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Objekttyp: **Article**

Zeitschrift: **Botanica Helvetica**

Band (Jahr): **107 (1997)**

Heft 1

PDF erstellt am: **21.09.2024**

Persistenter Link: https://doi.org/10.5169/seals-72638

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Bot. Helv. 107 (1997) 83–90
0253-1453/97/010083-08 $ 1.50 + 0.20/0

Botanica Helvetica

Growth habits of *Salix polaris* in snowbeds in the Khibini Mountains, Kola Peninsula, Russia

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Manuscript accepted January 23, 1997

Abstract

Douglas D. A., Jones M. H., and Pokhilko A. 1997. Growth habits of *Salix polaris* in snowbeds in the Khibini Mountains, Kola Peninsula, Russia. Bot. Helv. 107: 83–90.

The growth habits of *Salix polaris* Wahlenb. were examined in snowbeds at an alpine fellfield and an alpine dwarf-shrub tundra site in the Khibini Mountains, Russia. Plants were excavated and mapped for growth pattern analysis. With increasing size, *S. polaris* exhibited an increase in reproduction relative to vegetative growth. Vegetative density decreased with patch size. Patches at the fellfield were larger than those at the dwarf-shrub site, and significantly fewer patches flowered at the fellfield in 1991; otherwise, no statistically significant differences in growth variables were found between the two sites.

Introduction

The polar willow, *Salix polaris* Wahlenb. ssp. *polaris* Wahlenb., is a dwarf, prostrate, dioecious shrub found across the Asian arctic (Hultén 1968, Porsild and Cody 1980, Crawford and Balfour 1990). It occupies a variety of habitats from well-vegetated tundra to alpine fellfields, and is commonly found in long-lying snowbeds. Snow benefits plants by protecting against abrasion by wind-blown ice and mineral particles, providing insulation against cold extremes and desiccation, and preventing premature stem warming from direct insolation (Billings 1987, Sonesson and Callaghan 1991). Restriction to snowbeds could also be an indication of limited competitive ability in the plant communities found adjacent to snowbeds. Wijk (1986) found that *S. herbacea* L., another arctic willow with relatively similar life history traits, exhibited higher cover, biomass, and shoot density when located under the longest-lying snowbeds.

Most of the stem structure of *S. polaris* is within the substrate, with only the decumbent stem ends rising above the surface (Fig. 1). Numerous horizontal branches (rhizomes) originate at the caudex or "root collar complex" at the top of the central taproot and break the surface in their first or second year (Zhyikova 1979, Dervis-Sokolova 1966). Generally, one to three leaves are then produced on each stem terminal, and if present, only one catkin.

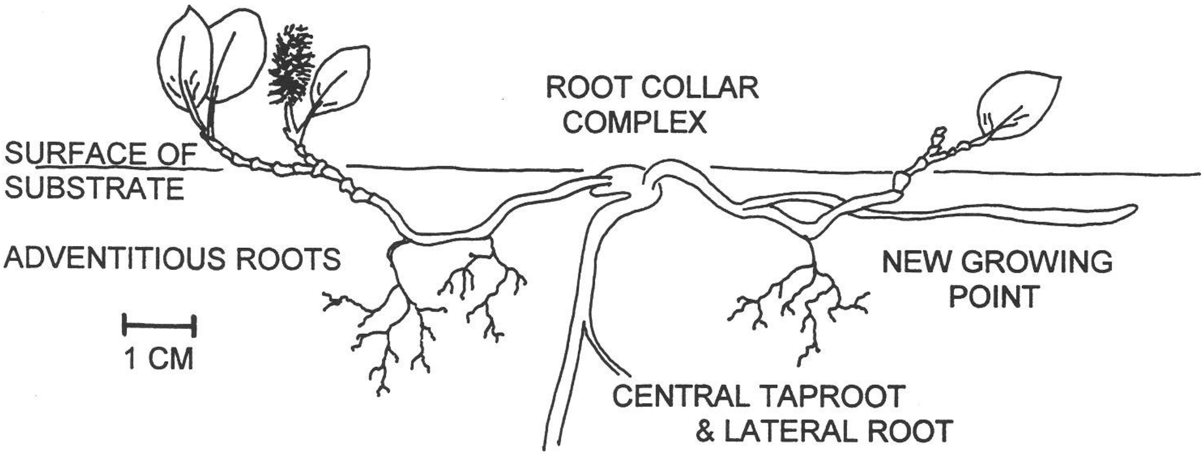

Fig. 1. Morphology of *Salix polaris*.

