Effect of Weeds on the Survival and Growth of Scots Pine Seedlings

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Abstract

Weeds are one of the most serious problems in growing high-quality seeding material in the open ground in forest nurseries. About 100 weed species were found in the fields of 11 forest nurseries in Republic of Karelia (Russia). The species can be formally divided into three groups according to morphological characteristics and damaging capacity: (1) annual and biennial herbs, (2) perennial weeds with the bulk of the underground organs in the upper soil layer, and (3) perennial weeds with deep-lying root system. The effects of weeds on the seedlings can be divided into direct (physical damage) and indirect through redistribution of nutrients and water, as well as through stimulation or inhibition of microorganism development in the soil.

Reforestation activities in Republic of Karelia still widely employ coniferous seedlings grown in open-air forest nurseries. This paper offers data on the effect of weeds on the performance of 1- and 2-year-old pine seedlings. Because the nurseries in question are located on poor sandy podzols, the following information may be useful in the recultivation of sand quarries by sowing or planting of pine.

Forest nurseries in Karelia host the total of about 100 weed species (Kuznetsova 1972 and Kryshen 1990). Standing out of the general number are several typical species most adapted to the conditions in forest nurseries: *Cirsium arvense (L.) Scop., Fallopia convolvulus (L.) A. Love, Polygonum lapathifolium L., Vicia cracca L., Trifolium repens L., Chenopodium album L., Elytrigia repens (L.) Nevski., Spergula arvensis L., Achillea millefolium L., Viola arvensis Murr., Chamomilla suaveolens (Pursh.) Rybd., Equisetum arvensis L., Rumex acetosella L.* All these species are widespread in Karelian nursery fields, the incontestable dominants being *Spergula arvensis* and *Elytrigia repens*, replaced in moister sites by *Equisetum arvensis*.

Methods

Percent cover of weeds was determined with a 1-by-0.25-m frame. The size (Vasilevich 1969 and Smirnov and Smirnova 1976) and shape of the frame are convenient as the width of the sowing row is normally 1 m, and weeds are absent or heavily damaged in tractor tracks in strips between the rows. The frame orientation in the sample was across the row to make the seedling counts more convenient (6 stretches, 25 cm each). The frames were established at given distances from each other following the path planned in advance. So that the total number of plots in each field was not less than 15, the number of samples depended on the species diversity, homogeneity of the ground cover, and size of the area. The most typical field sections were chosen on the basis of geobotanical description with regard to the species composition and weed abundance—weeds were mown down to determine the aboveground mass and soil was sampled to measure the root biomass. Soil samples were taken from 5 points of a 0.25-m^2 plot with a 5.7-cm^2 corer (Stankov 1951). Roots were rinsed on sieves with a mesh diameter of 0.25 mm, and then separated from the soil under a binocular microscope and using an electrically charged glass stick (Stankov 1951 and Taranovskaya 1957).

A number of experiments were staged to study vegetative propagation of *Elytrigia repens*. In the first experiment, quackgrass rootstocks were dug out and cut into sections. The sections were weighted, their length measured, and the number of nodes counted. A total of 28 rootstock sections were replanted. Precisely a year after the rootstocks were planted, part of them was excavated to be measured and weighted.

Various methods can be employed to study relationships between plants. Part of the methods is based on the comparison of various parameters in plants growing separately, surrounded by plants of the same species or plants belonging to other species. The parameters compared are biomass, percent cover, height (Gaudet and Keddy 1988, Goldberg 1987, Schoener 1983), productivity of photosynthesis, and other physiological processes (Bazzaz and Garbut 1988; Wray, Strain, 1987). The principal technique under field conditions is to place a plant into a community and monitor its development. This way competitive hierarchy is revealed (Miller and Werner 1987), which enables researcher to check whether the absence of a species from the community is a result of competition (Goldberg 1987). We used this approach to the study of relationships between plants to investigate the effects of weeds on Scots pine growth. *Elytrigia repens* and *Cirsium setosum* plants were planted in 1-m^2 plots. *Spergula arvensis* was not sown specifically, as it was abundant in the nursery soil. Pure one-species communities were established by removing all plants of other species from the plots, and removing all weeds from the control. The following year *Pinus sylvestris* seeds were sown. Sown in each plot were 600 seeds (6 rows of 100 seeds). Thirty plots were established for each variant. The surviving pine seedlings were counted twice. In 2 years, all seedlings were excavated, measured and weighted. In addition, the number of weed shoots was counted in each plot. At the termination of the experiment all weeds were dug out, air dried, and the above- and below-ground parts were weighted separately.

