The vertical structure of clover-cereal and cereal meadow grasses depending on their composition, mowing period and growing conditions in the Novgorod region of the North-West of Russia

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Abstract. Data are presented on the study of the influence of the composition of meadow cenoses, the term of their mowing, and the dose of mineral nitrogen on the distribution of phytomass along the height of clover-grass and grass meadow grass stands. It has been experimentally proved that the composition of agrocenoses, their mowing time and growing conditions have a great influence on the vertical distribution of the vegetative mass of meadow grass stands. For mowing use on medium-acid soils of heavy mechanical composition, legume-cereal grass with hybrid clover included in its composition is most suitable. On average over the years of research, this meadow agrocenosis cropped from the full budding phase to the full bloom phase is characterized by the most uniform phytomass distribution over the height of the grass stand. In addition, it was experimentally confirmed that the introduction of mineral nitrogen fertilizing under cereal meadow grass stands contributes to a more even distribution of vegetative mass along the agrocenoses height. When nitrogen is applied in a dose of 120 kg per 1 ha under cereal grass stand, there is a significant shift of the “center of equilibrium” up the height of the grass stand and a reduction in the amount of phytomass in the lower tier compared to unfertilized cereal agrocenosis, which is important when mowing grass meadows.

1. Introduction
The plant community is a collection of plants that are in a continuous, complex and diverse relationship. These relationships are built on the basis of plants’ struggling for existence [1].

The environment of phytocenoses is a combination of plant growth factors. Any change causes corresponding changes in the life of all components of the plant community. The structure of the plant community and the relationships within it are in close dialectic unity. Any change in the system of relations between plants and the environment causes a change in the structure of the community, and any change in the structure, usually caused by external factors, affects the relationship between the environment and plants [1, 4].

Knowing the basic laws of plant relationships in phytocenoses, it is possible to regulate certain features of plant communities in order to use them most rationally. Phytocenosis can manifest itself in tiers, that is, the placement of plants in a vertical plane. The vertical distribution of the aerial mass of meadow grass stands is an external manifestation of the relationship of plants with each other and environmental conditions.
The research purpose was to study the influence of the composition of meadow grass stands, the term of their mowing and growing conditions on the uniform distribution of the aerial mass of legume-cereal and cereal agrocenoses in the conditions of the Novgorod region located in North-West Russia.

The research objectives included:
1) Determining the uniform distribution of the phytomass of seeded clover-cereal and cereal meadow grass stands by years of research;
2) Study of the influence of the mowing period of seeded clover-cereal and cereal agrocenoses on the vertical distribution of their aboveground mass;
3) Study of the effect of the dose of mineral nitrogen on the vertical distribution of the phytomass of cereal grass stands.

2. Material and research methodology
The experimental part of the research on the composition of meadow agrocenoses, the term of their mowing and growing conditions for productivity in the Novgorod region was carried out on seeded clover-cereal and cereal grasses from the 1st to 3rd year of life on medium acid soils of heavy mechanical composition during the years 1998–2000 and the years 2016–2018.

Single-crop clover of meadow varieties Sedum, Volosovsky 86 and Sivortsky 416, Delets; two-crop clover varieties Carmine, hybrid clover varieties Luzhanin and Mayak were included into leguminous-cereal agrophytocenoses [3, 4].

The composition of cereal grass stands included meadow fescue of Suidinskaya variety, timothy grass of Leningradskaya-204 variety, awnless bromegrass of Dragon variety, cocksfoot grasses of Neva and Hlynovskaya varieties, two-spruce reed canary grass of Pervenets variety.

Observations and crop accounting were carried out according to the methods of the All-Russian Research Institute of Feed named after V.R. Williams (1971, 1987).

To study the uniform distribution of the phytomass of natural and seeded cenoses according to the height, studies were carried out to determine the vertical structure of the grass stand by sequentially dividing the vegetative mass of the grass stand into equal segments 10 cm long, followed by weighing.