Ecologists have speculated about differences in growth form varying by habitat type; studies quantifying the growth patterns of *S. polaris* are not known to exist. The objective of this study was to describe and quantify some aspects of the species' morphology as found in two low arctic snowbed sites.

Study sites

Research was conducted in the Khibini Mountains near the city of Kirovsk on the Kola Peninsula, in the Russian Republic, during July and August 1991. One study site was located in alpine dwarf-shrub tundra at approximately 550 m elevation, directly above the Polar Alpine Botanical Garden, hereafter referred to as the dwarf-shrub site. Vascular plant species with the highest cover included *Cassiope hypnoides* D. Don and *Juncus trifidus* L. Bryophytes included *Marsupella boeckii* (Aust.) Kaal., *Pleurocladula albescens* (Hook.) Grolle and others. Lichens were a minor component in the study area and were not identified. *Salix polaris* was located in a snowbed area approximately 15 × 100 m where the average time of snow melt is mid-June (A. Pokhilko, pers. obs.). Within the snowbed area, vegetation cover was approximately 60%, aspect was generally southeast, and slope averaged 15%.

A second study site was an alpine fellfield located at 1090 m elevation on the relatively flat top of the Lovchorr massif, approximately 20 km from the Garden site, hereafter referred to as the fellfield site. Vascular plant cover was less than 5%, and predominant species included *Saxifraga oppositifolia* L., *Luzula arcuata* (Wahlenb.) Sw., *Cardamine bellidifolia* L., and *Salix polaris*. Moss and lichen species were not identified. Research was conducted in an undisturbed area approximately 150 × 150 m; aspect was generally southwest on slopes of 2–4%. At this location, frost action had left sorted rock polygons, and many boulders were scattered throughout the study area. Strong prevailing winds restrict snow deposition to the lee of these larger rocks, creating small-scale snowbeds which generally melt at the end of June (A. Pokhilko, pers. obs.). *S. polaris* was found nearly exclusively in moss mats beneath these snowbeds. During the summer, this site is subject to heavy fog, substantially restricting insolation.

Methods

Each study site was intensively searched and all patches of *S. polaris* were located and flagged. We use the term patch because in some excavations more than one taproot (root collar) system suggested the potential presence of more than one genet; such patches were not included in our statistical analyses. The area of each patch was measured and recorded in one of five size-classes (Table 1). We defined individual patches as those with apparent edges at least 5 cm distant from one another. Both male and female catkins were in flower during the time of the study, and in a separate survey, gender was recorded for all patches in the study areas if inflorescences were present.

Table 1. Sizeclass distribution of patches of *Salix polaris* at the dwarf-shrub and fellfield sites. The excavated patches at each site are a subset of all surveyed patches. Numbers of patches in each category are shown. m = male; f = female; nf = non-flowering; t = total. Under Excavated Patches, "–" indicates no excavations were done in this category. Reproductive status was associated with size class only in excavated patches.

Size-class	Area (cm^2)	Dwarf-shrub Site					Fellfield Site				
		Patches Excavated				Number of Patches Surveyed	Patches Excavated				Number of Patches Surveyed
		m	f	nf	t		m	f	nf	t	
1	<25	–	–	–	–	34	–	–	–	–	9
2	25–100	2	5	2	9	29	0	1	8	9	14
3	100–300	–	–	–	–	27	–	–	–	–	18
4	300–625	2	5	0	7	14	–	–	1	–	11
5	>625	–	–	–	–	4	–	–	–	–	46
Total						108					98

Excavations were conducted on a subset of patches at each site. Selection was based primarily on whether patches appeared to be single individuals, and also upon the extensive amount of time required for careful excavation and mapping. Entire patches of size-class 2 were excavated in order to obtain information about entire patches, but we limited excavation of size-class 4 patches to 50–100% of the apparent aboveground area. Table 1 gives the number and gender of patches that were excavated at each site.

