Enzymatic Activity of Sod-Podzolic Soil under Sosnowsky’s Hogweed

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Abstract. The activity of soil phosphatase, urease and invertase enzymes in sod-podzolic soil under the influence of Sosnowsky's hogweed in the spring has been studied. In soil samples under the mono-community of Sosnowsky's hogweed, high activity of the phosphatase and urease enzymes has been noted; the indicator of invertase activity is characterized as very weak or absent.

1. Introduction
To diagnose the ecological state of soils, biological indicators are increasingly being used, which often turn out to be more effective in cases where the study of traditional morphogenetic, agrophysical or agrochemical indicators does not make it possible to fully reveal the probable response of the ecosystem to any influences. The factors that actively affect the indicators of the biological activity of soils include the root exudates of plants of natural and cultivated plant communities.

In agricultural practice, the phenomena of phytotoxicity and soil fatigue, arising from the permanent cultivation of crops not only of one family, but also with a high saturation of crop rotations of one group, as a result of a violation of the ecological balance in the soil-plant system, are widely known. At certain stages of decomposition, the remains of almost all cultures have phytotoxic properties but to varying degrees [1]. The enzyme activity depends on biodiversity [2], the qualitative composition of the soil [3, 4]. The enzyme activity depends on the season and the ecological state of the environment [5, 6, 7, 8, 9, 10].

The enzymatic activity of soil is an elementary soil characteristic which is the most important indicator of the activity of biological processes. Soil enzymes play the role of catalysts for many biochemical processes in the soil. The processes of transformation of substances and energy, mineralization and humification of organic residues, decomposition and synthesis of minerals, oxidation-reduction potential in the soil are associated with the activity of soil enzymes. At the same time, nutrients available to plants and microorganisms are formed, as well as energy is released [11, 12]. Soil enzymes determine the intensity of manifestation not only of soil microprocesses, but also the degree of development of horizon-forming elementary soil-forming processes, such as sod, podzol-forming or gley processes. Enzyme activity is largely the response of the soil to the influence exerted by various factors, both natural and anthropogenic ones.

Enzyme activity is a more stable and sensitive indicator of soil biogenicity than the intensity of microbiological processes, the number and composition of microflora and fauna. Usually, the activity
of enzymes is maximum in the upper most biogenic soil horizons and decreases down the soil profile, which is related to a decrease in the reserves of organic matter, a smaller number of animals, microorganisms, and plant roots in the lower horizons.

The enzymatic activity of soil is the result of a combination of the processes of intake, immobilization and action of enzymes in the soil. Accumulating in the soil, enzymes become an integral reactive component of the ecosystem. The soil is the richest system in terms of enzymatic diversity. The variety and richness of enzymes in the soil enable successive biochemical transformations of various incoming organic residues to be carried out [13].

The above is applicable for cultivated plant communities. We have made an attempt to consider these phenomena when studying plant communities under the influence of Sosnowsky’s hogweed. Sosnowsky’s hogweed is an invasive species, uncharacteristic for our zone, but very aggressive and extremely resistant. The rapidly growing shoots of Sosnowsky’s hogweed are actively displacing native plant species, every year mastering new territories, moving further north and affecting not only herbaceous, but also mixed and woody formations. Under the perennial thickets of Sosnowsky’s hogweed, only a few plant species remain, and the soil surface under large and fleshy leaves may be completely devoid of both herbaceous and moss vegetation. This situation can be caused by an extremely strong competitive ability of Sosnowsky’s hogweed to absorb nutrients, moisture and solar heat, by its huge biomass, and by the allelopathic properties of its root exudates which inhibit the growth and development of plants and change the composition and number of soil microorganisms. In connection with the above, we have tried to establish whether Sosnowsky’s hogweed has any significant effect on some indicators of biological activity, in particular, on the enzymatic activity of sod-podzolic soil. The objectives of the study were to determine the activity levels of such soil enzymes as phosphatase, urease and invertase in sod-podzolic soils which were under Sosnowsky’s hogweed for a long time. As a comparison, soil samples were taken from neighboring soil plots, where the growth of Sosnowsky’s hogweed was not visualized.