To quantify the features of the vertical addition of grass stands, an indicator was used with which it is possible to most accurately assess the vertical distribution of phytomass. The indicator coefficient makes it possible to determine the midpoint or “center of equilibrium” in the distribution of grass stand height. The value of the indicator coefficient (hereinafter – IC), approaching 100, indicates the location of the center of equilibrium in the highest tier from the soil surface. With an IC value of about 0, the center of equilibrium shifts to the lowest layer. An IC value of about 50 indicates the location of the center of equilibrium in the middle part of the layer (Larionova N.P., Kozlov L.G., 1985).

3. Results and discussion
In order to identify meadow grass stands that are most suitable for mowing with a uniform distribution of phytomass in height, studies were conducted to determine the vertical structure of cenoses.

Observations of the location of the aerial mass of seeded cereal and clover-grass stands of the first three years of life showed a significant difference between the individual experimental variants. Finding the midpoint or “center of equilibrium” in the height distribution of the grass stand phytomass depended on the composition of the cenosis, the height of all its components, the age, the mowing period, and the growing conditions of the meadow grasses.

In the first year of their life, legume-grass stands with the participation of meadow clover and cereal variants of the experiment formed agrocenoses up to 90 cm high (table 1). The height of the leguminous component in agrocenoses reached only 40 cm. On average, the indicator coefficient for the experiment variants was practically at the same level – 18.8–19.9. In the lowest layer (0–10 cm), 24.6–26.5% of the phytomass of meadow grass stands was concentrated. An exception was the variant with a single-crop clover of the Sedum variety, which scored 50–60 cm in height. This affected the uniform distribution of the aboveground mass of grass and the value of the indicator coefficient (25.3).
Table 1. Dependence of the indicator coefficient (IC) on the composition of the grass by years of life.

| Grass stand type                        | First year of life | Second year of life | Third year of life |
|----------------------------------------|--------------------|---------------------|--------------------|
|                                        | IC | Height, cm  | IC | Height, cm  | IC | Height, cm  |
| Legume-cereal with a single-crop meadow clover | 19.4 | 80–90       | 24.7 | 100–110  | 23.9 | 90–100       |
| Legume-cereal with a two-crop meadow clover | 18.8 | 80–90       | 18.7 | 70–80     | 27.3 | 90–100       |
| Legume-cereal with hybrid clover       | 28.1 | 70–80       | 27.6 | 100–110  | 28.5 | 100–110      |
| Cereal                                | 19.9 | 80–90       | 20.1 | 80–90     | 22.1 | 90–100       |

The smallest accumulation of phytomass in the surface layer (0–10 cm) and the largest value of the indicator coefficient were characterized by legume-cereal agroecoses with hybrid clover. Of all the clovers, this species was the tallest and reached a height of 80 cm, which affected the significant shift of the “center of equilibrium” up the height of the grass stand. The value of the indicator coefficient was maximum and amounted to 28.1, which confirmed the lowest concentration of phytomass of grass stands (19.8%) in the lower tier (0–10 cm from the soil surface). That is, this meadow agroecosystem in the first year of life was characterized by the most even distribution of the crop along the height of the grass stand.

In the next year of life, the height of the grass stands varied greatly, which affected the finding of a “center of equilibrium”. In the second year of life, the legume-cereal agroecoses with the participation of single-crop and hybrid clover reached a height of more than a meter and were characterized by the highest indicator coefficient (24.7–27.6). That is, the phytomass of these variants was distributed most evenly along the height of the grass stand. At the same time, in the tier of 0–10 cm from the soil surface, the smallest amount of aboveground mass was concentrated (13.9–16.1%), while the remaining options in this tier concentrated 22.5% of the crop.

The tallest legume component of all the studied legume-cereal agroecoses, as in the previous year, turned out to be a hybrid clover, which in the second year of life reached a height of 70 cm. This circumstance had a great influence on the shift of the “center of equilibrium” up the height of the grass stand. Only 13.9% of the crop was concentrated in the lower tier.

In the third year of life, the height of legume-cereal grass stands with the participation of the single-crop meadow clover and cereal cenoses did not exceed 1 m. The height of the legume component in agroecoses varied from 30 to 60 cm. The value of the indication coefficient varied from 22.1 to 23.9. In the lower layer, 23.9–24.4% of the total crop was concentrated. Legume-cereal grass stands including the tallest clovers (two-crop and hybrid) were characterized by the highest indicator coefficient (27.3–28.5), which confirmed the minimum accumulation of phytomass in the surface layer – 18.3–19.1% of the total crop weight.

