

REPRODUCTIVE INDICATORS OF LEGUMINOUS PLANTS AS A CHARACTERISTIC OF THE ECOLOGICAL STATE OF URBAN AREAS

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Abstract. This article examines the results of many years of research on the reproductive performance of six species of leguminous plants (Fabaceae Lind., 1836) under conditions of urbanization of habitat (Kazan). The range of variability of the main reproductive indices in six species is illustrated: the potential productivity, the actual productivity of the six main types of leguminous plants. The features of variability of seed death at different stages of development are shown depending on habitat conditions. It is established that the main regularities of changes in reproductive parameters depending on habitat conditions are manifested both in native species and in the introduced species *Caragana arborescens* Lam., 1785. Based on the results of the study we made conclusion about the advisability of monitoring the reproductive parameters of leguminous plants for indicating the state of the environment in a large city.

1. Introduction

At present, it is considered that the anthropogenic factor by the type of influence on biological systems does not fundamentally differ from the natural ones. However, in terms of intensity and combination of various human activities, the anthropogenic factor should be regarded as unique. The fact is that the economic activity of man in terms of the volume and depth of the transformations is now comparable to geological processes that took millions of years [1]. Modern cities represent a quintessence of the diversity of natural and anthropogenic environmental factors on living organisms. In this regard, the study of the reaction of living organisms to changes in habitat should be considered as adaptive mechanisms and apply them as a characteristic of the ecological state of urban areas.

The organism and its environment are in a dynamic equilibrium. The physical and chemical characteristics of the environment change under the influence of anthropogenic influences, which leads to a disturbance of the dynamic equilibrium of natural ecosystems. Such a situation makes studies that determine the quality of the environment and the degree of its comfort for living organisms particularly important. Basic information is required on any global and local environmental changes based on the response of various ecosystem components. However, the diversity and intensity of anthropogenic impact on the natural environment continues to grow. Evaluation of the cumulative impact of the entire variety of combinations of different effects becomes generally impossible.

The assessment of the quality of the natural environment in cities where most of the world's population lives is especially important. One of the modern and most promising methods for assessing the quality of the environment is the bioindication analysis, which provides an integral assessment of the situation, since living organisms summarize all biologically important environmental data and, without exception, reflect its state as a whole.

The process of urbanization leads to changes in the biology of each species. For a more detailed study of the ongoing processes, systematic monitoring studies are necessary. Reproduction is one of the central functions of a living organism. The probability of leaving offspring can be considered as a property of



adaptability [2]. In most studies, the deterioration in the parameters of the generative sphere under the influence of anthropogenic transformation of the habitat is displayed.

This report contains results of monitoring the reproductive parameters of leguminous species in urbanized areas, using the example of Kazan.

2. Material and methods

The material for this article was collected in the territory of Kazan in the period 2000-2015. The objects of research were the following types of legumes:

- Chinales *Lathyrus sylvestris* L., 1753
- Chinalug *Lathyrus pratensis* L., 1753
- Spring's spring (soviet grass) *Lathyrus vernus* L., 1753
- Caragana tree (acacia yellow) *Caragana arborescens* Lam., 1785
- Mouse *Vicia cracca* L., 1753
- Pickled vegetables *Vicia sepium* L., 1753

The choice of these species was due, firstly, to their widespread prevalence both in conditions of intense anthropogenic press, and, secondly, by the convenience of carrying out the assessment (a relatively small number of seeds in the fetus with a clear differentiation of the stages of seed development).

Assessment of reproductive parameters was carried out according to the following indicators:

1. Potential fertility.
2. The ovules.
3. Underdeveloped seeds.
4. Actual fecundity.

The indicator of potential fertility includes the sum of indicators 2-4. The ovules (seedlets) are the seeds that have stopped their development at the early stages. Undeveloped seeds are seeds that stopped their development at later stages. Actual fecundity is fully developed seeds. In other words, actual fecundity can be represented in the form of an expression of potential fertility - ovules - underdeveloped seeds = actual fertility.

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For an adequate assessment of the state of the environment, we conducted research; we used the approach of dividing city territory into anthropogenic impact gradient, which was tested earlier in similar works at other sites [3, 4].

