/m² a year. Underground phytomass is 84–94 % of the total productivity. The underground and aboveground phytomass ratio is 1:5–15, that is determined by various soil and environmental conditions of growing the communities.

1. Introduction

Steppes with *Leymus chinensis* (Trin.) Tzvel.) are the most spread plant associations in eastern Transbaikalia and Mongolia [1]. *Leymus chinensis* is a part of almost all coenoses in eastern Mongolia [2–3]. Currently, steppe pastures are degrading in Mongolia; however, in moist sites, *Leymus chinensis* retains its abundance from I to IV digression stages, and is digestively active species [4–6].

The study state of leymus coenoses and their phytocenotic characteristics in eastern Transbaikalia, including the Agin Steppes, is poor. However, there are data on the biological production of proper steppe communities with *Leymus chinensis* growing on the chernozems of southeastern Transbaikalia (the Kharanor Steppe) obtained in the second half of the 20th century [7]. This species is noted to describe vegetation or floristic composition as an accompanying permanent component of grass coenoses [8–12]. There are investigations of the adaptation of species forming coenosis (Bromopsis...
inermis, Stipa capillata, Leymus chinensis) in eastern Transbaikalian steppes to the habitat due to changes in reproductive functions and productivity of Leymus chinensis [13]. The research objective is to give a phytocenotic characteristics of the leymus communities in the steppe zone of eastern Transbaikalia, and to determine the level of their biological productivity under the climate aridization conditions.

2. Materials and Methods
The study was carried out in the steppe zone of the Transbaikal Region in 2019. The objects were mono-dominant leymus coenoses growing on various soil types (table 1).

Table 1. Leymus coenoses of eastern Transbaikalia.

| Number of descriptions, soil | Geographic coordinates | Total projective cover, % | Leymus projective cover, % | Number of species | Co-dominants |
|-----------------------------|------------------------|---------------------------|---------------------------|------------------|-------------|
| 1, typical saline           | N50.93630° E115.41905° h – 635.5 m | 80 | 55 | 19 | Artemisia anetifolia Web. ex Stechm. |
| 2, lithosol light-humus     | N50.86464° E115.46143° h – 692.9 m | 90 | 70 | 16 | Carex duriuscula C.A. Meyer |
| 3, lithosol light-humus     | N50.86435° E115.46164° h – 707.5 m | 95 | 80 | 24 | Thesium longifolium Turcz. ex Ledeb. |
| 4, alluvial light-color-humus quasi-gley | N50.86311° E115.46511° h – 691.2 m | 85 | 70 | 20 | Equisetum arvense L. |
| 5, alluvial light- humus quasi-gley | N51.04865° E114.37504° h – 702.1 m | 65 | 40 | 17 | Carex duriuscula |
| 6, alluvial humus stratified | N50.47533° E114.02410° h – 671.3 m | 55 | 40 | 9 | Potentilla bifurca L., Carex duriuscula |

The site choice is conditioned by the large area of grass ecosystems: hayfields make up 98,973 ha, pastures cover 247,608 ha in the Olovyannin District; and 55,746 and 326,467 ha the Agin District, respectively. Average long-term precipitation is 325 mm, and 306 mm during the growing season in the studied areas. The total precipitation for the research period in May-September was 309 mm. It should be noted the extremely uneven precipitation in southern Transbaikal Region due to prolonged aridization.

The soil properties and their supply with nutrients were carried out according to [14]. The soils differed in pH, granulometric composition, cation exchange capacity, and humus content. The degree of soil provision with nitrate nitrogen under leymus communities is low and very low; mobile phosphorus – average, except for Community 4; exchangeable potassium – mostly low.