Thus, the uniformity of the distribution of phytomass in height is greatly influenced by the composition of the components of agroecosystem and their height. Tall hybrid clover in all years of research led to the smallest accumulation of aboveground mass in the lower tier (0–10 cm from the soil surface) and the most uniform phytomass distribution along the height of the grass stand.

The vertical distribution of meadow grass stands phytomass also depends on the period of their harvesting. As a result of observations of changes in the vertical distribution of the aerial mass of agroecoses in the phases of meadow grass development, it was noted that as the phenological phases of development progress, the “center of equilibrium” of the agroecoses shifts upward to the higher tiers of meadow legumes-cereal and cereal grass stands (figure 1). A significant increase in the indicator coefficient for all variants of the experiment was observed during the transition of the development
phase from the beginning of budding to the bloom beginning in legumes and from the beginning of heading to complete heading in cereals. The maximum position of the “center of equilibrium” and, consequently, the most uniform vertical distribution of phytomass was observed in a legume-cereal agrocenosis with the participation of hybrid clover in the period from the phase of complete budding to the full bloom of the legume component. The indicator coefficient in this case corresponded to 28.1–28.3, which is 12% higher if compared with the beginning of budding phase.

The uniform distribution of the aboveground mass along the height of the meadow grass stand also depends on the conditions for the growth of grasses, including the use of fertilizers.

![Figure 1](image.png)

**Figure 1.** The influence of the mowing period on the vertical distribution of phytomass of clover-cereal and cereal grass stands.

It is known that cereal agrocenoses effectively respond to mineral nitrogen fertilizers. Therefore, we conducted studies on the effect of doses of nitrogen fertilizers on the vertical distribution of the phytomass of cereal grass stands along their height. It was established that an increase in the dose of mineral nitrogen leads to a more uniform distribution of phytomass along the height of the cereal agrocenosis and a shift of the “center of equilibrium” to the upper tiers of the grass stand (figure 2).

The introduction of mineral nitrogen in a dose of 60 kg per 1 ha led to an increase in the indicator coefficient by 13% and a decrease in the amount of phytomass in the layer of 0–10 cm from the soil surface by 11%, compared with the version without fertilizing. With the introduction of nitrogen at a dose of 120 kg per 1 ha, the amount of above-ground mass in the lower tier decreased by another 23%, and the “center of equilibrium” shifted 16% up the height of the cereal grass stand. The smallest accumulation of phytomass in the lower layer (16%) and the largest indicator coefficient (33.3) were observed in the variant consisting of timothy grass meadow, meadow fescue and awnless brome grass, with a dose of mineral nitrogen at a dose of 120 kg per 1 ha.

Thus, it has been experimentally proved that the composition of agrocenoses, their mowing time, and growing conditions have a great influence on the vertical distribution of the vegetative mass of meadow grass stands. For mowing use on medium-acid soils of heavy mechanical composition, legume-cereal grass with the inclusion of hybrid clover in its composition is most suitable. On average, over the years of research, this meadow agrocenosis harvested from the full budding phase to the full bloom phase was characterized by the most uniform distribution of phytomass along the height of the grass stand.
(indicator coefficient was 28.1–28.3) and the smallest accumulation of vegetative mass in the lower tier (16.1–18.5% of the total mass of the crop).

**Figure 2.** The effect of mineral nitrogen dose on the vertical distribution of the aerial mass of cereal grass stands.

In addition, it was experimentally confirmed that the introduction of mineral nitrogen fertilizing under cereal meadow grass stands contributes to a more even distribution of vegetative mass along the height of agrocenoses. When introducing nitrogen at a dose of 120 kg per 1 ha under the grass stand, consisting of meadow timothy grass, meadow fescue and awnless bromegrass, a significant shift of the “center of equilibrium” upward along the height of the grass stand and a decrease in the amount of phytomass in the lower tier by 4.9–10.4%, compared with non-fertilized cereal agrocenosis, were noted.

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Izvestiya Sankt-Peterburgskogo gosudarstvennogo agrarnogo universiteta [Bulletin of the St. Petersburg State Agrarian University] 32 22–6 [in Russ.]