Aspects of Ecology of *Drosera rotundifolia* L. at the White Sea Coast

P.A. Volkova • 119526, Prospect Vernadskogo St. • 95-3-123• Moscow • Russia • avolkov@orc.ru

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Introduction

Carnivorous plants found in oligotrophic habitats capture animals to obtain nitrogen and other mineral substances (Brewer, 1998; Chandler & Anderson, 1976a; Krafft & Handel, 1991; Masing, 1959; Redbo-Torstensson, 1994). The contents of different mineral substances in the soil can significantly influence the characteristics of plants (Chandler & Anderson, 1976a; De Ridder & Dhondt, 1992; Redbo-Torstensson, 1994). Various authors have established the abundance of carnivorous plants in the moist habitats (Kats, 1941; Dixon & Pate, 1978; Aldenius *et al.*, 1983; Brewer, 1998).

The positive connection between the number of caught animals, the size of the plant, and the possibility of its flowering was shown for *Drosera* species by Kraft & Handel (1991) and Redbo-Torstensson (1994). Many authors have reported on the dependence of the possibility of flowering, the intensity of vegetative growth, and the success of insect-catching on the environmental factors (Dixon & Pate, 1978; De Ridder & Dhondt, 1992; Redbo-Torstensson, 1994). This is contrary to Brewer's (1998) opinion.

Many publications about *Drosera* species are connected with the study of the influence of insect-eating on *Drosera rotundifolia* morphology (Krafft & Handel, 1991; Balandin & Balandina, 1993; Redbo-Torstensson, 1994), and also with the physiological and biochemical aspects of the carnivory for *Drosera* species in the laboratory (Kellermann & Raumer, 1878; Darwin, 1875; Busgen, 1883; Poretskij, 1914; Chandler & Anderson, 1976a; Chandler & Anderson, 1976b; Pate & Dixon, 1978; Dixon *et al.*, 1980; Thum, 1986). A discussion on some broader aspects of *D. rotundifolia* ecology is also found in Thum (1986).

However, the experiments in the laboratory described in the majority of cited papers, do not take into account many factors (for example wind, strong rains and overheating) that have an essential influence on the vital functions of carnivorous plants (Chandler, Anderson, 1976a; Hanslin and Karlsson, 1996).

This field-based research project investigates the ecology of *Drosera rotundifolia*, with an emphasis on studying the influence of the environment on the plant's morphophysiological characteristics.

Materials and methods

In July-August of both 2000 and 2001 the flora of fifty-one islands of the Keretskiy archipelago and Keev bay (the White Sea) was investigated during Moscow South-West High School expeditions. *Drosera rotundifolia* was found at 31.4% of the investigated islands. This implies that *D. rotundifolia* is a species typical for the study area, but its distribution is probably limited by various environmental factors.

The investigation of the morphophysiological characteristics of *D. rotundifolia* at the various ecotopes was carried out at the northern part of the Karelian coast of the White Sea during July 23-August 11, 2001 (Figure 1). These 22 sites were laid in random manner on the populations of *D. rotundifolia*. Seven of these spots were situated on the islands in Keev bay and in the Keretskiy archipelago, and the others were situated at the continental lakeside. The surface area of all the areas were 0.04 m^2, except for one which was 0.02 m^2, and another which was 0.01

