

Specialized pollinators and seed production of *Trollius* species introduced in Western Siberia

Anastasiya Gusar^{1,*}, and Lubov Buglova²

¹FSEE HPE FSEI “Novosibirsk State Agrarian University”, Russia

² FSIS “Central Siberian botanical garden SB RAS”, Russia

Abstract. In five species of *Trollius* L., seed production of fruits was studied, plants being grown in culture in the forest steppe zone in Western Siberia. 2 species representing *Chiastocheta* genus were identified as specialized pollinators (*Diptera, Anthomyiidae*). Those insects pollinate the flowers and damage the seeds of three globeflower species: *T. apertus*, *T. europaeus* *T. asiaticus*. The flower season of other two species (*T. chinensis* and *T. ledebourii*) starts later and the plants can't be exposed to invasion, as *Chiastocheta* flies are at their larval stage yet. Pollination of these species is performed by non-specialized agents. The lowest rate of seed production realization of about 20% is registered in *T. europaeus*, while in *T. ledebourii* it is the highest comprising 71%. We consider the flies of *Chiastocheta* genus as an important part of the complex of factors lowering seed productivity in *Trollius* and their relationship as parasitism. Thus, in West Siberia for *Trollius* seed production increase, measures intended to reduce *Chiastocheta* abundance will be useful.

1 Introduction

Trollius L. representatives growing in temperate latitudes are frost-resistant and promising for introduction in Siberian region. They possess valuable decorative and medicinal properties [1, 2]. In *T. chinensis*, there have been extracted flavonoids exposing proved cancer-fighting activity [3].

Plants of *Trollius* genus being allogamous, pollination agents study turns to be a question of strategy for obtaining seeds. Flowering of introduced species shows its species-specific character in culture as well [4].

Specialized pollinators for *Trollius* genus the flies of *Chiastocheta* genus (*Diptera, Anthomyiidae*) are [5]. The influence of those agents is controversial. *Chiastocheta* imago individuals eat nectar of *Trollius* flowers and concurrently perform pollination gaining to production of seeds. On the other hand, larvae are parasites feeding on nothing but seeds and fruit tissues of *Trollius* genus plants. That decreases seed productivity [6, 7].

For *T. europaeus* L., *Chiastocheta* flies are described to be the only pollinator, as the closed globe-shaped flower makes getting in possible for small-sized insects exclusively. *T.*

* Corresponding author: gusara663@gmail.com

europaeus and *Chiastocheta* have mutual evolution, so their relationship can be identified as obligate mutualism. However, for other *Trollius* species *Trollius–Chiastocheta* interaction is parasitism, since the plants can also be pollinated by non-specialized agents as bees and bumblebees. Thus, the importance of specialized agents for seed production in species with open flower turns less sufficient [8].

The study targets to identify *Chiastocheta* species and to assess seed production in their host-plants of *Trollius* genus from the collection of Central Siberian botanical garden SB RAS.

2 Materials and Methods

The collection ground of Central Siberian botanical garden is located in the south-east of the West Siberian Plain in the southern outskirts of Novosibirsk. The coordinates are N 54.82; E 83.10 by google/maps; h: 130m.a.s.l. seed production in five species was assessed in 2017.

Chiastocheta species were identified in the generally recognized way according to the key reference-books [9, 10] by male genitalia morphology (surstyli, cerci and V sternite projections) and by comparison with the identified species of St. Petersburg outskirts from the collection of Zoology Institute RAS.

Chiastocheta eggs and larvae along with *Trollius* seed production were calculated per fruit comprising a number of uncombed follicles (Table 1, 2). Seed productivity was studied according to the technique proposed by I.V. Vaynaghy [11] and being modified for aggregate follicles of *Trollius*. The percentage of seeds eaten by larvae was calculated from the total number of the developed ones. Potential seed productivity was assessed with a *SteREO Discovery V12* stereomicroscope photos taken by *AxioCam MRc-5* camera.

3 Results

For all the *Trollius* species, we have determined *Diptera* и *Hymenoptera* orders representatives as pollinators. In every *T. Europaeus* individual, sepals are not completely closed in the upper part, thus the flowers can be pollinated by non-specialized agents (Fig. 1).



Fig. 1. *T. europaeus* in USU № 440534 collection.