Determining the projective cover and species abundance in the communities was carried out according to Brown Blanc on a 100 m² plot (10 × 10 m). The plant names are given according according to O.A. Anenkhonov et al. [15]. To assess the similarity of the species composition of leymus communities, the following gradations of coefficient values were used [16]: from 0 to 0.3 – weak, from 0.4 to 0.6 – average, from 0.7 to 1.0 – high, 1.0 – complete similarity. The species similarity was calculated using the Sorensen coefficient [17]:
The species resistance to salinity was established by using a saline habitat flora compendium [18]; and biomorphs – by I.G. Serebryakov [19]. The above- and underground phytomass reserves were determined in the third decade of July. The root mass maximum reserves and grass highest productivity occurred at this period. The grass stand was cut near the land surface at 50 × 50 cm plots in 5 replicates. The underground mass reserves in the communities were studied by the monoliths’ technique followed by washing on soil sieves. Soil monoliths were sampled in each coenosis at three 25 × 25 cm plots, layer by layer every 10 cm to 20 cm depth in 3 replicates. The aboveground mass and washed roots were dried to air-dry state and weighed. The biological productivity was estimated according to R. Whittaker gradation [20]. Statistical data processing was carried out in Microsoft Excel.

3. Discussion of results

3.1. Phytocenotic characteristics of leymus coenoses

The species composition of the studied leymus coenoses is represented by 62 species belonging to 21 families (table 2, figure 1). Asteraceae (19) and Poaceae (11) are classified as multi-species families. Rosaceae is presented by 5 species. The number of genera is 45: the genera Artemisia (9) and Potentilla (4) are multi-species; the genera Heteropappus, Poa, Carex are two-species, the rest genera – single-species. The species participation of families to form the productive cover and productivity of Leymus communities belongs mainly to multi-species families, but to create the diversity – to single-species ones. 11.3 % of the total number of species in leymus coenoses are attributed to halophytes, 29.0 % – to halotolerant glycophytes, and 59.7 % – to glycophytes. It should be noted that Leymus chinensis has a bluish color in Description 3, whereas plants with a bluish color in all other communities are interspersed with small contours among the green color.

| Family         | Number of descriptions | Family         | Number of descriptions |
|----------------|------------------------|----------------|------------------------|
| Poaceae        | 4 4 7 2 7 1            | Alliaceae      | 1 2 1                  |
| Asteraceae     | 7 3 3 8 4 3            | Santalaceae    | 1 1 1                  |
| Chenopodiaceae | 2                      | Fabaceae       | 1 1                    |
| Cyperaceae     | 1 1 1 2 1              | Apiaceae       | 1 1 2                  |
| Iridaceae      | 1                      | Caryophyllaceae| 1                      |
| Polygonaceae   | 1 1                    | Dipsacaceae    | 1                      |
| Rosaceae       | 1 2 2 2 2 1            | Equisetaceae   | 1                      |
| Plantaginaceae | 1                      | Asparagaceae   | 1                      |
| Juncaceae      | 1                      | Onagraceae     | 1                      |
| Ranunculaceae  | 1 2                    | Brassicaceae   | 1                      |
| Rubiaceae      | 1 1 1 1 1              |                |                        |

The taxonomic diversity of leymus coenoses is insignificant. Its parameters expressed by the ratios of the number of species to the number of families (s/f), the number of species to the number of genera (s/g), and the number of genera to the number of families (g/f) are 3.0, 1.4, and 2.1, respectively. This ratio is determined by habitat conditions of leymus coenoses, including climatic ones. For example, the total flora of the Ivolgin Depression in western Transbaikalia is characterized with 8.7, 2.3, 3.8 value, respectively [21].

\[ Ks = \frac{2c}{a+b} \times 100, \]  

where: \( c \) – a number of species common in two coenoses; \( a \) – a number of species in a coenosis; \( b \) – a number of species in another coenosis.
Figure 1. The share of family species forming leymus coenoses, % of the total number of species.

