On Rhythm-Types in the Development of Boreal Cereals

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Abstract: The article examines the ecological attributes of the seasonal development of boreal cereals: the rhythmicity of the development of cereals, the attributes of the formation of the leaf surface, the attributes of the development of renewal buds, the rhythmicity of the vegetative and generative phases and the duration of active vegetation and dormancy. The author has determined the attributes of the development of boreal cereals and worked out classifications for their rhythm-types. The author has come up with new schedule charting systems reflecting the rhythm of the seasonal development of boreal cereals.

Key words: Poaceae • Ecology • Boreal cereals • Seasonal development • Rhythm-types • Phenophases

INTRODUCTION

Boreal vegetation is an aggregate of vegetative communities associated in their distribution with the taiga of the temperate zone of the Northern Hemisphere. It includes various communities genetically related to dark and light coniferous forests. Thanks to their high level of adaptiveness, cereals (Poaceae) make up the base of the majority of meadows in all botanico-geographical zones [1]. However, the mechanisms behind these adaptations have not been adequately explored as yet. The scanty publications available at the moment, including foreign works on this area, are devoted to cultural plants, while there appears to be paucity of research exploring wild-growing species, especially boreal cereals [2]. That being the case, the issue of exploring the ecological and biological attributes of the development of wild-growing cereals appears to be topical and resolving it will greatly contribute to our apprehension of the adaptation characteristics of plants in a particular habitat.

The aim of our studies was to explore the ecological attributes of the seasonal development of boreal cereals and determine their rhythm-types. Our objective was to come up with a new schedule charting system reflecting the rhythms of the development of boreal cereals.

Methods: Our field trips and expeditions, which made up the bulk of our work, were conducted throughout the boreal zone of the European part of Russia. In addition, stationary observations were conducted with regard to feed cereals and grain cereals by way of continuous sample taking and determination of biometric indicators. Vegetative experiments were conducted at the State Budgetary Educational Institution of Supplemental Children’s Learning of the Republic of Mordovia “The Republican Center for Supplemental Children’s Learning”. Phenological observation methods were employed in studying the development of cereals. Field studies included observing the development of particular species in natural swards. The study included observing plants’ development by the seasons of the year on land-parcels under the stations in sown and “natural” pastures, conducting growing in field conditions and in vegetative vessels with subsequent laboratorium inspection (every 5-7 days), determining biometric parameters and describing plants’ state. In some experiments, one takes out the whole plant (up to 10-12 specimens of each species), describes it and records the data for in-depth study. In our research, we go by the methodology by I.G. Serebryakov (1954) [3].

This work summarizes the results of out studies into the development of boreal cereals spanning the vegetative seasons of 2009-2012.
Main Part: Our observations of the vegetation of cereals indicate that seasonality in their development is to a large extent defined by ecological conditions. With most cereals, the curve reflecting the formation of elongated vegetative and generative shoots is characterized by two summits: its first rise is observed in late spring and the first half of fall, which is associated with the regimen of precipitation. The duration of vegetation and dormancy during the year varies for cereals and changes differently under the influence of ecological conditions [4-8]. In our observations of the development of cereals, we examined the formation of leaves, the positioning of renewal buds, the rhythms of vegetation blossoming, as well as the duration of active vegetation and dormancy.

Let us examine the data obtained. We believe that the character of the rhythm of the seasonal development of cereals investigated directly depends on the temperature regimen and dampness of soil. In 2010, plant vegetation was taking place in conditions of drought – therefore, all indicators were higher than average. While in 2009, due to low temperatures and insufficient amounts of precipitation, the same indicators were lower than average. Thus, the life potential of wild-growing cereals is quite high, which leads us to presume that in the process of evolution plants work out certain adaptation properties that enable them to sustainably exist in extreme conditions of the environment.

We subsume boreal cereals into several groups depending on terms for completing the main phenophases of development and growth. The first and largest group is composed of species which demonstrated just slight fluctuations in the dates phenological phases occurred in the course of the years observed – 5 to 7 days. The group includes plants from different ecological groups and of various life forms, which attests to high adaptation capabilities of these species (Poa pratensis L. s. 1., Phalaroides arundinacea (L.) Rausch., Stipa sp., Festuca pseudovina Hack. ex Wiesb., etc.). The second rhythmological group deals with so-called “unsustainable species” whose earing phase occurs at specific times year after year despite their unsustainability in terms of completing their spring phenophases. It includes species from various ecological groups which reproduce both by seeds and vegetatively. The spring development of these plants can vary in different years by 9 ± 3.2 days (Elymus caninus (L.) L., Poa nemoralis L., Alopecurus arundinaceus Poir.).