Prior to excavation, a 25 × 25 cm quadrat with a 5 cm by 5 cm grid was secured over the whole patch or the portion to be excavated. Excavation was done carefully using forceps and dissecting probes. The shoots, root collar complex, and upper portion of the taproot were then mapped on large-scale graph paper. Number and positions of leaves, catkins, and new rhizomes (growing horizontally and not yet producing leaves) were noted on these maps (Fig. 2).

Data analysis

Only excavated patches with single taproot systems were used in the statistical analyses. The length of the horizontal system in each excavated patch (or portion thereof) was determined from the maps using a map-distance measurer. The numbers of leaves, catkins, shoot terminals, and new rhizomes were counted.

Two variables involving patch size were calculated and used in the analyses. The first, patch area, was calculated as the polygon produced by the most peripheral plant parts drawn on the maps,

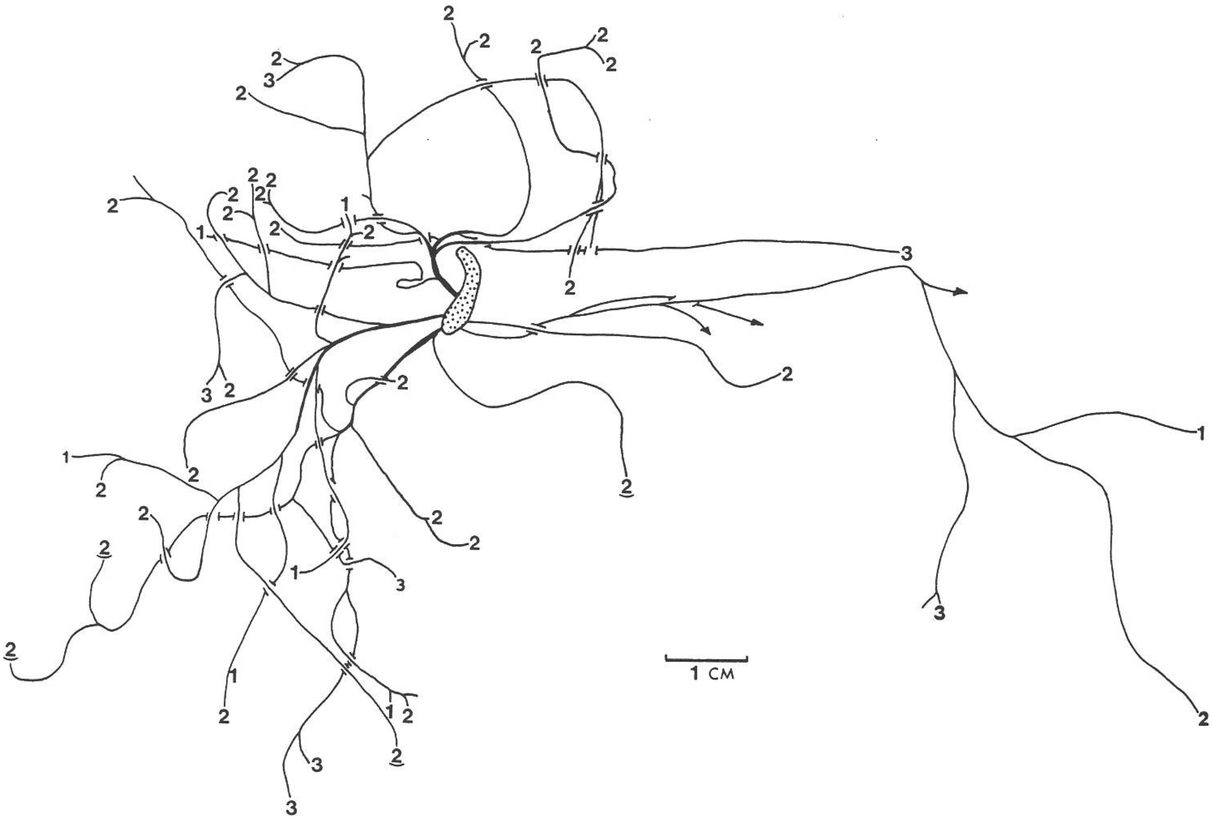

Fig. 2. Map resulting from the excavation of a size-class 2 patch at the dwarf-shrub site. The central stippled area is the root collar complex. The number of leaves on each shoot terminal is indicated; the lack of a number next to a shoot terminal means that it had no leaves. A curved line beneath a number indicates a catkin. A dark arrow signifies a new rhizome.