Observations were performed to study the effect of *Elytrigia repens* on 1-year-old pine seedlings: points where quackgrass rootstock crossed the seeding row were chosen, each centimeter all seedlings were excavated at various distances from the point. The number of seedlings in 1 cm of the row was counted, the masses of the above- and below-ground parts of each seedling were measured. Counts were made in 13 points in two directions.

The distance from the weeds to the closest surviving pine seedling was measured. Isolated weeds were chosen in fields of 1-year-old seedlings so that the stem base was in the sown row. These two conditions do not often happen to appear together, therefore impact zones were analyzed in just 17 cases for *Elytrigia repens*, 22 for *Spergula arvensis*, 11 for *Achillea millefolium*, 16 for *Senecio vulgaris,* 18 for *Viola arvensis*, 8 for *Rumex acetosella*, 9 for *Equisetum arvense*, and 4 for *Chamomilla suaveolens*.

Weeds for the study of the qualitative and quantitative composition of mycoflora were sampled from plots where only the species of interest grew. Microbiological analysis of the soil root layer was carried out following M.A. Litvinov (1969) technique by S.N. Kiviniemi, researcher of the Forest Research Institute.

Results and discussion

Geobotanical description of the nursery fields of the Kondopoga integrated forestry enterprise revealed a connection between the number of Scots pine seedlings and the species composition of weeds (tables 1 and 4).

Table 1. *Survival of 1-year-old Scots pine seedlings in relation to the species composition of weeds.*

Species	No of seedlings in 1 linear m of the row	No. of observations
All observations	75.4±4.60*	266
No weeds	102.3±24.10	15
Spergula arvensis	112.2±12.10	42
Elytrigia repens	59.1±8.77	23
Equisetum arvense	43.7±12.74	34

Note: Equal number of pine seeds was sown in all plots. In the study of a species effect on the survival of pine seedlings, we took into account observations where the percent cover of the species in question was no less than 10 percent, given that no other perennials were present and the percent cover of other annual species was lower than 10 percent.

** This and other tables show the arithmetic mean ± single standard error.*

Analysis proved that *Fusarium* fungi was the main reason for the death of some first-year seedlings in seeded Scots pine plantations. Along with other microorganisms, phytopathogenic fungi are constantly present in the plant root zone. The species composition of microorganisms depends on their competitive ability and the composition of active substances excreted by the plants (Krasilnikov 1955, Bilaj 1977, Mirchink 1988, Kiviniemi, and Kryshen 1994, Durynina et al. 1998, Westover et al. 1997). The surface of weed roots is inhabited by *saprotrophic* fungi and facultative parasites. The latter are represented mainly by root rot pathogens, which include i. a. some *Fusarium* species, as well as fungi of genera *Pythium, Phytophtora,* and *Rizoctonia* (Krasilnikov 1955).

Microbiological analysis of the soil root layer in plots occupied by different weeds demonstrated that *Elytrigia* *repens* and *Equisetum arvense* enhance the development of *Fusarium*, whereas the rhizosphere of *Spergula arvensis* shows the accumulation of fungi of the genus *Trichoderma* (table 2) antagonistic to soil pathogens (Shubin and Kiviniemi 1986), which explains a certain positive effect of *Spergula arvensis* on the survival of pine seedlings (table 1).

The distance from the weeds growing right in the sowing row to the nearest surviving seedling was measured in the fields with 1-year-old Scots pine seedlings. Despite the small size of their above-ground part, the greatest effect on the seedlings in their first year is produced by rhizomatous plants (table 3).

In addition to the species composition of weeds, the survival of the second-year pine seedlings depends also on their percent cover (table 4). The assumed reason for the death of the seedlings is the lack of nutrients and water, as well as possible mechanical damage.

Tables 5, 6, and 7 show the results of experiments on the effects of weeds on Scots pine seedlings in pure one-species weed communities artificially established a year prior to pine seeding. The aim of the experiments was to assess the damaging capacity of the weeds. Upon the completion of the experiment, all plants growing in a plot were excavated simultaneously with pine seedlings. By this time, all *Spergula arvensis* plants had died out, therefore, *Spergula arvensis* above- and below-ground biomass was estimated indirectly, by means of the percent cover, which was around 50 percent in all plots. The purity of one-species communities was maintained by means of hand weeding, which could not stop the invasion of rootstocks from outside the plot. All these factors prevent the comparison of the effect of the studied weeds on pine seedlings. Although leaving the possibility of a general evaluation of the weeds' damaging capacity, the experiment demonstrated that the most expressed effect of the weeds is the reduction in the seedlings biomass. This result is corroborated by data on the effect of *Rumex*

