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# ONTOGENETIC STRUCTURE OF CEREAL POPULATIONS UNDER THE INFLUENCE OF GRAZING AND MOWING ON FLOODPLAIN MEADOWS IN FOREST-STEPPE ZONE OF UKRAINE

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***Abstract***

*The effects of grazing and mowing on the ontogenetic structure of cereal population of Dactylis glomerata L., Festuca pratensis Huds., Phleum pratense L., Deschampsia cespitosa (L.) P. Beauv., Alopecurus pratensis L., Elytrigia repens (L.) Nevski., Bromopsis inermis (Leyss.) Holub. were studied in the floodplains meadows of Psel River and Sula River (Forest-Steppe zone of the North-Eastern Ukraine). It was established with the decrease in the abundance (projective cover) of cereal grasses significant changes in the ontogenetic structure of populations occurred simultaneously on the pasture and mowing gradients. Grazing caused deeper transformation of the population structure of meadow grass than moving. The experimental results confirmed that the systematic implementation of geobotanical and population monitoring of meadow lands can be the advisable tool for organizing their optimal use and successful management. This will allow making corrections to the technology of using pastures and hayfields in order to prevent their degradation.*

***Key words****: cereals, populations, mowing, grazing, degradation.*

## INTRODUCTION

Floodplain meadows are very important ecosystem and habitats. Floodplain meadows have been common part of the farmed landscape for a long time. Traditionally, floodplain meadows were managed either for hay making or as pasture with low-level grazing throughout much of the growing season. Nowdays many of these ecosystems have been converted to grasslands which characterized by intensive agricultural use and strong human impact. Floodplain meadows of the Forest-Steppe zone of Ukraine are located in a region with high population density and high level of plowed soils. Meadow phytocenoses have been in conditions of active economic use for a long time in the region. Therefore, grazing and mowing practiced here with particular intensity.

As mentioned above the floodplain meadows can be sustained by managing the meadow for hay making or as pasture. Both types of management may be very successful at maintaining and restoring meadows species and their diversity. Diverse grasslands and meadows with abundance species of local communities and large cenoeses differences between for the functionality of ecosystems are very important on a global scale (Hautier et al., 2018; Li et al., 2018; Wang &Tang, 2019).

Knowledge base on the impact of mowing and grazing regimes, fertilization, disturbances in the meadow have been established (Bondarieva & Bjelan, 2010; Socher et al., 2012). Differences in grazing regimes and thus vegetation can also contribute to the landscape biodiversity (Klimek et al., 2008; Gaujour et al., 2012; Steinshamn et al., 2018).

Floodplain meadow grasses are traditionally used for haymaking so their flora is adapted to cutting, and it is vital to continue this practice to maintain this plant community. However changes in mowing regime may also influence the species composition, biomass production, vegetation structure, cover, and domination of grasslands as well as the performance and life cycle of individual species (Bomanowska et al., 2019; Milberg et al., 2017; Kohler et al., 2005; Close et al., 2007; Beltman et al., 2003). Transition from the meadow to the pasture regime can result in the loss of plants that are not well adapted to being grazed (Krahulec et al., 2001; Schmitz & Isselstein, 2020).

During economic use various changes occur in the grass species of meadow ecosystem. The

amount of aboveground phytomass available for use decreases, floristic diversity becomes lower, the abundance and the ratio of grass in the herbage changes. As the result of digression processes in such sites of the meadow the biodiversity decreases (Kuzemko & Kozyr, 2011; Ternovaya & Rusev, 2012; Sizykh et al., 2016; Wehn et al., 2017).

The degradation ranks of the meadow vegetation cover under the influence of grazing are usually called pasture digression and under the haymaking influence - moving digression. Taking into account the degree of transformation of the meadow grass stand, the ranks of pasture and moving digression are divided into different degrees.

The main value in meadow phytocenoses are populations of cereal grass. Population is the real form of species existence (Zlobin, 2009). At this level the main changes occur determining the existence of phytocenosis. One of the indicators of permissible limits of anthropogenic impact is the vitality structure of plant populations (Zlobin, 2018; Bondarieva et al., 2019). The ontogenetic structure of populations is always present as part of a comprehensive population analysis (Skliar et al., 2020; Zhivotovsky, 2001; Zhukova, 2001). The correlation of individuals of different ontogenetic states and their implementation of certain survival strategies in the population makes it is possible to draw conclusions about the further population dynamics and to predict the development of the phytocenosis as a whole. (Roberta et al., 2018). The general patterns of changes in meadow phytocenoses under the influence of pasture and moving have been investigated in many researches, but information on the individual response of cenoses-forming species of meadow cereals to the same anthropogenic impact has hardly been studied. The aim of this work was to study changes in the state of populations of forage cereals species under the influence of grazing and mowing of different intensity degrees.