The gradient of anthropogenic impact in city conditions was compiled on the basis of functional zoning of the territory. Within the city of Kazan, we identified four main zones [5, 6]:

- I - the industrial zone of the city (zone of the greatest anthropogenic impact);
- II zone - zone of multi-storey building;
- III - low-rise building zone;
- IV - zone outside of the city (zone of least human impact).

100-120 ture fruits were harvested for samples of each habitat.

3. Results and discussion

Habitats in urban areas for most organisms can be considered as an analogy of island populations. The presence of insurmountable reproductive barriers actually gives grounds to consider these isolated populations as independent units of the microevolutionary process [4].

Habitats in an urbanized area for most plant species can be considered as an analog of island populations, where the reproduction mechanism is well traced, which allows the implementation of microevolutionary processes [7, 8]. Thus, we can consider the dynamics of reproductive parameters as a mechanism. Currently, it is considered that the stressful conditions of the habitat lead to an increase in potential fertility [9]. This gives us grounds to consider fertility indicators as an indicator of the body's response to environmental changes.

The state of the maternal individual primarily acts as a factor limiting the indicators of seed production. The influence of pollution, weather conditions and other external factors in this case has indirect significance.

Great importance has the amount of developed seeds in the fetus or, so-called in the literature, the seeds that have been made, since they are the ones that are involved in the resumption of the population. The realization of potential seed productivity depends on the number of underdeveloped seeds and unfertilized

ovules. In most of the studied species, a large percentage of death is made from unfertilized ovules, in some - underdeveloped seeds and ovules and rarely underdeveloped seeds.

According to the obtained data, with increasing intensity of anthropogenic impact (from zone IV to I), an increase in potential fertility is observed. This corresponds to the general trend, which was previously described in the literature. In fact, this means that in the conditions of urbanization, beans have an adaptive mechanism for ensuring the effectiveness of seed reproduction. Figure 1 shows the average dynamics of reproductive indicators of leguminous plants in Kazan.

