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INTEGRATED EFFECT OF ATMOSPHERE POLLUTION AND CUTTING ON SEED PRODUCTION OF DANDELION (TARAXACUM OFFICINALE WIGG.) URBAN POPULATIONS

A. F. Khamidullin*[1], S.F. Kotov[3] and V. N. Vorob'ev[1,2]
[1]Kazan (Volga) Federal University, 16, Kremlevskaya st., Kazan, 420008, Russian Federation.
[2]Kazan Institute of Biochemistry and Biophysics, Kazan Scientific Center, Russian Academy of Sciences, 2/31, p/o box 30, Lobachevskogo st., Kazan, 420111, Russian Federation.
[3]V.I. Vernadsky Crimean Federal University, 4, Akad. Vernadsky av., Simferopol, 295007, Russian Federation.
Email: russia@prescopus.com

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Abstract

We considered the influence of air pollution by road transport on the total number of seeds, seed weight and the formation of seeds able to germinate in the inflorescences of Taraxacum officinale Wigg cut off on the fourth day after flowering, and in the inflorescences formed on the parent plant. The monotonous dependence dose-response is characteristic for the seeds developed on the parent plant.

The dependencies of other seed production indicators from air pollution intensity by motor traffic are nonmonotonic ones, which can be attributed to the paradoxical effects that appear brighter in the inflorescences cut off on the fourth day after flowering. The intensity of seed germination, formed on the mother plant, is also difficult and depends nonmonotonically on the degree of atmosphere contamination, but the seeds with the weight less than 0.25 mg are not developed. A significant influence on the relationship between the weight of seeds and their germination is made by negative impact factor duration.

At the same weight (0,39 ± 0,02 mg) the maximum germination of the option "cut off florets" and a minimum one for the version "ripened on parent plant". At the same time a lot of seeds correlated with their germination differently. For the seeds ripened in the cut off inflorescences R^2 = 0.80 (p = 0.00027), and for the seeds ripened on the parent plant R^2 = 0.55 (p = 0.008). The critical mass of viable seeds for their germination in cut off inflorescences made 0.23 ± 0.007 mg, which is 10% more than a certain critical mass of Taraxacum officinale seeds stated earlier.

Keywords: Taraxacum officinale Wigg, dose-response dependences, seed reproduction indices, motor traffic pollution, plant paradoxical effects

Introduction

Seed production of various plant species with the environment contamination increase may be as directly proportional [1, 2], so as inversely proportional [3, 4]. Despite these differences, some authors propose to use the indicators of seed productivity indicators to measure the level of environmental pollution and for biomonitoring [1, 5].

Currently, toxicology accumulated the evidence of non-monotonic responses that include hormesis [6, 7] and paradoxical effects [8, 9, 10] besides classical monotonic dose-response dependencies. Hormesis is a biphasic dose-response, which is characterized by low dose stimulation and high dose inhibition [11]. Paradoxical effects include the phenomena at which a low dose of a toxic agent inhibits the process and a toxic effect decrease is observed with the dose increase [9]. Thus, the determination of the dose-response relationship nature during the study of the reproductive capacity among different plant species under the influence of anthropogenic load involves the analysis of a wide range of values.

Dandelion (Taraxacum officinale Wigg. S.l.) is widely used as a test object for environmental studies [12, 13]. It is often found in urban areas near the roads with different traffic volume.

There are the studies concerning the influence of mowing on dandelion reproduction [14]. But the question concerning dandelion reproductive capabilities change in terms of city service functioning remains open and when does the factor of vehicle emission impact is combined with another one i.e. periodic mowing?

The aim of this work was to determine the dependence of dandelion (Taraxacum officinale Wigg. S.l.) reproductive capacity under the terms of periodic mowing on the intensity of car traffic volume.

Materials and Methods

Object of study

The dandelion Taraxacum officinale Wigg. s.l. - the plant of the Asteraceae Dumort (Compositae Giseke) family, Taraxacum officinale Wigg genus was selected as an object of research [15].

Plant material collection sites

The collection of plant material was held in late May of 2015 in the areas located at the distance of 1-4 meters from the roads with different levels of pollution in the city of Kazan, Russia. Dust collection places were chosen so that the intensity of vehicle traffic varies in a wide range. A control site was located 7 km from the city on the territory of the garden community "Tatarstan" (Table 1).