minus any square centimeters defined by the map grid lines that did not contain any plant parts. This correction was consistent with field observations that patches often are interrupted by other species and/or rocks. The variable patch area was used when the *occupied* area was of interest, i.e., in the calculation of density parameters. The other variable quantifying patch size was patch radius. It was calculated from the variable patch area (before correcting for unoccupied square centimeters), and assumed the area to be circular; unoccupied areas were not removed as this better reflected radial growth and possibly age.

Several density parameters were calculated for each patch (Table 2). Most of these were in terms of area (using the variable patch area); two were on a linear density basis, calculated as the number of structures (leaves or shoot terminals) per cm along the horizontal system.

A variable quantifying reproduction, catkins/leaf, was used to describe the emphasis on reproduction in relation to vegetative growth. Analysis of this variable was restricted to data from the dwarf-shrub site because only one of nine patches excavated at the fellfield site was producing catkins. Leaf variables quantified the vegetative state of the patches; new rhizomes, though vegetative in nature, also have an expansionary function, and thus were examined separately. Vegetative death was quantified as dead shoot terminals/cm^2.

All statistical analyses were done using SAS (1990). Because we were looking for growth patterns, we performed correlation analyses on vegetative variables for the entire data set, and on reproductive variables for data from the dwarf-shrub site. Stepwise regressions were performed involving calculated densities as dependent variables, using patch radius and site as the independent variables (Table 2).

Table 2. Variables from excavated patches with single taproot systems; mean (±SD).

Variable	Dwarf-shrub Site		Fellfield Site
	Size-class 4 (N=7)	Size-class 2 (N=9)	Size-class 2 (N=9)
Patch area (polygonal area minus unoccupied cm^2) (cm^2)	179.0 (82.5)	43.2 (17.5)	49.1 (21.9)
Patch radius (cm)	8.4 (2.6)	3.8 (0.9)	4.0 (1.0)
Leaves/cm^2	0.964 (0.279)	1.783 (0.499)	1.686 (0.954)
Leaf linear density[1]	0.496 (0.207)	1.030 (0.239)	0.870 (0.270)
New rhizomes/cm^2	0.058 (0.036)	0.055 (0.047)	0.076 (0.069)
Catkins/leaf	0.146 (0.107)	0.036 (0.025)	0.001 (0.002)
Dead shoot terminals/cm^2	0.174 (0.098)	0.354 (0.211)	0.389 (0.245)
Total shoot terminal linear density[1] (alive and dead)	0.305 (0.085)	0.658 (0.133)	0.630 (0.203)

[1] Linear density = number of a particular structure/cm of horizontal stem.

Results

Sex and size-class distributions of patches

Of the 108 patches surveyed for reproductive status at the dwarf-shrub site, 20% were producing male catkins, 22% female catkins, and the remaining 58% were non-flowering. At the fellfield site, 3% were producing male catkins, 15% female catkins, and 82% were non-flowering (N=98). In no instance did we observe male and female flowers in the same patch. Smaller size-class patches predominated at the dwarf-shrub site, whereas the largest size-class was the most common at the fellfield site (Table 1).

Size-class and site comparisons

A positive correlation (though not significant) was found between catkins/leaf and patch radius ($r=0.43$, $P=0.10$, dwarf-shrub site only). That is, larger patches showed a greater emphasis on reproduction relative to vegetative growth (Fig. 3a). Negative correlations were found between catkins/leaf and leaves/cm^2 ($r=-0.41$, $P=0.11$) and between catkins/leaf and leaf linear density ($r=-0.68$, $P=0.004$).