There have been a number of ecological studies on the periodicity of the development of assimilating leaves [9, 10, 2]. On non-irrigated lands, based on the dynamics of the development of leaves and analysis of attributes of growth boreal cereals can be subsumed under the following rhythm-groups: summertime and wintergreen plants. Summertime green plants remain green from spring till fall (Poa palustris L., Hordeum brevisubulatum (Trin.) Link) and summer-and-wintergreen plants are species that remain green throughout the year, but compared with evergreen plants they develop two specialized generations of leaves – summertime and wintertime, which alternate throughout the year (Poa pratensis, Festuca pseudovina, Alopecurus arundinaceus). Summertime green plants have the larger percentage in the forest vegetation zone, which is characterized by there being one generation of leaves. In transition to the steppe zone, there is an increase in the percentage of summer-and-wintergreen species with two generations of leaves. However, it should be noted that in the forest zone there grow species with two generations of assimilating leaves too. In that way, meadows ecologically drastically differ from zonal types of vegetation. Summertime and wintergreen plants with two generations of leaves are widely common in the steppe and forest-and-steppe zones. In investigating the intensity of shoot-formation of particular species (Phleum pratense, Festuca pseudovina), the fall generation of leaves was, as a rule, more powerful than the spring one, which let the species grow in spring.

Often time buds, rootstocks and other organs of vegetative renewal, having reached the soil surface, form rosette-like vegetative shoots in the middle of the second half of summer or at the beginning of fall. Thus, the second generation of leaves is formed during the vegetation period, which produces regrowth (Dactylis glomerata L.). Second generation leaves remain green during the winter period and spring shoot-generation leaves die down as early as the end of summer or fall (Poa pratensis, Phleum pratense, Alopecurus pratensis, etc.) (Figures 1, 2).

Data on the rhythms of the seasonal development of plants are also illustrated through figures and charts. We have created new scheduling systems, having derived particular elements from older systems [3]. Thus, each species is assigned a separate row. The second column of the schedule chart is broken up into 12 equal spaces to denote the months of the year. The double vertical lines denote a period of snowfall and formation of a new mantle of snow, during which no plant vegetation occurs. The curves denote changes in the leaf surface during the vegetation period. All the curves start at the unfolding of buds and end at the dying down of the given generation of leaves. Curves can help determine the number of leaf generations during the year, the presence or absence of
Fig. 1: A chart of the seasonal development of cereals from mixed forests

<table>
<thead>
<tr>
<th>Species</th>
<th>Months</th>
<th>Buds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elymus caninus (L.) L.</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12</td>
<td></td>
</tr>
<tr>
<td>Brachypodium hybridum (Roth)</td>
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<td></td>
</tr>
<tr>
<td>Brachypodium hybridum (L.) Roth</td>
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<td></td>
</tr>
<tr>
<td>Calamagrostis arundinacea (L.) Roth</td>
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<tr>
<td>Festuca gigantea (L.) Vill.</td>
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<td></td>
</tr>
<tr>
<td>Festuca altissima All.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melica nutans L.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melica nutans L.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poa nemoralis L.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

changes in the leaf surface | beginning and end of flowering
fruit and seed ripening and formation | open buds
closed buds | buds expanding partially

Fig. 2: A schedule of the seasonal development of cereals of forest clearings

<table>
<thead>
<tr>
<th>Species</th>
<th>Months</th>
<th>Buds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthoxanthum odoratum L.</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12</td>
<td></td>
</tr>
<tr>
<td>Betula media L.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calamagrostis epigejos (L.) Roth</td>
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<td></td>
</tr>
<tr>
<td>Dactylis glomerata L.</td>
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<td></td>
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<tr>
<td>Hierochloe odorata (L.) Beauv.</td>
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<tr>
<td>Ptilium pratense L.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

changes in the leaf surface | beginning and end of flowering
fruit and seed ripening and formation | open buds
closed buds | buds expanding partially

leaves during the winter period, the relative surface area of leaves remaining for the winter period (the leaf surface of the summer origin is taken as 100 %), the character of leaves remaining for winter, preserved spring-and-summer leaves and winter generation leaves and the lifespan of leaves of different generations.

Let us examine the way processes of the development of renewal organs are reflected in our charts. The time for the formation of bud scales or other forms of lower leaves is denoted with a dotted line. The period of initiation of the primordia of green leaves of the future year is denoted with horizontal dashes and the period of
initiation and formation of the elements of inflorescences and florets is illustrated in the form of flower bud symbols. Charts also make it easy to see plants with inflorescences and florets initiated ahead of time and plants that do not have such properties. We also use the symbols proposed by V.V. Alekhin (1933) to denote the beginning and end of flowering, the ripening of fruits and seeds and semination [11]. Such charts give us an idea of the ratio between the flowering and development of the leaf apparatus. Symbols denoting the character of renewal buds (open – devoid of the bud envelope and closed – with special bud envelope-scales) are provided to the right of the schedules. Thus, schedule charts for different ecotopes illustrate differences between them based on the rhythms of development.

