MATERIALS ON THE STUDY OF SEED PRODUCTIVITY OF SOME LEGUMINOUS PLANTS SPECIES (FABACEAE LIND., 1836) IN THE CONDITIONS OF HABITAT URBANIZATION

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Abstract.The article presents generalized data on the variability of reproductive parameters of leguminous plants (*Fabaceae* Lind., 1836), growing in the gradient of habitat transformation in Kazan. The range of variability of potential productivity indicators, the actual productivity of six main kinds of leguminous plants are shown. The features of variability of seeds failure at different stages of development are given. It was shown, that the greatest rate of mortality at the early stages of development (seed bud) was characteristic for populations, growing under conditions of intense anthropogenic press. Failure at later stages of development (underdeveloped seeds) was more typical for populations, growing in less transformed habitats. On the basis of long-term data, it was shown, that there was the common pattern of decreasing the actual fecundity rate with increasing the gradient of life environment urbanization. It was concluded, that monitoring of the reproductive parameters of leguminous plants should be used to indicate the state of the environment under the conditions of large city.
Keywords: bioindication, microevolution, reproductive parameters, potential fecundity, actual fecundity, embryonic death, urbanization.

1 Introduction

Urbanized areas for plants and animals are specific ecosystems. They combine both slightly transformed biotopes and those that underwent a significant change. The share of the latter in the cities is constantly increasing. This throws into question the conservation of biological diversity. At present, it is considered, that the prospects for preservation of biological diversity in the conditions of development of urbanized territories are determined mainly by economic conditions (Ishchenko,2008).

Along with an assessment of the state of biological diversity in urban areas, it is very important to study microevolutionary aspects. This circumstance is due to the fact, that in the conditions of urbanized areas the fragmentation of populations occurs, which makes it possible to compare them with island populations. Accordingly, all the main regularities, which are typical for island populations (Spencer,1996 ; Laurance,2008).

The effects of habitat fragmentation lead to changes in the biology of each species. More detailed study of these processes requires systematic monitoring investigations. Reproduction is one of the central functions of a living organism. The probability of bringing offspring can be considered as a property of adaptability (Sapunov,1986).

When studying the toxic effects of the environment, early warning signs of toxic impact, which directly affect the fate of the population, should have an undoubted priority: the influence on reproductive parameters and survival (Bezel et al, 1994). The study of such reproductive parameters in plants, as potential and actual seed productivity is very important for identifying mechanisms, ensuring population adaptation of the species to changing environmental factors.

In most studies, the deterioration in the parameters of generative sphere under the influence of habitat anthropogenic transformation is shown. The indicators of seed productivity, which determine the stability of numbers and their age structure, are especially important in the problem of reproductive capacities of populations, in the conditions of chemical stress (Zhuikova et a, 2002 ; Zhuikova,2009).

This article represents the preliminary results of monitoring the reproductive parameters of some species of leguminous plants (Fabaceae Lind., 1836) under the conditions of urbanization (Kazan).

2 Material And Methods

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:

- Wood pea Lathirus sylvestris L., 1753;
- Meadow pea Lathyrus pratensis L., 1753;
- Bitter pea vine (Orobus) Lathyrus vernus L., 1753;
- Caragana arborescens (Siberian pea shrub) Caragana arborescens Lam., 1785;
- Downy pea Vicia cracca L., 1753;
- Bush vetch Vicia sepium L., 1753.

The choice of these species was due, firstly, to their wide distribution both in conditions of intense anthropogenic press, and, secondly, by the convenience of assessing (a relatively small number of seeds in the pulse with a clear differentiation of the seed development stages).

The evaluation of reproductive parameters was carried out according to the following indices:

1. Potential fecundity.
2. Seed buds.
3. Underdeveloped seeds.
4. Actual fecundity.

The indicator of potential fecundity includes the sum of indicators 2-4. Seed buds (ovules) - are the seeds, which stopped their development at the early stages. Underdeveloped seeds - are seeds, stopping their development at later stages. Actual fecundity - is fully developed seeds. In other words, actual fecundity can be represented in the form of expression: potential fecundity – seed buds – underdeveloped seeds = actual fecundity.

Figure 1. Appearance of mature seeds, underdeveloped fruits and seed buds by the example of *Vicia cracca.*

All the above indicators can be easily distinguished (Figure 1).