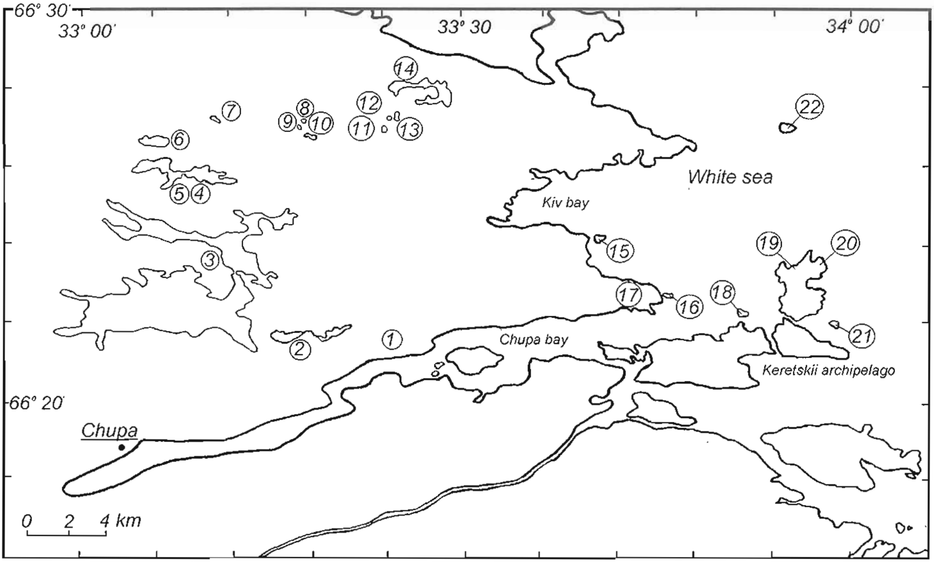

Figure 1: The region where *D. rotundifolia* was investigated. The study spots are indicated with numbers.

m^2. There were 222 *D. rotundifolia* plants in the sample area. During the investigation we also recorded all discovered plant species including mosses. Lichens were also recorded.

For each *D. rotundifolia* plant in our sample, we measured the leaf blade diameter of the largest leaf, the length of its petiole, the diameter of the leaf rosette, and (if present) the length of the flower stalk (see Figure 2). We also recorded the number of captured prey (see Figure 3), and the number of developing, active, and dead leaves for each plant.

We calculated the fractions of plants with caught animals, and the fractions of plants with developing leaves in the total number of *D. rotundifolia* plants on each site. We also estimated the capturing surface S of *D. rotundifolia* as $S=\pi d^2 N/4$, where d is the diameter of the largest leaf blade, and N is the number of active leaves per plant (see Figure 4). (The largest leaf blade diam-

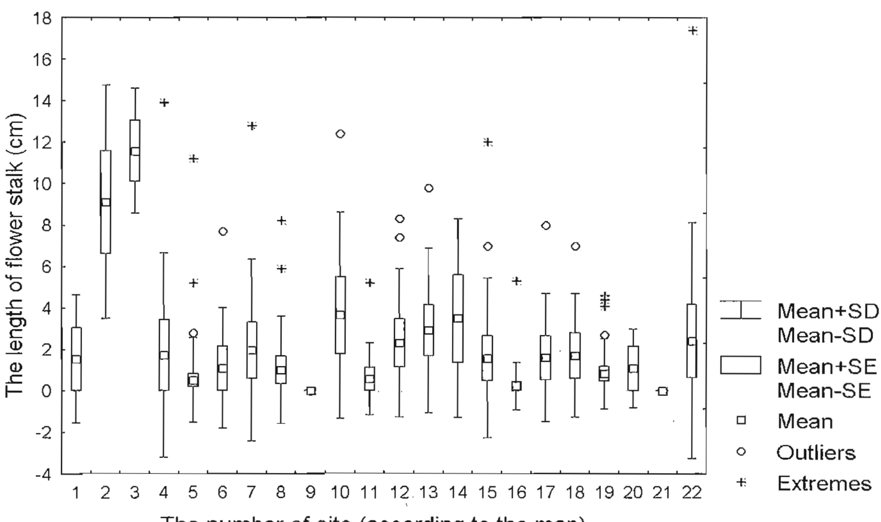

Figure 2: The length of flower stalk (with flowers)of *D. rotundifolia* plants for each of the investigated sites.