The analysis of Sørensen's coefficient values revealed a weak similarity in the species composition in Descriptions 1, 4, 6. This is due to different soil and environmental conditions of growing *Leymus chinensis* coenoses: haloxeromorphic steppe, steppe meadows. Leymus cenoses of Descriptions 2, 3, and 5 were characterized by an average level of similarity, which is related to their growth under alike conditions of meadow steppe. Thus, the similarity of the species composition of leymus coenoses is low (weak or average), characterizing them as ecologically heterogeneous [10].

As there are no phytocenotic characteristics of *Leymus chinensis* coenoses in eastern Transbaikalia, the authors considered it necessary to provide data for each description (figure 2–5), but the data analysis is generalized for the entire species composition. First of all, the character features of the edificator of *Leymus chinensis* coenoses are given: it is a member of the latitudinal forest-steppe group, xeromesophyte, belongs to the Central Asian type of the area, and is presented by long-rhizome biomorphs.

The distribution of the species composition of leymus coenoses by main ecological-coenotic elements is shown in figure 2. It has been revealed that the species of steppe group (proper steppe, mountain-steppe, desert-steppe) in the communities vary from 40.0 to 58.8 %; forest-steppe – from 26.2 to 44.4 %. Meadow groups are represented by 1–3 species.

The analysis of the species composition by ecological groups has shown that the natural habitat conditions of leymus coenoses determine the growth of predominately mesoxerophytes and xeromesophytes (figure 3). Their share is rather high – 52.9-75.0 of the total number of species. Eumesophytes are presented from 4.2 to 11.8 %, or 1–2 species, in the leymus steppe communities. However, this group proportion is significant in Descriptions 1 and 4, and reaches 21.0 and 30.0 %, respectively, which is related to better moisture conditions for plants located in depressions. The most variable euxerophyte group is from 15.0 to 33.3 %.

The plant species composition of the leymus coenoses belongs to 9 types of geographic ranges, in some coenoses – to 6–9 ones (figure 4). The Asian group of habitats has the largest number of species, from 43.8 to 54.3 %. The second most widespread is the Eurasian habitat – from 8.0 to 22.2 %. The lowest number of species (2) of this habitat is presented in Description 3. The maximum number of species of the South Siberian and Mongolian area is revealed here as well. Only 1–2 species belong to the Manchu-Daurian area (Descriptions 3 and 4). 1–2 species are attributed to the Holarctic area, except for Description 4, where this type is represented by 5 species.

The biomorphological composition of leymus coenoses is characterized by a wide diversity and variability, 4-8 forms (figure 5). The study has identified 2 groups of biomorphs differ in vegetative mobility. The proportion of vegetative immobile species – spur-root, dense-shrub and loose-shrub grasses varies in frames 22.0–50.0 % of the total number of species. This group of species is character for steppes, and able to use water of different soil horizons.
Figure 2. Ecological-cenotic composition of the species of leymus coenoses, % of the total number of species.
Groups: PS – proper steppe; MS – mountain-steppe; DS – desert-steppe; FS – forest-steppe; Md – meadow; LC – light coniferous; Rr – riverine.

Figure 3. Ecological structure of leymus coenoses related to humidity, % of the total number of species. EX – euxerophytes; MX – mesoxerophytes; XM – xeromesophytes; EM – eumesophytes; HM – hygromesophytes.
Figure 4. Representation of species in leymus coenoses by the type of area, % of the total number of species. HA – Holarctic; PA – pan-Asian; CA – Central Asian; EA – East Asian; NA – North Asian; EA – Eurasian; ES – Euro-Siberian; SS – South Siberian; AA – American-Asian; MD – Manchu-Daurian.

Figure 5. Biomorphological structure of leymus coenoses, % of the total number of species: LR – long-rhizome; SR – short-rhizome; SpR – spur-root; LS – loose-shrub; DS – dense-shrub; Bul – bulbous; SLC – short life cycle (annuals, biennials); SS – subshrub.