Among the plants studied, the most readily available were downy pea *Vicia cracca* and *Caragana arborescens*. In each habitat, 100-120 mature beans were picked, in which potential seed productivity (mature and undeveloped seeds and seed buds); actual seed productivity (developed seeds) and failure (underdeveloped seeds and ovules) were assessed.

The gradient of anthropogenic press, under the city conditions, was made on the basis of the functional zoning of the city territory. Within the city of Kazan, we identified four main zones (Zamaletdinov, 2008 ; Khairutdinov,2010):

- I zone. This is an industrial zone of the city. Within this zone, the natural environment was completely destroyed.

- II zone. This is a zone of high-rise development. Currently, these are mostly "bedroom" districts. Elements of the natural environment here are squares, gardens, parks, as well as water objects.

- III zone. This is a zone of low-rise (1-2 floors) development. It is referred to historical buildings, mainly wooden houses. The main elements of the environment are wastelands, parks, water objects, etc.

- IV zone. Green area of the city. This is the territory, which is the closest to the natural environment (forest park "Lebyazhye", some special protected natural areas, etc.).

3 Results And Discussion

Habitats in urbanized 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 (Vershinin,2002).

The mechanism, that allows to realize these processes - is a reproduction. There is an opinion, that the stressful conditions of the habitat lead to an increase in potential fecundity (Artemiev,1980).

Table 1 provides information on the volume of material and the obtained indicators.

Table 1.The averaged data of reproductive parameters of the studied species of leguminous plants

Functional zone	Number of studied habitats	Potential fecundity		Seed buds		Underdeveloped seeds		Actual fecundity	
		min-max	M±m	min-max	M±m	min-max	M±m	min-max	M±m
Lathirus sylvestris									
II	1	8,00-13,00	11,22±0,1	0,00-9,00	2,93±0,22	0,00-8,00	2,45±0,21	0,00-11,00	5,84±0,27
III	1	7,00-14,00	11,81±0,17	0,00-5,00	1,6±0,19	2,00-9,00	4,91±0,2	2,00-10,00	5,3±0,25
IV	1	11,00-15,00	13,25±0,09	0,00-4,00	1,25±0,12	4,00-11,00	6,69±0,14	2,00-8,00	5,31±0,13
Lathyrus pratensis									
II	2	5,00-18,00	12,02±0,13	0,00-12,00	5,00±0,21	0,00-9,00	1,75±0,14	1,00-11,00	5,27±0,18
III	2	4,00-14,00	9,73±0,17	0,00-9,00	2,87±0,17	0,00-8,00	2,74±0,16	1,00-9,00	4,13±0,17
IV	2	6,00-14,00	9,32±0,17	0,00-8,00	2,42±0,15	0,00-6,00	1,4±0,11	2,00-12,00	5,5±0,21
Lathyrus vernus									
II	1	8,00-19,00	13,65±0,17	0,00-14,00	4,62±0,22	0,00-9,00	2,97±0,17	0,00-15,00	6,06±0,24

III	2	9,00-18,00	13,88±0,17	0,00-12,00	5,28±0,22	0,00-10,00	2,34±0,18	3,00-12,00	6,26±0,17
IV	2	6,00-18,00	13,34±0,19	0,00-11,00	4,88±0,22	0,00-8,00	1,8±0,16	2,00-13,00	6,67±0,26
Caragana arborescens									
II	3	15,00-26,00	20,52±0,21	8,00-19,00	13,13±0,23	1,00-12,00	5,95±0,19	1,00-5,00	1,44±0,06
III	3	11,00-28,00	18,64±0,28	1,00-19,00	10,26±0,3	0,00-13,00	5,29±0,21	1,00-9,00	3,09±0,13
IV	2	11,00-28,00	17,5±0,25	0,00-22,00	8,89±0,34	0,00-13,00	5,19±0,24	1,00-7,00	3,42±0,13
Vicia cracca									
II	4	2,00-8,00	5,43±0,091	0,00-4,00	1,55±0,1	0,00-5,00	1,66±0,1	1,00-5,00	2,23±0,087
III	2	3,00-8,00	5,883±0,08	0,00-5,00	2,23±0,1	0,00-5,00	1,28±0,09	1,00-5,00	2,383±0,083
IV	2	2,00-7,00	4,408±0,07	0,00-3,00	0,63±0,07	0,00-4,00	1,55±0,09	1,00-4,00	2,233±0,079
Vicia sepium									
I	1	10,00-17,00	14,41±0,12	0,00-14,00	4,25±0,21	0,00-10,00	5,52±0,17	2,00-9,00	4,64±0,15
II	2	9,00-15,00	12,08±0,11	0,00-9,00	2,86±0,17	0,00-11,00	5,06±0,16	2,00-7,00	4,16±0,1
III	2	8,00-17,00	12,77±0,13	0,00-10,00	3,08±0,19	0,00-12,00	5,12±0,21	2,00-11,00	4,58±0,17
IV	2	9,00-16,00	12,65±0,13	0,00-10,00	2,18±0,22	0,00-10,00	5,41±0,22	2,00-11,00	5,06±0,19