Table 1. Traffic volume on the the studied areas of the city of Kazan (average ± SD, n=10).

No.	Study plots	Traffic intensity, vehicles per hour
1	Kontrol	50±6
2	Ippodromnaja Street	380±45
3	Pavlyukhina Street	720±111
4	Tatarstan Street	965±98
5	Ostrovsky Street	1180±107
6	Halturin Street	1460±88
7	Akademika Parina Street	1632±74
8	Mavlutova Street	2100±103
9	Gor'kovskoe Shosse Street	2596±112
10	Orenburg tract Street	2992±108

Evaluation of pollution by motor transport

Road traffic pollution was evaluated by traffic volume (vehicles per hour). The counting of cars was performed in the morning (from 8 to 10) and in the evening (from 17 to 19) [16].

Traffic intensity correlates with the main pollutant content (oxides of sulfur, nitrogen, carbon, gasoline, kerosene, benzo[a]pyrene and formaldehyde) in the air along highways [12, 13].

Assessment of reproduction parameters and germination

In order to analyze the effects of pollution young generative (q1) plants of ontogenetic state were used, the flowering shoots of which were cut off on the fourth day after the end of flowering [14]. Ten of inflorescences with a peduncle (10 cm) were cut randomly from the sites of 10 × 40 m.

Each inflorescence was placed in a separate paper bag. Ripened seeds were stored in a refrigerator at the temperature of -18 ^{0}C. For comparison, the seeds were used matured on the parent plant, collected and stored as well as cut off ones during the period of ripening.

Seeds were germinated in petri dishes, 50 seeds per dish in a settled tap water. The counting of germinated seeds was carried out on the seventh day of germination.

Statistical analysis

Statistical analysis was performed using the program OriginPro 9. In order to evaluate the studied parameters on the traffic intensity a regression analysis was used. The reliability of differences was determined using the Mann-Whitney test.

One-sided ANOVA was used for multiple comparisons of studied parameters. The average (mean) and standard deviation (SD) were used for the graphical representation of data at n = 9-15.

Results and Discussion

Regression analysis showed a significant dependence of the total number of seeds in the inflorescence Taraxacum officinale on traffic intensity (Fig. 1).

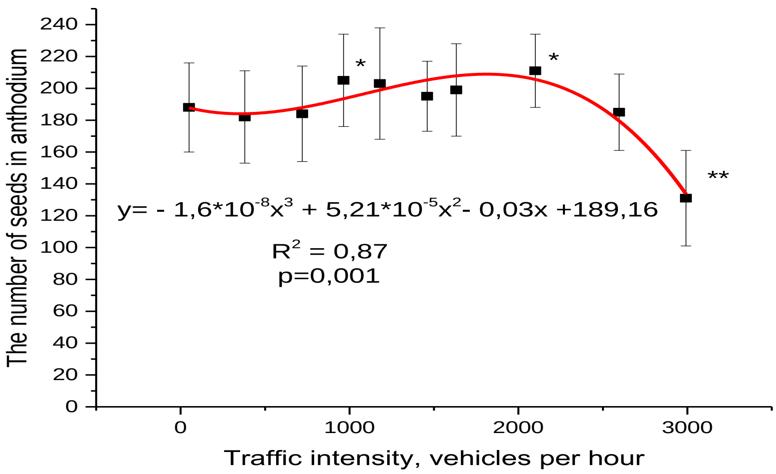

Figure 1. The change of seed total number in the inflorescence with the increase of vehicular traffic (*indicates a significant difference in this parameter between the plants growing in contaminated and control populations, *p<0,05, **p<0,01).

The impact of pollution on seed productivity of plants is actively discussed in the scientific literature. Nevertheless, the consensus on this issue has not developed yet. Several studies show the decrease of production by the seeds of plants with the environment pollution increase [3, 4]. There are also data on seed productivity increase in the gradient of plant habitat pollution [1, 2]. As in the first so as in the second case the authors observed a monotonic dose-response relationship. Works have appeared recently, which stated not the monotony of such dependencies, which are manifested of toxicant impact study in a wide range of values [13]. There is also the impact on the nature of weather condition dependence. In our case, there is a three-phase nature of this dependence (Figure 1). There is a slight decrease of seed number in an anthodium at air pollution increase by motor transport up to 380 cars/hour inclusive.