## MATERIALS AND METHODS

Ontogenetic characteristics of populations of seven cereal species were studied in natural meadow phytocenoses during 2010-2019 growing seasons. They were in economic use of varying degrees of intensity. The objects of research were species: *Dactylis glomerata* L., *Festuca pratensis* Huds., *Phleum pratense* L., *Deschampsia cespitosa* (L.) P. Beauv., *Alopecurus pratensis* L., *Elytrigia repens* (L.) Nevski., *Bromopsis inermis* (Leyss.) Holub. The study was carried out in the central parts of the floodplains of two left tributaries of the Dnipro River - Psel River and Sula River (within the boundaries of the Sumy administrative region). The research areas were located in the most typical phytocenoses of the floodplains meadows of the region: *Festuceta pratensis*, *Phleeta pratensis*, *Elytrigieta repentis*, *Dactylieta glomeratae*. According to the Brown-Blanca system, these phytocenoses belong to the classes of *Festuca-Brometea* Br.-Bl. et Tux. and *Arrhenatheretea* R. Tx.

Stages of pasture and mowing gradients were established by the changes in the floristic composition and intensity of economic use. Control plots (CP) corresponded to meadow phytocenoses not be included in economic use. Pasture gradient was subdivided into 5 degrees (CP, PD1, PD2, PD3 and PD4) depending on the number of grazed animals per hectare of pasture. Mowing gradient was divided into 4 degrees: CP, MD1, MD2, MD3 depending on the frequency of mowing during the vegetation season. On the pasture gradient, the degrees corresponded to the following ones: CP - without grazing (control plot), PD1 (pasture degression) - weak grazing up to 1-3 cattle per 1 ha, PD2 - moderate grazing, with 4-8 cattle per 1 ha, PD3 - high pasture impact with 9-12 cattle per 1 ha, and PD4 - severe degradation of the grass stand, grazing more than 12 cattle per 1 ha. On the mowing gradient, the stages corresponded to the following ones: CP - without mowing (control plot), MD1 (mowing degression) - the initial phase of mowing digression, one-time mowing per year, MD2 - moderate digression, two-times mowing per year: during the budding phase of the grass stands and in after grass, MD3 - strong digression, multiple mowing during the growing season.

To study the state of meadow phytocenoses and populations of the cereal species geobotanical and population methods were used.

Schemes for the periodization of ontogenesis for cereal species have been developed.

(Zhukova, 2001). In our study they were used with minor refinements. In accordance with the generally accepted methodology, for each of the cereal species, we identified 9 stages of ontogenesis: p - seedlings; *j* - juvenile, *im* - immature, v - virginal, *g1, g2, g3* - young, medium and old generative, *ss* - subsenile, *s* - senile plants.

For an integral estimation of ontogenetic spectra, the generativity and age indices were applied (Kovalenko, 2006). The generativity index shows the ratio of the individuals part in the flowering-maturing phase and is calculated by the formula:

$$I_{gener.} = (\sum_{i=1}^{g_1-g_3} n_i / \sum_{i=1}^{p-s} n_i) \cdot 100.$$

The population age index reflects the ratio of the aging index to the renewability index of a particular population and is determined by the formula:

$$I_{age} = [(\sum_{i=1}^{g_3-s} n_i / \sum_{i=1}^{p-s} n_i) \cdot 100] / [(\sum_{i=1}^{p-v} n_i / \sum_{i=1}^{p-s} n_i) \cdot 100],$$

where: *p, j, im,v, g1, g2, g3, ss, s* are symbols of ontogenetic states of individuals in standard notation;

*i* - is the number of individuals in a population.

Increase in the values of these indices means the growth in the generativity and age of populations, respectively.

## RESULTS AND DISCUSSIONS

According to the classical method, the age composition of phytopopulations is divided into three categories: invasive, normal and regressive (Rabotnov, 1950; Uranov, 1975). At the same time, no objective criteria for determining the age category of the population have been developed. Thus, the assessment is carried out only by the predominance in the population of individuals of certain ages. To objectify the integrated assessment of age categories of populations, in our research we have developed a model for the species of cereals, which made it more objective to assign a specific population to one of these three categories. We assumed that all studied cereals had an average lifespan of 12 to 15 years and the ontogenesis of all studied cereal species was equally divided into nine age stages. In this case, in the normal population under optimal growth conditions, individuals of each age group (separately) should be 11.1% (Figure 1a). However, the actual duration of the plant in a particular age was not the same. Based on the literature data and our own field research, we found that the the duration of cereals in the state of seedlings (*p*) was shortest, more longer - in the juvenile (*j*), immature (*im*) and senile (*s*) states. For the longest time, cereals can be in the state of virginal individuals (v) and, especially, in the state of $g_2$. Taking into account this fact, the normal age spectrum for cereals should include the following proportions of individuals (in percent): *p* - 3.6, *j* - 5.6, *im* - 5.6, *v* - 18.5, *g1* - 11.1, *g2* - 22.3, *g3* - 11.1, *ss* - 16.6, *s* - 5.6 (Figure 1b). In this population, the share of pregenerative individuals is 33.3%, generative - 44.5% and postgenerative - 22.2%. The ideal normal age population of cereals can contain pregenerative individuals in the range of 28.3-38.3%, generative individuals - 39.5-49.5% and postgenerative - 17.2-27.2% (with a 95% confidence interval).