According to the data obtained, the increase in the potential fecundity is observed with the growth of the urbanization gradient. This corresponds to the general trend, which was previously described in the literature. In fact, this means, that in the conditions of urbanization, an adaptive mechanism was formed in beans, for ensuring the effectiveness of seed reproduction.

The number of developed seeds in the pulse of filled seeds is also important, as they are involved in the reproduction of population. Realization of potential seed productivity depends on the number of unfilled seeds (underdeveloped seeds) and unfertilized ovules.

Legumes belong to the group of plants, in which the process of seedification, even under optimal conditions of their growth, is lower than the potential seed productivity - the mortality of seeds is 40-50% (Knyazev,2014).

According to the received data, in general, there was the tendency to decrease in actual fecundity (the number of filled seeds, the number of mature seeds) with the increase of urbanization gradient. A similar tendency has been identified for all species. However, the values of all the reproductive parameters for each species varied significantly.

High values of potential fecundity, as well as high level of mortality at all levels of development were revealed for *Caragana arborescens*. This species is not aboriginal in Kazan. Initially, it was introduced for the greening of parks and squares of the city.

The results obtained by us show, that in the conditions of Kazan, the realization of reproductive potential is achieved by an extremely high level of mortality and low actual fecundity.

On the whole, there is a tendency of the increase in mortality rate at the early stages of development (ovules) for populations, growing under conditions of intense anthropogenic press. Greater mortality at later stages of development (underdeveloped seeds) is more typical of populations, growing in less transformed habitats.

A similar picture was noted for almost all species. Similar results are also characteristic for other organisms, in particular for amphibians (Vershinin,2002). Obviously, in this case a large role is played by a high level of stabilizing selection, in conditions of increased stress from the environment (Shmalgauzen,1946).

The viability of offspring can be influenced both by the functional state of the parent individual and by the habitat (6; 7). The state of parent individual is the most significant factor, limiting the indicators of seed productivity. The influence of pollution and weather conditions, in this case, is indirect.

The variability of reproduction rates can be considered as the most important criterion for the ability of living organisms to adapt to environmental conditions, including its anthropogenic transformation (Okulova,2005).

Some researchers note the narrowing of seed reproduction heterogeneity in conditions of anthropogenic transformation of the habitat; others note the increased variability. Such discrepancies are probably related to the dose of the toxic factor, its duration for a given population, its specificity, etc. Probably, with a high level of anthropogenic transformation, there should be a minimum variability in the signs of viability, since the selection eliminates the most sensitive individuals to the toxic agent.

In habitats with a persistent organic toxicity factor, *Caragana arborescens* and *Vicia cracca* had a significant increase in potential seed productivity and unfilled seeds, but with high rates of eliminating pulses and unfertilized ovules, the actual fecundity remained low.

Thus, on the basis of the research of reproductive indicators of legume populations, growing under the conditions of anthropogenic transformation of the environment, it can be said about a whole complex of nonspecific manifestations.

4 Deductions

Thus, the comparative studies of changes, occurring in populations of living organisms from biotopes, that are the subject of anthropogenic influence to varying degrees, are promising in theoretical (evolutionary) and practical aspects: on the one hand, for studying microevolutionary processes under conditions of a different anthropogenic impact, on the other hand, the features of organisms can be used for bioindication and monitoring of ecosystems.

5 Conclusion

Various estimation scales are widely used now. On their basis, it is possible to create a general picture of the ecological situation in the city. These scales are also applicable for particular objects (Bagautdinova et al, 2015 ; Derevenskaya et al, 2015 ; Mingazova et al, 2015). However, this approach does not reflect the true ecological situation and does not allow the creation of predictive models. For an adequate assessment it is necessary to conduct research, using natural populations of organisms.

According to the state of legumes reproductive parameters, 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 human.