The seed productivity of a dandelion increases with traffic volume increase up to 2100 vehicles/hour. Further growth of atmosphere pollution by road transport leads to a drastic reduction of seed number in an anthodium (inhibition by 31% relative to the control). The character of dependence did not change according to inflorescence development stage. Then it is known that the weight of unseasoned seeds weight in cut off inflorescences did not depend on the stage of a flower development [14]. In our study, the seed weight in inflorescences, cut off on the third day of flowering did not depend on the pollution gradient. The weight of seeds in an inflorescence, cut off on the fourth day after the end of flowering, depended a lot on air contamination degree (Figure 2, A).

The reduction of weight is observed with the intensity up to 720 vehicles/hour inclusive. Then, the weight of seed increases with the growth of road traffic. At that the weight of seeds with a more polluted cenopopulation (2100 vehicles/hour) is 20% higher than the control. Further increase of road traffic led to a sharp decrease in the total weight of seeds.

Similar studies performed in Nizhny Novgorod, showed the presence of paradoxical effects depending on a dose-number of seeds in an inflorescence and the monotonic decrease of seeds matured on the parent plant in the gradient of air pollution by road transport [13]. Figure 2b showed the dependence of seed mass matured on a parent plant on vehicular traffic intensity. We also observed a monotonic dependence.

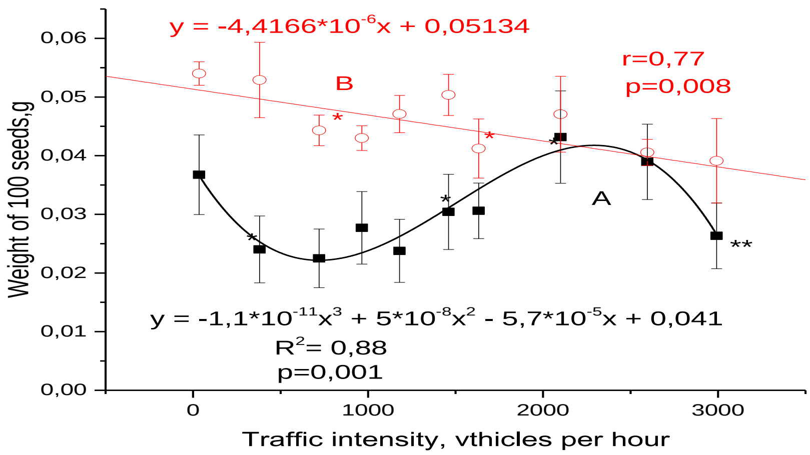

Figure 2. The dependence of seed weight on vehicular traffic volume. A (■) – cut off on the fourth day after the end of flowering, B (○) – matured on parent plants (*indicates significant differences of values from the previous ones, *p<0,05, **p<0,001).

Currently the causes of non-monotonic response in living organisms are studied insufficiently. At the same time, it was shown that at various stages of non-monotonous dependence dose-response a polluting agent may act on different types of receptors or on various cell signal pathways that cause nonmonotonic dependence [17]. It is logical to assume that not the monotony of observed dependencies is caused by the work of antioxidant plant system enzymes, which is consistent with the hypothesis of the progressive involvement of different adaptive mechanisms in the process of phenotypic adaptation to environmental factor [18, 19]. It was assumed that these terms are not only reflected on the weight, but also on the seed quality ripened after cutting.

The adaptation to the air pollution by motor transport is associated with organism energy costs [12]. Obviously, the process of seed formation exhibits lower tolerance to anthropogenic stressor due to limited energy resources in inflorescence cut off on the fourth day of maturing process. Under these conditions, the accumulation of nutrients in seeds should be inversely proportional to the energy costs on adaptation to anthropogenic stressor [19].