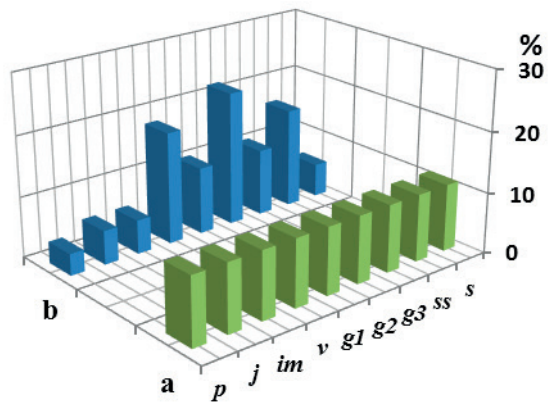


Figure 1. Models of the distribution of cereal individuals by age in the normal coenopopulation of the studied species of cereal plants:
a - percentage of individuals in the population with the same duration of all stages of ontogenesis (%);
b - percentage of individuals in the population, based the real duration of each of the stages of ontogenesis (%)

When pregenerative individuals are more than 38.3%, the population belongs to the category of invasive. Population can be classified as regressive one with postgenerative individuals more than 27.2%. The category of normal

populations is defined as quite broad: it can be incomplete, but generative individuals should be at least 28.3%. This approach was used by us in estimating the age category of populations of cereals under different growth conditions. To analyze the age structure of populations of seven cereal species an assessment of the ontogenetic state of 4796 individuals (genets and ramets) was carried out.

Comparative analysis of the ontogenetic spectra of the populations showed that due to the peculiarities of life forms and the long evolutionary process, cereals in meadow ecosystems under conditions of grazing and mowing mainly preserve normal or incomplete populations of the normal type (Table 1).

This population types were registered at the pasture and mowing gradients in 70% of cases. Only on the pastures (last degrees, PD4) as well as at unsystematic mowing (PD3) they transfer to the category of invasive or regressive. Similar results were got in the study of the population ontogenetic structure of forbs; some species turned out to be even less resistant to anthropogenic effects. (Zhivotovsky, 2001). Species of *Deschampsia cespitosa* and *Phleum pretense* were most resistant to the preservation of normal type populations.

Table 1. Ontogenetic categories[1] of cereals populations on the pasture and mowing gradients

| Species / Stages[2] | ***Dactylis glomerata*** | ***Festuca pratensis*** | ***Phleum pratense*** | ***Alopecurus pratensis*** | ***Bromopsis inermis*** | ***Deschampsia cespitosa*** | ***Elytrigia repens*** |
|---|---|---|---|---|---|---|---|
| **CP** | ***N*** | ***N*** | ***N*** | ***N*** | ***N*** | ***N*** | ***N*** |
| *PASTURE DIGRESSION* | | | | | | | |
| **PD1** | N | I | N | N | N | N | N |
| **PD2** | I | I | N | I | N | N | N |
| **PD 3** | I | N | R | I | R | N | R |
| **PD 4** | N | R | R | I | R | N | R |
| *MOWING* DIGRESSION | | | | | | | |
| **MD1** | N | N | N | I | N | N | N |
| **MD2** | N | N | N | N | N | N | N |
| **MD3** | N | N | N | R | N | N | N |

[1]I - invasive, N - normal, R - regressive categories of populations (according to Rabotnov T.A.).

[2]CP - control plot, PD1-PD4 - stages of pasture digression, MD1-MD3 - stages of mowing digression.

Change of meadow grass generations on pastures and hayfields was primarily determined by the preservation of their ability for reproduction (Table 2).