The revealed tendencies to change the reproductive parameters in various populations of leguminous plants can be considered also as evidence of microevolutionary processes. Adaptogenesis is ensured by successful self-reproduction within the isolated territory. As a result, under different anthropogenic impact, various mechanisms of adaptation of the reproductive system, within the relatively compact urban area, can be observed.

Acknowledgement

The work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

References

1. Artemiev Yu.T. *Biology of reproduction (microevolutionary aspects).* Kazan: Publishing House of KSU, 1980. - 87p.
2. Bezel V.S., Bolshakov V.N., Vorobeichik E.L. *Population ecotoxicology*. - M.: Nauka, 1994. - 80p.
3. Bagautdinova N.G., Mingazova N.M., Zamaletdinov R.I., Panasyuk M.V., Safiullin L.N., Gafurov I.R., Glebova I.S., Zotova F.R., Kadyrov A.R., Suslova O.B. *Economic, Social and Environmental Aspects of the Impact of the Universiade - 2013 on Development of Kazan City and Tatarstan Republic* // Asian Social Science. – 2015. - Vol. 11. –№. 11. – Pp. 115-122.
4. Derevenskaya O.Yu., Mingazova N.N, Zamaletdinov R.I, Pavlova L.R., Schigapov I.S. *Condition of Water Bodies in the Kazan City Due to the Organization of the Summer World Universiade 2013* // Mediterranean Journal of Social Sciences. Vol. 6, №. 1, January 2015, Supplement 2. – Pp. 465-469.
5. Ishchenko V.G., Mitchell J.C. *Urban Herpetology in Russia and Adjacent Territories* // Urban Herpetology / Eds.: J. C. Mitchell (et al.); Soc. for the Study of Amphibians and Reptiles. Saint Louis, Mo.: SSAR, 2008. Pp. 405-421. (Herpetological Conservation; Vol. 3).
6. Knyazev M.S. Legumes (*Fabaceae* Lindl.) of the Urals: speciation, geographical distribution, historical and ecological suites. Dis. ... Doc. Biol. Sciences. - Yekaterinburg, 2014. -607p.
7. Khairutdinov I.Z. *Ecology of reptiles from the urbanized territories (on the example of Kazan).* Author's abstract … Cand. Biol. Sciences - Kazan, 2010. - 24p.
8. Laurance W.F. *Theory meets reality: How habitat fragmentation research has transcended island biogeographic theory* // Biological conservation. 2008. 141. – Pp. 1731-1744.
9. Mingazova N.M., Zamaletdinov R.I., Derevenskaya O.Yu., Palagushkina O.V., Nabeeva E.G., Pavlova L.R., Shigapov I.S., Mingaliev R.R., Nazarov N.G., Zaripova N.R. *The Impact of XXVII Summer Universiade on the Environment in Kazan* // Mediterranean Journal of Social Sciences. Vol. 6, №. 1, January 2015, Supplement 2, – Pp. 470-474.
10. Okulova S.M. 3.1.3. *Reproductive characteristics of urban plant populations (by the example of legumes)* // Kazan Ecology. - Kazan: Fen, 2005. - Pp. 171-176.
11. Spencer C., Barrett H. *The reproductive biology and genetics of island plants* // Phil. Trans. R. Soc. Lond. B. 1996. 351. – Pp. 725-733.
12. Sapunov V.B. *Quantitative estimation of the limits of intraspecies variability* // Journal of General Biology. 1986. Vol. 47. № 6.- Pp. 790-798.
13. Shmalgauzen I.I. *The factors of evolution (the theory of stabilizing selection).* -M-L.: Academy of Sciences of the USSR. 1946. - 396p.
14. Vershinin V.L. *Ecological specificity and microevolution in amphibian populations in urbanized areas* // Advances in amphibian research in the former Soviet Union. Volume 7. Pensoft Publishers. – Moscow-Sophia, 2002. – Pp. 1-161.
15. Zhuikova T.V. *The reaction of cenopopulations of grassy communities to chemical pollution of the environment*. Author's abstract. ... Doc. Biol. Sciences. - Yekaterinburg, 2009. -40p.
16. Zamaletdinov R.I. *Ecology of amphibians in the conditions of a large city (by the example of Kazan).* Author's abstract ... Cand. Biol. Sciences. - Kazan, 2003. - 24p.
17. Zhuikova T.V., Bezel V.S., Pozolotina V.N., Severyukhina O.A. *The Reproductive Capacity of Plants in a Gradient of Chemical Environmental Pollution* // Ecology. 2002. № 6. – Pp. 432-437.