Observations of the positioning of renewal buds in plants in a period of adverse conditions revealed that there are considerable differences between species, which leads us to point up the following groups: 1) Group I: renewal buds are located at the soil surface or close to it (near-the-ground buds of elongated shoots, buds of the tillering zone) and are protected against drying up by a mass of leaves and specialized scales; these are loose-turf rosette-forming and compact-turf cereals (Brachypodium sylvaticum, Poa bulbosa L.); 2) Group II: renewal buds are located not deep in soil (buds of rootstocks and tillering zones) and on the surface (stolon-forming shoots); are protected against drying up by shortened leaf films; these are rhyzomatous-stoloniferous, loose-turf-stoloniferous and loose-turf cereals (Agrostis stolonifera L., Dactylis glomerata, Bromopsis inermis, Alopecurus arundinaceus, Melica transsilvanica Schur, etc.); Group III: renewal buds are quite deep in soil (on rootstocks and in the tillering zone); these are long-rootstock cereals (Calamagrostis epigeios (L.) Roth, Calamagrostis arundinacea, Phalaroides arundinacea, Festuca rubra, etc.).

The vegetative phase begins in boreal cereals quite early. In species with on-surface bud positioning, it overlaps with first spring rains. Spring in the European part of Russia passes relatively quickly. It lasts for 69-71 days. The spring period sees 75-80 mm of precipitation. The maximum of the accumulation of biomass overlaps with plants’ entering the generative phase. Not all species have the same kind of transition from one phase into another.

Based on rhythms of vegetation and flowering, boreal cereals can be divided into the following rhythm-types: 1) plants of summer growth and fall flowering, which are characterized by having narrow ecological potential (Molinia caerulea (L.) Moench, Melica altissima L., Calamagrostis epigeios) and are distinguished by the formation of powerful rootstocks or stretched tillering zones and the formation of generative organs at the end of dry and beginning of humid seasons (from September till January-February), rosetteless plants;
are characterized by a marked short-day reaction (11-12 hours); 2) plants of spring-and-summer growth and development, which are characterized by having narrow ecological potential which is attributable to the need for the development of high temperatures (Poa pratensis, Elymus repens (L.) Nevski, Alopecurus arundinaceus, Dactylis glomerata, Bromopsis inermis, Festuca pratensis, etc.). In conditions of relatively long days (up to 16 hours in July and high temperatures (+26-+32°C, at times up to +35°C) in the summer period, plants actively complete all the phases of the vegetative and generative cycles and form shoot structures characteristic of them. In the winter period, with days being shorter than 8 hours and temperatures decreasing (–4°C down to –9°C in the nighttime), plants mainly form shortened shoots. This group includes both wild-growing (Poa pratensis, Elymus repens, Alopecurus arundinaceus, Dactylis glomerata, Bromopsis inermis, Festuca pratensis, etc.) and cultural cereals (Zea mays L., Secale cereale L).

Cereals are characterized by a distinct rhythmicity in forming generative organs, which is mainly attributable to the temperature regimen [12]. According to the findings of our observations, cereals form the maximum of biomass in conditions of high temperature and humidity (June-September). In growing Festuca orientalis (Hack.) V. Krecz. et Bobrov and Dactylis glomerata with no additional lighting in greenhouses where air temperature in the spring months is on average 5-7°C higher and diurnal fluctuations are smaller than in the field, generative shoots form as early as May (1-1.5 months earlier than in the field). In fall, cereals vegetate in the greenhouse approximately a month longer than in the field. In periods of lower temperatures, cereals enter a state of dormancy. Their renewal buds are quite deep in soil.

Cereals are also characterized by rhythmicity in forming the above-ground organs (Figure 3).

CONCLUSION

Lower temperatures in spring inhibit the growth of cereals and in fall cause the growth to cease. High temperatures in fall facilitate considerable prolongation of cereal vegetation, whereas lower temperatures first stop the growth and then cause them to enter a state of forced dormancy which generally lasts from 3.5-4.5 to 4-5 months. The degree of markedness of the rhythms of development of cereals correlates with the breadth of their ecological potential. Cereals with a marked development rhythms in Southern regions of the CIS cannot cope with low winter temperatures and die down. In the majority of species in the rest of the rhythm-groups, stems and leaves die down in winter.

Inferences: Based on the ratio of periods of growth and dormancy, boreal cereals can be divided into four groups:

1) those that begin their vegetation early and finish it early (Elymus caninus, Festuca rubra, Festuca pseudovina, Stipa sp., etc.); 2) those that begin their vegetation early and finish it late (Poa pratensis, P. trivialis L., Dactylis glomerata, etc.); 3) those that begin their vegetation late and finish it late (Alopecurus pratensis, Agrostis gigantean, Bromopsis inermis, Brachypodium sylvaticum, etc.); 4) those that begin their vegetation late and finish it early (Festuca altissima, F. pratensis, Lolium perenne L.).

Plants in the first group turned out to be the least winter-hardy, spreading in steppe areas; plants in the second-fourth groups are more cold-hardy. The first group copes poorly with low temperatures and most of its interesting forms in the South of the CIS can only be grown as annuals.

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REFERENCES