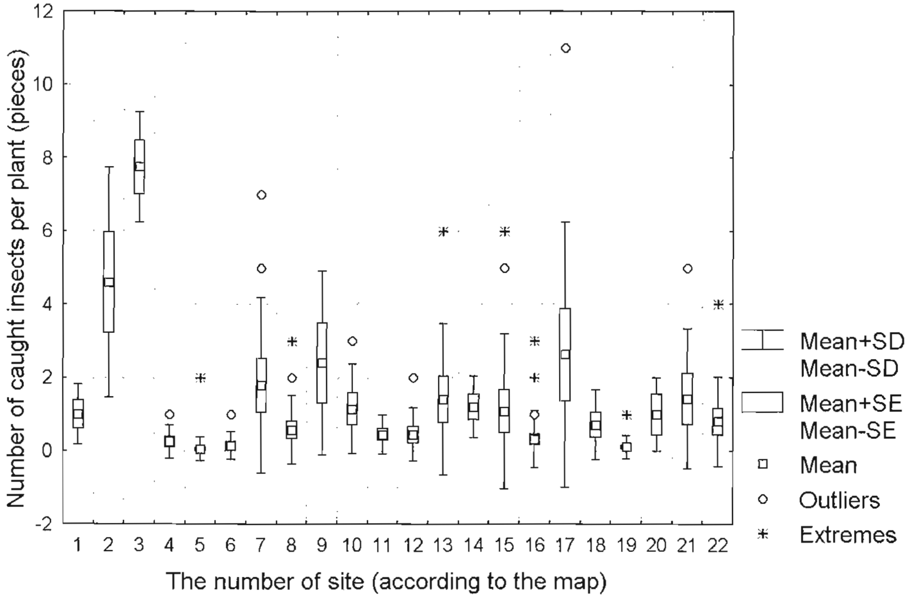

Figure 3: The number of caught animals per *D. rotundifolia* plant for each of the investigated sites.

eter was used to estimate the size each leaf would become at its point of maximum development.) Indicator-species plants observed at each site were used to estimate the site's environmental factors.

It is well known that a *D. rotundifolia* seedling can reach its full size within one vegetative season (Thum, 1986; Kraft & Handel, 1991). As such, we can use the size of the vegetative parts of each plant as a characteristics of the intensity of its vegetative growth, and the length of flowering stalk as a characteristic of the plant's reproductive intensity. The number of animals caught by each plant can be used as the characteristic of the success of insect catching by the plant.

A factorial analysis of the site-averaged values of *D. rotundifolia* morphophysiological characteristics was carried out (see Figure 5). Cluster and discriminate analyses of morphophysiological characteristics for each of observed *D. rotundifolia* plants were made. We also used the t-test for independent samples to compare average leaf length and average catching surface under different environmental conditions. The distribution of the plants into clusters was tested by performing a χ^2 goodness of fit test to the Poisson distribution. The parametric correlation analysis of our data was carried out. The statistical data processing was performed using the STATISTICA program package (StatSoft, Inc.).

Results and analysis

A factorial analysis of the spot-averaged values of *D. rotundifolia* morphophysiological characteristics was carried out (Figure 2). Two factors completely describing the plant development were found. Factor #1 describes the intensity of reproduction and vegetative growth of *D. rotundifolia* and the success of it insect catching. Factor #2 describes the spot-averaged quantity of developing leaves (which are not unfolded and so can not catch prey) and the percentage of plants with such type of leaves located on this spot.

The correlation analysis of the obtained data shows that the success of insect catching by *D. rotundifolia*, intensity of its reproduction, and vegetative growth are related to each other ($N=222$, $r=0.48$-0.61, $p<0.05$). This conclusion confirms the data obtained by Krafft & Handel (1991) and Redbo-Torstensson (1994).

The increase in a density of *D. rotundifolia* on any spot leads to the decrease of the num-