Table 2. Generation indices ($I_{gener.}$) of cereal populations depending on the level of pasture and mowing pressure

| Species / Stages[1] | ***Dactylis glomerata*** | ***Festuca pratensis*** | ***Phleum pratense*** | ***Alopecurus pratensis*** | ***Bromopsis inermis*** | ***Deschampsia cespitosa*** | ***Elytrigi repens*** |
|---|---|---|---|---|---|---|---|
| **CP** | 55.9 | 50 | 54.3 | 51.1 | 65.7 | 40 | 66.4 |
| *PASTURE DIGRESSION* | | | | | | | |
| **PD1** | 56.9 | 52.9 | 60.9 | 68.7 | 63.4 | 56.3 | 60 |
| **PD2** | 47.2 | 21.7 | 55 | 44.4 | 65.7 | 52 | 60.9 |
| **PD 3** | 50.6 | 57 | 37.8 | 50 | 48.6 | 66.7 | 62.8 |
| **PD 4** | 53.7 | 23.1 | 22.9 | 33.3 | 40 | 60 | 47.4 |
| *MOWING DIGRESSION* | | | | | | | |
| **MD1** | 59.2 | 54 | 58.7 | 25 | 69.2 | 38 | 68.6 |
| **MD2** | 50.6 | 51.9 | 46.7 | 80.7 | 73.4 | 45 | 60.8 |
| **MD3** | 57.5 | 64.6 | 42.9 | 25 | 65.2 | 40 | 52.8 |

[1]CP - control plot, PD1 - PD4 - stages of pasture digression, MD1 - MD3 - stages of mowing digression.

The data show that the proportion of plants in the flowering and maturing phase, estimated by the index of generativity, in the control plots was high, at the level of 50-66%.

With impact increasing, the generativity of cereal populations stably remained and decreased to 23-53% only on pasture. Species of *Deschampsia cespitosa* as dense bush plants had an individual reaction to grazing: according to the pasture gradient, the proportion of generative individuals in its populations increased from 40 to 60–66%. Unlike pastures, even several-times mowing during the growing season do not significantly changed the index of cereal population generativity.

The ratio of the rejuvenation and aging processes of individuals in populations reveals an age index. In response to increasing pasture pressure, cereals can be divided into three groups (Table 3).

Table 3. The age indices ($I_{age}$) of cereal populations depending on the level of pasture and mowing pressure

| Species / Stages[1] | *Dactylis glomerata* | *Festuca pratensis* | *Phleum pratense* | *Alopecurus pratensis* | *Bromopsis inermis* | *Deschampsia cespitosa* | *Elytrigia repens* |
|---|---|---|---|---|---|---|---|
| **CP** | 1.89 | 1.47 | 1.7 | 0.87 | 0.42 | 0.75 | 1.36 |
| *PASTURE DIGRESSION* | | | | | | | |
| **PD1** | 0.93 | 1.11 | 1.59 | 0.88 | 2.22 | 0.86 | 0.66 |
| **PD2** | 0.96 | 0.59 | 1.5 | 0.75 | 5.51 | 0.6 | 1.91 |
| **PD 3** | 1.07 | 1.26 | 1.68 | 0.46 | 3.23 | 0.49 | 3.46 |
| **PD 4** | 1.6 | 1 | 2.19 | 0.81 | 4.13 | 0.31 | 1.36 |
| *MOWING DIGRESSION* | | | | | | | |
| **MD1** | 1.56 | 1.96 | 1.99 | 0 | 0,89 | 0.32 | 0.89 |
| **MD2** | 1.39 | 2.36 | 1.11 | 2.7 | 1,75 | 0.75 | 0.68 |
| **MD3** | 1.55 | 2.37 | 1.28 | 6.65 | 1,78 | 1 | 0.62 |

[1]CP - control plot, PD1-PD4 - stages of pasturable digression, MD1-MD3 - stages of mowing digression.

In the first species group (*Alopecurus pratensis*, *Elytrigia repens*) no regular changes in the age of the populations were observed. The process of rejuvenation of populations, characterized by increase in the proportion of pregenerative plants was fixed in the second spesies group (*Dactylis glomerata*, *Festuca pratensis*, *Deschampsia cespitosa*). In the third group (spesies of *Phleum pratense, Bromopsis inermis*) pasture pressure led to population aging with increase in the proportion of plants of the $g_3$, *ss*, and *s* ontogenetic states.

Species of cereals differed in individual reaction to mowing. The sharp increase in age was characteristic of populations of *Alopecurus pratensis*.

## CONCLUSIONS

General analysis of the population ontogenetic structures shows that the most dangerous changes in cereal populations occur at the degrees of the PD3 and PD4 gradient, when the number of grazed animals exceeds 7-10 cattle per 1 ha. When meadows are used as hayfields, the most dangerous is the unsystematic mowing of the grass stand throughout the entire growing season (MD3 of the mowing gradient). Early mowing and early grazing of farm animals are especially harmful. Thus, different types of cereals react to grazing and mowing individually. This reflects the different degree of their adaptation to economic use. Populations of cereal grasses within the same taxonomic species at different stages of gradients of pasture and mowing digression are distinctive and differ from each other in the characteristic of the ontogenesis and, accordingly, the specificity of the ontogenetic composition. The level of population degradation on pastures and hayfields must be taken into account when determining the optimal modes of their use and management.

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