In *T. apertus* and *T. europaeus*, the terms of flowering are very similar, being mainly overlapped by flowering of the aboriginal *T. asiaticus* species. For them, two specialized pollinator species have been revealed: *Ch. trollii* and *Ch. sp. (rotundiventris)*; both got acclimatized to the introduced successfully.

In *T. chinensis* and *T. ledebourii* the flowering starts about three weeks later than in *T. asiaticus*. During this period, all the specialized flies are passing the larvae stage; that is why summer-blossoming species can't be invaded. Larvae emergence from eggs occurs on the 2–4th day after the flowering period of the vulnerable species is over.

Table 1. Eggs and larvae number on *Trollius* fruits.

Number Species \ Number	N		Eggs		Larvae	
	total	Without larvae	maximum	average	maximum	average
<i>T. apertus</i>	6	1	8	2.83	6	2
<i>T. asiaticus</i>	15	4	6	1.53	3	0,67
<i>T. europaeus</i>	14	3	5	1.93	3	1,8

Number of eggs blown by *Chiastocheta* flies onto the host plant follicles can vary a lot (Table 1). The most active blowing is observed on *T. apertus* plants. There may be up to 8 eggs per fruit. Correspondingly, up to 6 larvae may be feeding on one fruit. However, in all the species, some fruits have been detected without any eggs or larvae. The largest number of totally larvae-free fruits is registered in *T. asiaticus*, thus providing a lower average rate of invasion. The average invasion rate in fruits of the aboriginal species turns to be more than three times lower, in comparison to the one in the introduced *T. apertus* и *T. europaeus*.

Table 2. Seed production of the globeflower introduced species.

Data to compare Species \ Data to compare Species	Follicle, actual average number of seeds	Fruit (aggregate follicle)		Developed seeds, %	Eaten seeds, %
		Actual average number of seeds	Potential average number of seeds		
<i>T. apertus</i>	10.23±0.24	63.67±18.22	226.03±39.98	28.38	19.62
<i>T. asiaticus</i>	9.90±0.29	66.67±8.31	224.88±16.88	30.23	17.93
<i>T. europaeus</i>	7.83±0.60	47.70±8.94	231.97±21.62	20.48	17.56
<i>T. chinensis</i>	13.10±0.16	94.06±7.60	316.48±12.96	32.31	-
<i>T. ledebourii</i>	11.14±0.21	216.09±17.93	324.62±17.41	71.48	-

The potential seed production of fruits is higher in the species not exposed to *Chiastocheta* invasion than in the vulnerable ones (Table 2). The actual seed production appears to be the highest in *T. ledebourii*, while the lowest – in *T. europaeus* up to complete withering of fruits during their maturation period. However, no direct dependence of productivity on the invasion rate is revealed. In *T. ledebourii*, the actual seed production is more than twice as high as in *T. chinensis*. Similar tendency is observed in the vulnerable species. All the three species involved have nearly equal potential production, while the actual seed production is the lowest in *T. europaeus*, despite the flyblown of *T. europaeus* and *T. asiaticus* plants being close.

4 Discussion

In the region under the study in West Siberia, we have detected 2 species of specialized pollinators *Ch. trollii* and *Ch. sp. (rotundiventris)*, which are found in Europe as well [8]. Their behavior corresponds to the data of literature [12].

The tendency of the introduced *T. apertus* and *T. europaeus* species to higher invasion rate can most probably be explained by the peculiarities of *Trollius–Chiastocheta* consortium mutual evolution in each region, thus the aboriginal species *T. asiaticus* turns to be a little more resistant to the invasion by flies. This confirms the reports on plants ability to increase the content of *Chiastocheta*-protective compounds [13, 14].

Aside from the pollination agent's blown, seed production decrease in *T. europaeus* can additionally be caused by the introduction of plants to more severe climatic conditions.

Introduction effectiveness is determined by the plant ability to reproduction [15], so in West Siberia, *T. ledebourii* proved to be the most successful and productive, as here this species is affected by two more beneficial factors (rhythm and climate) than within its natural habitat. Both factors provide them the invulnerability to *Chiastocheta* larvae invasion. Pollination by non-specialized agents turns to be enough for *Trollius* species mass seed production when grown in culture under conditions of West Siberia.

In this connection, *Trollius–Chiastocheta* relationship should be considered as the form of parasitism even for *T. europaeus*. For *Trollius* species cultivation, measures intended to reduce *Chiastocheta* abundance are desired to increase plant seed production.

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