Figure 3 shows the dependence of seed number germinated on the seventh day on the air pollution intensity by motor transport. One should note the differences in seed germination of control cenopopulation. The germination of seeds ripened in the parent plant is equal to 85 ± 3% (Fig. 3,B), while the germination of seeds ripened in a cut off inflorescence is two time less and amounts to 42 ± 8% (Figure 3, A). Three-phase dependence is characteristic as for ripened seeds in a parent plant, so as for the ripened seeds in a cut off inflorescence. The inhibition of germination is observed during the first phase. At the traffic intensity of 720 cars/hour the seeds of cut off inflorescences did not germinate, and the germination of matured seeds in a parent plant decreased by 51%. During the second stage the further increase of atmospheric pollution increased germination due to the vehicular traffic intensity increase. In the version of "cut off inflorescences" the maximum germination rate is 15% higher than the control one (p = 0.03) at vehicular traffic volume of 2100 aut./hour. The maximum germination of seed, matured in a parent plant, is achieved at car traffic intensity of 1460 aut./hour and its value is lower than the control one by 13% (p = 0.048).

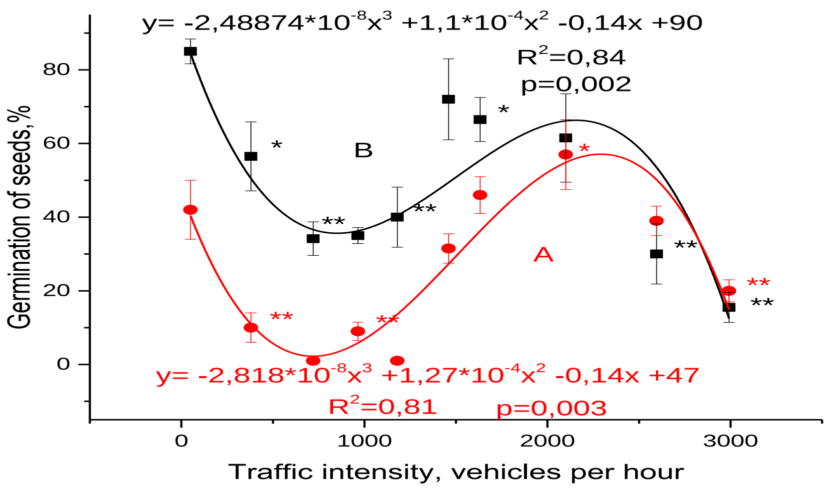

Figure 3. The percentage of seed germination, depending on air pollution by motor transport. A (●) – cut off on the fourth day after the end of flowering, B (■) – matured in parent plants (*indicates significant differences of values from control plants, *$p<0,05$, **$p<0,001$).

The third phase of dependence is characterized by a sharp decrease of germination for both versions, but the level of reduction from control for the "cut off inflorescences" made 22%, and for seeds ripened on parent plants it made 70%. The period of dandelion flowering to seed dispersal lasts 15 ± 3 days during spring period [14]. Consequently, the seeds, ripening on parent plants, received a double dose of benz[a]pyrene and formaldehyde as compared to the version of "cut off inflorescences", which had a negative impact on an embryo viability. In both cases, the weight of seeds in a contaminated cenopopulation decreased by 28% from the control one. It made 0,26 ± 0,005 mg for the cut off inflorescence, and it made 0,39 ± 0,007 mg for the norm. At these differences the percentage of germinated seeds was the same one (Fig. 3). It is known that the critical mass of seeds Taraxacum officinale is equal to 0.212 ± 0.006 mg for their viability in environmentally safe conditions [14]. It made 0.23 ± 0.007 mg in studied coenopopulations. At that the weight of seeds was correlated with their germination differently (Table 2).

Table 2. Correlations between weight and the germination of Taraxacum officinale seeds.

Studied parameters	Seed weight, mg	
	Cut off inflorescences	Norm
Germination of seeds,%	R^2=0.80; p=0.00027	R^2=0.55; p=0.008

A large dose of toxicants made an effect on the relationship between the weight of seeds and their germination. At the same weight (0,39 ± 0,02 mg) the maximum germination of "cut off inflorescences" and a minimum germination was observed for the version "ripened on parent plant".

Conclusion

According to the study, one may make the following conclusions:

1. The dependence of seed weight in Taraxacum officinale inflorescences cut off on the fourth day after flowering on the degree of air pollution is not a monotonic one, and refers to the paradoxical effects.
2. The main factor in the manifestation of Taraxacum officinale seed germination paradoxical effects among urban cenopopulations is an anthropogenic impact dose during their maturation.
3. The critical mass of seeds for their germination is 10% higher than among the plants growing under favorable environmental conditions in terms of increased air pollution.

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Corresponding Author:

A. F. Khamidullin*,

Email: russia@prescopus.com