The two dependent variables used to describe vegetative state (leaves/cm^2 and leaf linear density) were examined in stepwise regressions; the independent variable patch radius explained a significant amount of variability ($P<0.005$) in each case. In no case was the independent variable site significant. A negative correlation was found between leaves/cm^2 and patch radius ($r=-0.55$, $P<0.005$) (Fig. 3b) and between leaf linear density and patch radius ($r=-0.62$, $P<0.005$). A third vegetative variable, total shoot terminal linear density, was calculated specifically for growth strategy determination (see Discussion), and included both alive and dead shoot terminals. Figure 3c shows the negative correlation found between this variable and patch radius ($r=-0.72$, $P=0.0001$).

Stepwise regression did not explain a significant amount of the variation in the dependent variable new rhizomes/cm^2. In a stepwise regression involving death of vege-

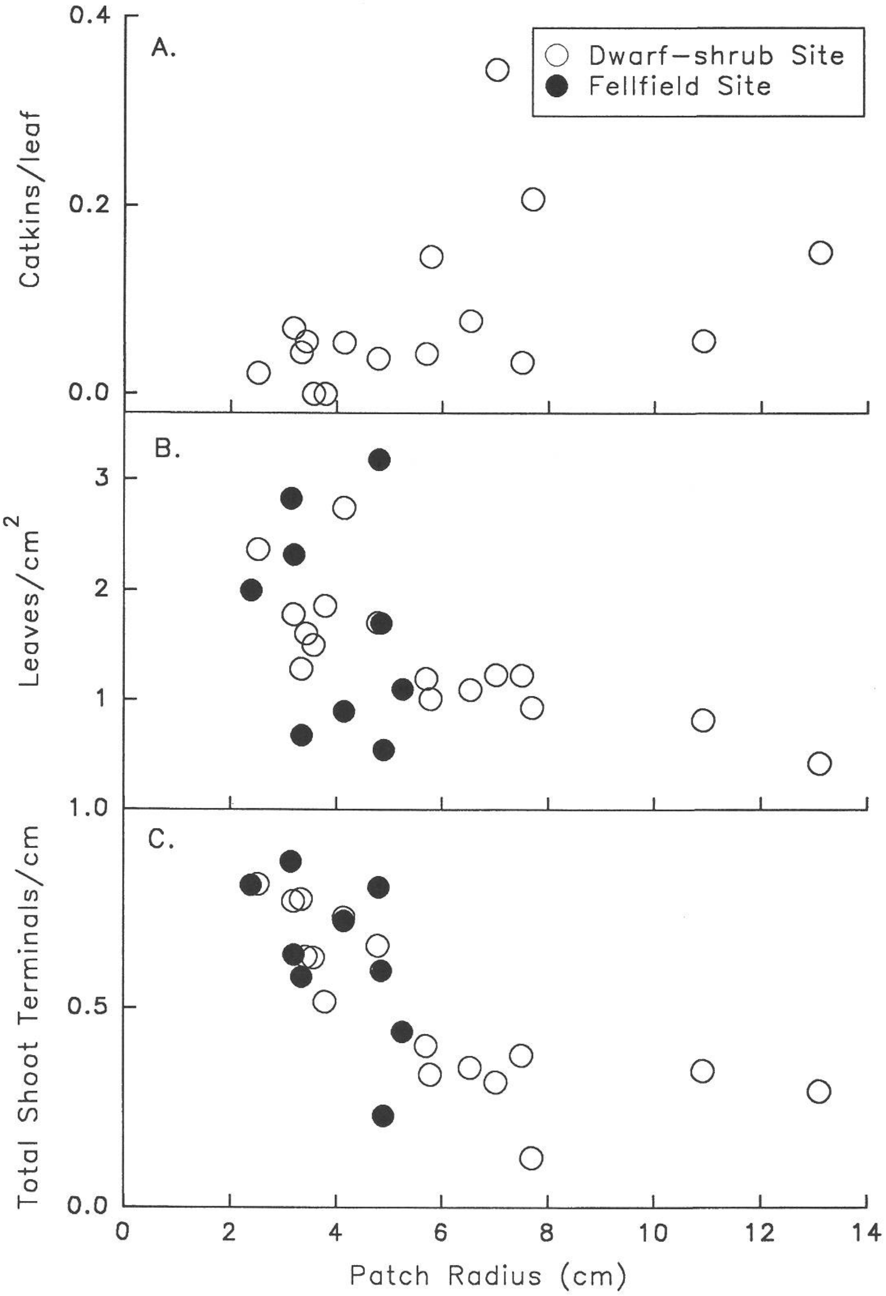

Fig. 3. (a) The relationship between relative emphasis on reproduction (catkins/leaf) and patch radius. N = 16 (dwarf-shrub site data only). (b) The relationship between leaves/cm^2 and patch radius. N = 25 (data from both sites included). (c) The relationship between total shoot terminal linear density and patch radius. N = 25 (data from both sites included).

tative parts, the independent variable patch radius did explain a significant amount of variability in dead shoot terminals/cm^2 ($P < 0.01$). In neither instance was the independent variable site significant.

Discussion

We quantified morphological characteristics of a small arctic willow in two snowbed environments. The dwarf-shrub site represents a large snowbank community within alpine dwarf-shrub tundra vegetation, while the fellfield site, composed of a mosaic of small-scale snowbanks, is 440 m higher in elevation and presents *S. polaris* with colder growing conditions and a shorter growing season. These habitat differences are reflected in the composition and cover of the two plant communities. However, because we found no significant differences in growth parameters, differences between the environmental conditions at the two sites appear inadequate to alter the basic growth form of small *S. polaris* patches.