The vegetative mobile biomorphs include long and short rhizome species, which account for 41.1–50.0 % of the total number of species in the coenosis. The rest of the perennial biomorphs are...
represented by one or two bulbous species (Descriptions 2, 3, 5). Subshrubs are only in coenoses of Descriptions 3 and 5. The largest portion of annuals and biennials is in Descriptions 1 and 6 (21.0 and 33.0 %), which can be an indicator of instability and dynamism of the ecological conditions of leymus coenoses.

3.2. Biological productivity

The biological productivity is an integral parameter of the environmental and soil conditions of functioning a coenosis.

According to R. Whittaker [20], the biological productivity of leymus coenoses is estimated as high, 2105–3189 g/m² a year, which is due to sufficient precipitation in May-September in the studied year and previous ones (table 4). This phenomenon is not typical for Transbaikalian steppes. The underground phytomass is 84.0–94.0 % of the total productivity. Different ratio values of the aboveground to underground phytomass is the diversity consequence of species and biomorphological compositions, grass density, as well as the degree of external factor effects (grazing). The underground phytomass excess aboveground one as 1:5–15. The share of aboveground phytomass is 3.9–9.0 % of the total primary productivity, its main part (55–80 %) is formed by the dominant – Leymus chinensis.

Alluvial soddy soils, on which floodplain steppe communities predominantly grow, differ considerably in the content of humus, nitrogen, particle size distribution and water availability, that has a great impact on the coenosis bioproductivity. The same effect is noted for leymus coenoses on saline soils, where the decisive role is played by the accumulation of freely soluble salts in the root layer of soils determining the grass density and coenosis species composition (table 3). The aboveground phytomass production of Leymus chinensis reflects the soil-ecological conditions of plant growth. The leymus phytomass was maximum in Description 2, and a bit lower in Description 3. Decreasing the aboveground phytomass in other coenoses is 1.4–2.7 times compared to Description 2.

Table 3. Biological productivity of leymus coenosis phytomass (above the line – g/m², below the line – % of aboveground phytomass).

| Number of descriptions, soil | Primary production aboveground | Underground (0–20 cm) | Total | Aboveground Underground |
|-----------------------------|--------------------------------|-----------------------|-------|------------------------|
|                            | Leymus chinensis               | other species         | died grass |                     |
| 1, typical saline           | 142±33.3                       | 25±7.1                | 36±7.9 | 1902±339               | 2105 | 1:9                   |
|                            | 70                             | 12.3                  | 17.7   |                        |      |                       |
| 2, lithosol light-humus     | 289±43.2                       | 57±9.8                | 62±11.2| 2651±203               | 3059 | 1:6                   |
|                            | 70.8                           | 14.0                  | 15.2   |                        |      |                       |
| 3, lithosol light-humus     | 263±26.4                       | 52±8.1                | 103±22 | 2096±81                | 2514 | 1:5                   |
|                            | 62.9                           | 12.4                  | 24.6   |                        |      |                       |
| 4, alluvial light-humus quasi-gley | 208±19.0               | 28±4.8                | 81±10.7| 2872±263               | 3189 | 1:9                   |
|                            | 65.6                           | 8.8                   | 25     |                        |      |                       |
| 5, alluvial light-humus quasi-gley | 108±8.8                | 76±7.8                | 11±3.2 | 2348±86                | 2543 | 1:12                  |
|                            | 55.4                           | 39.0                  | 5.6    |                        |      |                       |
| 6, alluvial humus stratified | 114±4.6                        | 26±3.1                | 3±0.4  | 2134±215               | 2277 | 1:15                  |
|                            | 79.7                           | 18.2                  | 2.1    |                        |      |                       |

The structure of plant organs has a great effect in forming the aboveground mass of Leymus chinensis. The largest share belongs to leaves (44.0–63.0 %) and stems (35.0–42.0 %). A significant participation of ears in the production of Leymus chinensis is revealed only in coenoses of Descriptions 4 and 5 (10 and 14 % correspondingly).