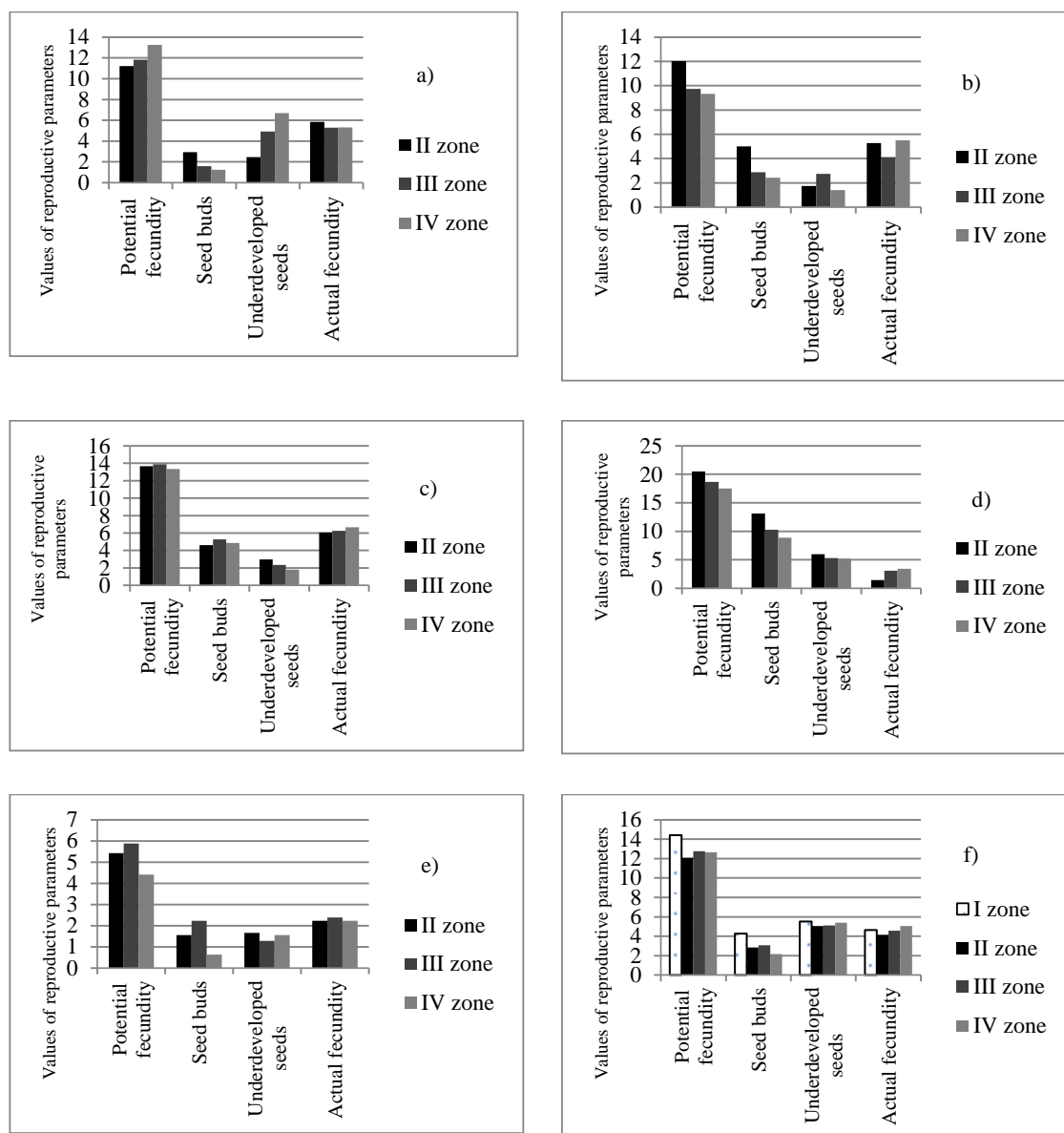


Figure 1. Dynamics of reproductive parameters of leguminous plants in the gradient of urbanization: a) *Lathyrus sylvestris*; b) *Lathyrus pratensis*; c) *Lathyrus vernus*; d) *Caragana arborescens*; e) *Vicia cracca*; f) *Vicia sepium*

We found out that in different habitats the character of dynamics of reproductive parameters for each species in different habitats can vary. However, for each of the studied species, the same patterns are observed. These are the following patterns.

1. High values of potential fertility are identified for populations that have a low actual fertility.

Accordingly, low values of potential fertility, as a rule, indicate a high level of actual fertility. The increase in potential fertility should be considered in this case, as a response to the deterioration of living conditions.

2. The high mortality rate at the stage of ovules in the population is associated with a lower mortality rate at the stage of underdeveloped seeds. This picture may be the evidence of similar results that are typical for other organisms, particularly for amphibians [3]. Obviously, in this case a large role is played by a high level of stabilizing selection in conditions of increased stress from the environment [10].

3. Fertility of native species is approximately at the same level under similar growing conditions. The introduced species of *Caragana arborescens* has significantly higher values of potential fertility, as well as a high level of death at all levels of development. However, the patterns described above are common for this species. This circumstance should be considered for the possibility of using this species as an indicator of the state of the environment under urbanization conditions. According to the data received, the overall trend is a decrease in actual fertility with an increase in the urbanization gradient. A similar trend has been identified for all species.

In general, there is a tendency for an increase in mortality in the early stages of development (ovule) for populations growing under conditions of intense anthropogenic press. Large death in later stages of development (underdeveloped seeds) is more typical of populations growing in less transformed habitats.

Thus, comparative studies of changes occurring in populations of living organisms from biotopes that are subject to anthropogenic influence to varying degrees are promising. Conditions with different degrees of anthropogenic impact are important both in theoretical and applied aspects.

On the one hand, the study of reproductive parameters is an object for studying microevolutionary processes in conditions of diverse anthropogenic impact. This method of bioindication is quite informative considering all the stress factors, both chemical and physical, for estimating and making predictions of the suitability of the surrounding environment of the studied city for the urban population.

By the state of the reproductive parameters of beans, it is possible to judge the quality of the natural environment in urbanized areas; bioindication integrates all chemical and physical stress factors and is most informative for social and hygienic assessments of the suitability of the urban natural environment for humans. On the other hand, the registered features of organisms can be used for bioindication and monitoring of ecosystems [11, 12].

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