We found a significant negative correlation between patch radius and variables describing vegetative (leaf) densities (Fig. 3b). Larger patches, like smaller ones, produce leaves primarily at their branch terminals. Therefore, simply because of the morphology of such larger patches, there is a reduction in their vegetative densities. Because of these reduced vegetative densities, larger patches also show an increase in reproduction relative to vegetative variables (Fig. 3a). In larger plants, the observed changes in vegetative growth could be thought of as a shift from battalion to guerilla growth strategy, as defined by total number of shoot terminals (Fig. 3c) (Lovett Doust 1981, Panos 1989). However, the absence of tight correlations between leaf and catkin densities and patch radius (Figs. 3a, 3b) indicates substantial morphological variability, and other factors may be at work. Whether the observed variability is an indication of unmeasured microenvironmental characteristics, ecotypic variation (see McGraw and Fetcher 1992), or simply represents the amplitude of growth form variability is unclear.

Zusammenfassung

Die Wachstumsformen von *Salix polaris* Wahlenb. wurden in den Schneemulden eines alpinen Geröllfeldes und in einer alpinen Zwergstrauch-Tundra in den Khibini-Bergen in Rußland untersucht. Die Pflanzen wurden ausgegraben und für die Analyse der Wachstumsformen abgezeichnet. Mit zunehmender Größe zeigte *S. polaris* eine Zunahme der reproduktiven Organe im Verhältnis zur Anzahl Blätter. Die Dichte der vegetativen Teile nahm mit der Bewuchsfläche ab. Die Bewuchsflächen im Geröllfeld waren größer als diejenigen in der Zwergstrauch-Tundra. Im Jahre 1991 blühten im Geröllfeld deutlich weniger Bewuchsflächen als in der Zwergstrauch-Tundra. Im Übrigen wurden keine statistisch signifikanten Unterschiede der Wuchsformen zwischen den beiden Habitaten gefunden.

This research was funded by a grant from the Trust for Mutual Understanding. The first two authors were guests of the Polar-Alpine Botanical Garden, Kirovsk, Russia, July–August 1991. The Garden's logistical support was greatly appreciated, as was the time made available by a Boise State University Faculty Research Associates position (to D.A.D.). J. Van Deventer provided valuable statistical advice; discussions with W. Büchler, J. Munger, and W. Owen contributed significantly to the development of this paper. Earlier versions of the manuscript were improved by comments from G. Argus, W. Büchler, T. Callaghan, R. Jeffries, J. van Deventer, A. Dufty, J. Zasada, and anonymous reviewers.

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