2. Research methodology
To carry out analytical work on the determination of soil enzymes, soil samples under Sosnowsky’s hogweed and natural herbaceous vegetation were taken at the beginning of the growing season at three different plots. The sampling of soil samples was carried out in the Tosno district near the Fedorovsky urban-type settlement, the village of Pioner and the village of Annolovo, where there were areas with perennial thickets of Sosnowsky's hogweed (Heracleum sosnowskyi).

Soil samples were taken directly under Sosnowsky's hogweed and outside the rhizosphere. Soil samples were taken with a sterile instrument from a depth of 20 cm and immediately placed in a cooler bag with cooling elements. The determination of the enzymatic activity was carried out 1–2 days after the selection of soil samples. For simplicity, the samples were labeled with letters and numbers. The control is a substrate without soil and soil sterilized with dry heat.

T1 – samples were taken near the village of Pioner, where the vegetation was represented by forbs (Taraxacum officinale, Alchemilla vulgaris, Alopecurus pratensis, Dactylis glomerata, Rumex acutisella, Stellaria graminea, Vicia cracca, Lathyrus pratensis).

T1 under the hogweed – samples were taken near the village of Pioner, where the vegetation was represented mainly by Sosnowsky’s hogweed, and single plants of cock’s-foot (Dactylis glomerata) were present.

T2 – samples were taken near the village of Annolovo, where the vegetation was represented mainly by cereal crops (Dactylis glomerata, Elymus repens, Alopecurus pratensis, Phleum pratense) with an admixture of common dandelions (Taraxacum officinale) and rosebay willowherb (or fireweed; Chamaenerion angustifolium).

T2 under the hogweed – samples were taken near the village of Annolovo, where the vegetation was represented by the mono-community of Sosnowsky’s hogweed; in the ground layer, there were green leafy mosses (Bryidae) which made up 25% of the ground cover.
T3 – samples were taken near Fedorovsky urban-type settlement, where the vegetation was represented by rosebay willowherb (or fireweed; Chamaenerion angustifolium).

T3 under the hogweed – samples were taken near Fedorovsky urban-type settlement, where the vegetation was represented by Sosnowsky hogweed.

The soil samples were taken three times every two weeks from April 23 to June 01, 2019.

The classification scale of D. G. Zvyagintsev was used as an assessment of the level of activity of soil enzymes [14].

Determination of phosphatase activity was carried out by the method of A. Sh. Galstyan and E. A. Harutyunyan, of invertase activity – by the method of V. F. Kuprevich, of urease activity – by the method of A. Sh. Galstyan modified by Khaziev [15, 16].

3. Results and discussion

The summary data obtained during the analysis on the content of soil enzymes in soddy-podzolic soils under various plant associations is presented in tables 1 (phosphatase), 2 (urease) and 3 (invertase). Changes in enzyme activity over time are shown in Figures 1 (phosphatase), 2 (urease) and 3 (invertase).

**Table 1. Content of the phosphatase enzyme in soil samples under various plant associations.**

| Date      | Indicator | Soil samples |
|-----------|-----------|--------------|
|           |           | T1 | T1 under the hogweed | T2 | T2 under the hogweed | T3 | T3 under the hogweed |
| 23.04.19  | Phosphatase, mg/10g /h | 1.26 | 3.46 | 1.94 | 4.14 | 2.00 | 5.26 |
| 18.05.19  | Phosphatase, mg/10g /h | 1.26 | 2.94 | 1.00 | 1.74 | 0.86 | 4.26 |
| 01.06.19  | Phosphatase, mg/10g /h | 1.86 | 2.86 | 2.06 | 2.20 | 2.20 | 3.26 |

Phosphatase activity appeared in all soil samples. In the soils under Sosnowsky’s hogweed, in all three samples, a higher phosphatase activity was noted in comparison with the soil variant without the presence of the hogweed. The phosphatase activity ranges from 2.20 to 5.26 mg/10g /h, while the minimum value of the activity of this enzyme under Sosnowsky’s hogweed was comparable to the maximum activity observed in the area with rosebay willowherb (2.20 mg/10g /h).