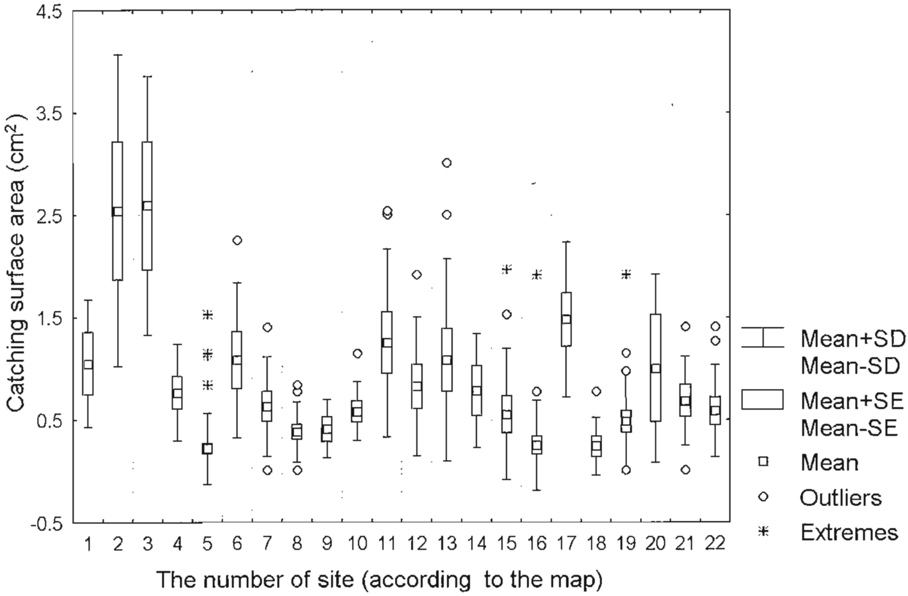

Figure 4: The capturing surface of *D. rotundifolia* plants for each of the investigated sites.

ber of plants with captured prey at the spot (N=22, r =-0.50, $p<0.05$). This suggests intrapopulation competition for prey. As the density of plants on a spot increases, the length of their active leaves (i.e. that are capable of capturing animals) decreases (N=22, r =-0.50, $p<0.05$). Thus the overlapping of active leaves is prevented, allowing for decreased competition for prey within a population.

Most of the *D. rotundifolia* grew on sphagnous spots (36.4% of the 22 investigated populations) or on bogs situated on the heights formed by rocky outcrops (27.3% of the 22 investigated populations). Populations were also found on typical raised bogs (13.6%); in sparse waterlogged stands of conifers with *Betula nana* (9.1%); on a stony ground (9.1%); and once on a moist track (4.5%). All these ecotopes can be characterized by treeless or sparse pine woods, and little or no slope. In such exposed environments, plants have little wind protection or shading. The exposure to the wind may increase the probability of catching flying animals, while the high light levels promote active leaf formation (Masing, 1959; Chandler & Anderson, 1976a; Redbo-Torstensson, 1994; Brewer, 1998).

Drosera rotundifolia usually grows in association with *Vaccinium oxycoccus, Rubus chamaemorus, Empetrum hermaphroditum* and *Sphagnum fuscum* (Various species of *Sphagnum* occur at 90.9% of the sites).

In the cluster analysis of morphophysiological characteristics, all the investigated plants were divided into seven clusters, one of which included about one third of the total plants. For ten of the investigation spots, more than 50% of the plants were included in this large cluster. In most cases, plants from the a single spot distribute themselves more or less uniformly into 2-4 various clusters. (χ^2=242.3, 11 degrees of freedom, P=0.0). According to results of discriminant analysis only 39.6% of the total number of the investigated instances of *D. rotundifolia* are grouped by morphophysiological characteristics according to their location. This confirms there is no significant influence of the environment on the morphophysiological characteristics of *D. rotundifolia* in our study area.

The largest active *D. rotundifolia* leaf had a greater diameter if *Andromeda polifolia* is present, than if *A. polifolia* is absent (0.4±0.03 cm and 0.3±0.01 cm, respectively). Redbo-Torstensson (1994) noted the increase of the *A. polifolia* density after the addition of nitrogen in the soil, the occurrence of *A. polifolia* probably indicates increased soil nitrogen levels. As such, it is likely that the size of *D. rotundifolia* depends positively on the nitrogen content in the soil.

The leaf-trapping surface area of *D. rotundifolia* is greater in the presence of *Carex pauciflora* than when *C. pauciflora* is absent (1.14±0.16 and 0.62±0.05 respectively). *Carex pauciflora* is considered to be a plant typical of damp ecotopes (Katz, 1941), so it follows that the total leaf trapping area of *D. rotundifolia* depends positively on a moistness of its ecotope. Such dependence can be hypothesized as being due to the increased water demand of a larger, transpirating leaf surface that is covered by secretory glands. This hypothesis explains the observations of many authors (e.g. Katz, 1941; Dixon & Pate, 1978; Aldenius *et al.*, 1983; de Ridder & Dhondt, 1992; Brewer, 1998; and others) about the confinement of carnivore plants to damp ecotopes.