The seed productivity is influenced by the age of an individual plant, flowering duration, meteorological conditions, especially precipitation in autumn and spring-early summer. Along with a high potential seed productivity of Leymus chinensis varying from 74.1 to 116.7 units/shoot in
different coenoses, the real seed productivity is twice as low, sometimes – 8–10 times (table 4). The seed productivity coefficient varies from 7.5 to 57.8 % in different communities. This value is higher in the steppe zone of eastern Transbaikalia than in dry steppes of western Transbaikalia [22].

The species have different vegetating phenotypes, and died plants are usually formed by the species of spring–early summer development. The litter accumulation differs significantly in each community from others (table 3). Its variability reaches 34 times (Descriptions 3 and 6). Died plants are the base to form steppe felt. Therefore, its content is of great importance in communities functioning in at various soil and environmental conditions.

Table 4. Seed productivity of *Leymus chinensis* in southeastern Transbaikalia.

| Coenosis | Plant height, cm | Ear length, cm | Spikelet number, pcs. | Number of flowers per a spikelet, pcs. | Seed productivity, potential (PSP) pcs/stem | Seed productivity, real (RSP) | Productivity coefficient, RSP/PSP, % |
|----------|-----------------|----------------|-----------------------|----------------------------------------|---------------------------------------------|-------------------------------|-------------------------------------|
| 1        | 54.2±1.4        | 8.3±0.3        | 18.9±3.2              | 4.3±0.4                                | 81.6±17.0                                  | 8.6±3.7                       | 10.5                                |
| 2        | 56.7±2.1        | 10.2±0.4       | 24.1±2.8              | 4.8±0.2                                | 116.7±10.0                                 | 36.9±5.0                      | 31.6                                |
| 3        | 60.3±2.2        | 10.7±0.5       | 23.6±3.0              | 4.3±0.4                                | 100.9±7.2                                  | 58.4±4.8                      | 57.8                                |
| 4        | 64.1±2.4        | 9.9±0.7        | 21.0±3.0              | 3.8±0.7                                | 80.8±18.9                                  | 42.2±3.2                      | 52.3                                |
| 5        | 48.7±2.7        | 7.7±0.5        | 16.3±1.5              | 4.6±0.3                                | 74.1±7.0                                   | 10.6±5.4                      | 14.4                                |
| 6        | 45.9±2.8        | 9.3±0.6        | 21.8±2.4              | 4.4±0.4                                | 95.4±14.8                                  | 7.1±3.2                       | 7.5                                 |

4. Conclusion
The study covers monodominant leymus communities growing on different soils of meadow steppe, steppe floodplain meadows, and haloxerophytic steppe in southeastern Transbaikalia. The species composition of coenoses is represented by 21 families, 45 genera, 62 species. Halophytes make up 11.3 % (7 species), halotolerant – 29 % (18 species), glycyphytes – 59.7 % (37 species). The largest share in forming the projective cover of coenoses belongs to species of the families: *Asteraceae* – 30.6 %, *Poaceae* – 17.7 %, *Rosaceae* – 8.0 %. The rest of the families are of 1–2 species. The similarity of the species composition is low – weak or average. The species composition of leymus coenoses is represented mainly by the steppe complex with different variants of xerophytes of the Asian type of habitat. The main share of the biomorph composition is presented by rhizome species, and the portion of annuals and biennials is significant as well. The similarity between the coenoses is in frames “weak – average” due to the significant participation of single-species families and genera. The primary production of leymus coenoses is assessed as high, 2105–3189 g/m²/year. The edificator contribution to form the aboveground phytomass was 55.4–79.7 %, the other species share was 8.8–39.0, and died grass – 2.1–24.6 %. The greatest contribution of ears to the aboveground phytomass production is marked only in Descriptions 4 and 5. The coefficient of seed productivity has the highest value of 52–58 % in Descriptions 3 and 4, in the rest – 7.5–14 %. The underground phytomass is equal 84–94 % of the total productivity. The excess of the underground phytomass over the aboveground one is 1: 5–15.

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