The assessment of the biological activity of the soils was carried out using the Zvyagintsev point scale, and, based on this, the results of activity can be presented as follows:

T1 – weak activity
T1 under the hogweed – medium activity
T2 – 23.04.19 and 01.06.19 0-medium, and 18.05.19 – weak activity
T2 under the hogweed – medium activity
T3 – 23.04.19 and 01.06.19 0-medium, and 18.05.19 – weak activity
T3 under the hogweed – 23.04.19 – high, and 18.05.19 and 01.06.19 – medium

In the period from April to June, there were some fluctuations in the phosphatase activity but the maximum phosphatase activity in the soils under Sosnowsky’s hogweed occurred at the end of April (figure 1).

Thus, the phosphatase activity during the sampling period in sod-podzolic soil under Sosnowsky’s hogweed was high in April and gradually decreased to a medium level. Under the forbs, the phosphatase activity was generally weak.
Figure 1. Changes in the activity of the enzyme phosphatase over time.

The urease activity was manifested differently in the cases of all samples. Very high values of the activity of this soil enzyme were noted in 4 out of 6 samples in April (2400–7415 mg/10 g per day) and it was absent in subsequent samples (Table 2).

Table 2. The content of the urease enzyme in soil samples under various plant associations.

| Date       | Indicator            | Soil samples          |          |          |          |          |
|------------|----------------------|-----------------------|----------|----------|----------|----------|
|            |                      | T1                    | T1 under the hogweed | T2       | T2 under the hogweed | T3       | T3 under the hogweed |
| 23.04.19   | Urease, mg/10g per day | 7415                  | 5800     | 6935     | 2400     |
| 18.05.19   |                      | 85                    | -        | -        | -        | -        |
| 01.06.19   |                      | 3.17                  | -        | 0.50     | 142.50   | -        |

Changes in the activity of the urease enzyme over time are shown in figure 2.
At the same time, the urease activity level under the vegetation of forbs was significantly higher than in soil samples with Sosnowsky’s hogweed.
T1 – activity was absent.
T2 – 23.04.19 – very high activity, 18.05.19 and 01.06.19 – absent.
T2 under the hogweed – 23.04.19 – very high, 01.06.19 – very weak, 18.05.19 – absent.
T3 – 23.04.19 and 01.06.19 – very high, 18.05.19 – absent.
T3 under the hogweed – 23.04.19 – very high and 18.05.19 and 01.06.19 – absent.
Figure 2. Changes in the activity of the urease enzyme over time.

The invertase activity was not manifested in all studied soil samples (table 3).

Table 3. Content of the invertase enzyme in the soil samples under various plant associations.

| Date       | Indicator | Soil samples | T₁ | T₁ Under the hogweed | T₂ | T₂ Under the hogweed | T₃ | T₃ Under the hogweed |
|------------|-----------|--------------|----|-----------------------|----|-----------------------|----|-----------------------|
| 23.04.19   | Invertase, mg/g per day | T₁ | 0.14 | 0.15 | 0.18 | - | 0.13 | 0.14 |
| 18.05.19   |           | T₂ | 0.18 | - | - | - | 0.21 | - |
| 01.06.19   |           | T₃ | 0.18 | 0.15 | 0.15 | 0.19 | - | 0.14 |

In soils under the vegetation of forbs, the invertase activity was generally very weak. In soil samples under Sosnowsky’s hogweed, it was very weak or absent (figure 3).
Figure 3. Changes in the activity of the invertase enzyme over time.

Assessment of the biological activity of invertase in the studied soil samples:
T1 – very weak.
T1 under the hogweed – very weak or absent.
T2 – very weak or absent.
T2 under hogweed – absent or very weak.
T3 – very weak or absent
T3 under the hogweed – very weak or absent.

4. Conclusion
The activity of the soil enzymes in sod-podzolic soils under different plant associations turned out to be very different in time and space.

In soil samples under the perennial thickets of Sosnowsky’s hogweed, only the phosphatase enzyme was highly active in comparison with the variants without the hogweed, the activity of this enzyme was characterized as high in spring, and a gradual decrease in the phosphatase activity was noted in late spring-early summer.

The activity of urease in the soils varied over a very wide range: there was an extremely high activity of urease in April both under the hogweed and forbs, and then the activity sharply reduced or was absent.

In all studied samples, the invertase activity indicator was characterized as very weak or absent.

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