The number density of the plants in the investigated spots varied from 75 m^{-2} up to 925 m^{-2}, and the average value was 256±43.8 m^{-2}. Redbo-Torstensson (1994) reports densities of 380-520 m^{-2}. The disparity in number densities can probably be explained by the fewer types of ecotypes Redbo-Torstensson investigated. Thum (1986) recorded 405 plants m^{-2} at a small silted bog in Germany—this suggests that the density of *D. rotundifolia* varies considerably according to its environment. This fact suggests that the density of *D. rotundifolia* varies considerably according to its environment.

In summary, we conclude:

1. The success of insect catching, intensity of reproduction and vegetative growth of *D. rotundi-*

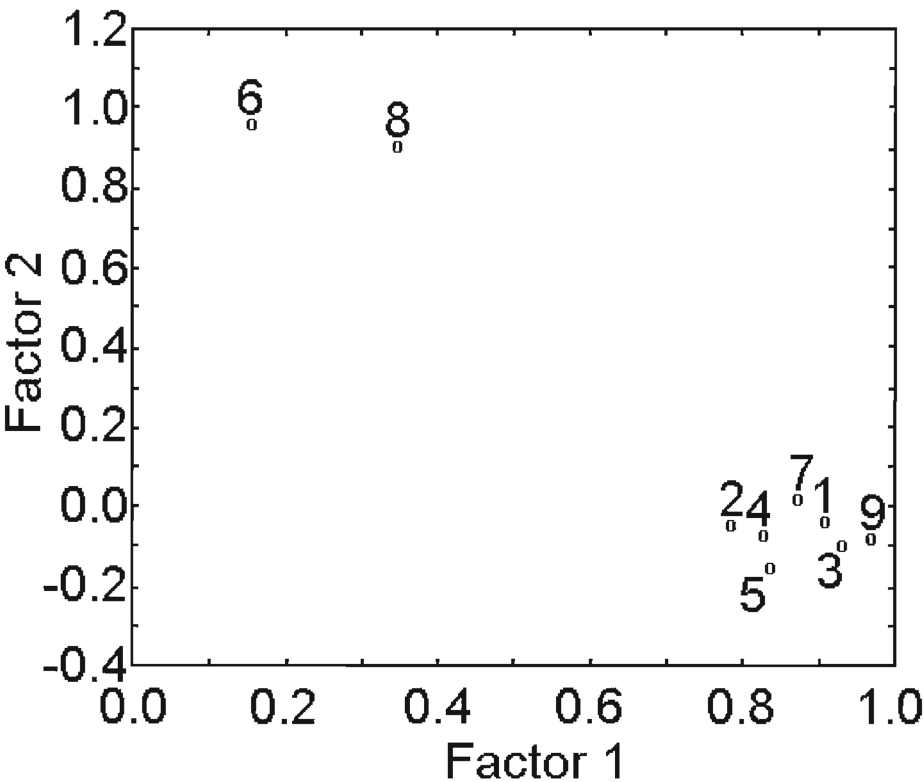

Figure 5: The results of factorial analysis of the spot-averaged values of *D. rotundifolia* morphophysiological characteristics. 1- the diameter of the blade of the greatest active leaf; 2- the petiole length of the greatest active leaf; 3- the diameter of the leaf rosette; 4- the number of prey per plant; 5- the number of active leaves per plant; 6- the number of developing leaves per plant; 7- the length of the flower stalk; 8- the percentage of plants with developing leaves; 9- the whole catching surface of the plant.

folia, and the quantity of its developing leaves completely characterize the development of this species.

2. There is an intrapopulation prey competition within populations of *D. rotundifolia*.
3. Usually *D. rotundifolia* grows in raised bogs and waterlogged ecotopes.
4. The size of *D. rotundifolia* depends positively on the nitrogen content in the soil.
5. The total prey-trapping leaf surface area of *D. rotundifolia* depends positively on the moisture level of its environment.
6. The number density of *D. rotundifolia* varies considerably, depending on its environment.

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