Table 3. *Distance from weeds to the nearest surviving seedling.*

Species	Weed leaf area, cm^2	Distance to the nearest surviving seedling, cm
Achillea millefolium	321.8	2.8±0.65
Elytrigia repens	29.0	2.7±0.47
Equisetum arvense	123.6	5.2±0.82
Rumex acetosella	249.1	2.1±0.61
Senecio vulgaris	724.0	2.2±0.71
Spergula arvensis	192.6	1.4±0.34
Viola arvensis	690.6	1.3±0.45

Table 2. *Fungi content in the soil weed root layer.*

Variant	Sampling site	No. of microorganisms in 1 g of dry soil, 1000 ind.		
		Fuzarium	*Trichoderma*	*Penicillium*
Control	soil	sparse*	3.6	24.0
Spergula arvensis	soil	sparse	-	19.2
	rhizosphere	-	6.0	4.8
Rumex acetosella	soil	-	3.6	9.6
	rhizosphere	sparse	2.4	2.2
Equisetum arvense	soil	-	-	15.6
	rhizosphere	3.6	-	6.0
Elytrigia repens	soil	1.2	4.8	13.2
	rhizosphere	3.6	-	3.6

* *Not over 1,000 germs in 1 gram of absolutely dry soil.*

Table 4. *Correlation between the survival of Scots pine seedlings and the percent cover of weeds in plantations of different age.*

Species	Correlation coefficient		Correlation ratio square	
	1-year-old	2-year-old	1-year-old	2-year-old
Achillea millefolium	-0.05	-0.18	0.02	0.16
Elytrigia repens	-0.07	-0.12	0.03	0.12
Equisetum arvense	-0.15	-0.48	0.08	0.33
Rumex acetosella	0.08	-0.11	0.06	0.34
Spergula arvensis	0.17	-	0.08	-
Total cover	-0.09	-0.54	0.10	0.44
No. of observations	264	102		

Note: Underlined numbers are reliable values at P=0.05.

Table 5. *Effect of weeds on the survival of Scots pine seedlings.*

Variant	Number of 1-year-old seedlings		Number of 2-year-old seedlings		
	Percent of the no. of seeds sown	Percent of the control	Percent of the no. of seeds sown	Percent of the control	Percent of the no. of 1st year seedlings
Control	82.0	100.0	81.8	100.0	99.9
Spergul arvensis	62.2	76.0	59.0	72.1	94.8
Cirsium setosum	54.3	66.2	49.2	60.1	90.6
Elytrigia repens	61.8	75.4	51.8	63.3	83.7

acetosella on Scots pine seedlings (table 8). In this case, pine seedling height was observed to grow with the growth of *Rumex acetosella* biomass, which happens in dense pine plantations (Igaunis 1974). In the author's opinion, the similar response of pine seedlings in these two cases indicates that the reason is competition for light. In addition, weeds, which consume water and nutrients, reduce the supply of the resources to seedlings. Competition for nutrients is an essential factor in forest nurseries in Karelia, most of which lie on poor soils.

If the distribution of nutrients in a community is assessed by the biomass produced by plants, and the distribution of the biomass across horizons is taken into account, the negligible effect produced on pine seedling performance by *Cirsium setosum* can be explained by its deep-lying root system. The weed, therefore, does not compete with seedlings for nutrients and water. At a depth of 20 cm, *Cirsium setosum* root mass is not over 10 g/m^2. The species does not cause heavy shading either, while the number of aboveground shoots is rarely more than 20 in m^2, and their total mass does not exceed 200 g in m^2.

The effect of *Spergula arvensis* on the growth of pine seedlings is more pronounced as the species is noted for the strong development of the above-ground part (the cover often reaches 100 percent). Its root system, though not very powerful, lies in the upper soil layer, just as the bulk of pine seedling roots. *Spergula arvensis* completes its development cycle in the period between two weeding events, developing a biomass of 500 g per m^2. Plantations are hand-weeded two to three times during the growing period, so the total mass reaches 1,000 and more gram in square meters, whereas the increment of total pine seedling biomass is not over 150 g in m^2 in the first year and no more than 400 g in the second year.

Table 6. *Effect of weeds on the growth of Scots pine seedlings.*

Variant	Seedling height		Root length		Biomass of air-dried 2-year-old seedlings					
	cm	% of control	cm	% of control	Above-Ground part		Roots		Total	
					g	% of control	g	% of control	g	% of control
Control	4.6± 0.14	100	23.8± 0.30	100	0.30± 0.14	100	0.12± 0.005	100	0.42± 0.017	100
Spergula arvensis	3.0± 0.11	65	21.8± 0.35	92	0.19± 0.012	63	0.10± 0.005	83	0.28± 0.015	67
Cirsium setosum	4.0± 0.16	88	21.3± 0.37	89	0.30± 0.033	100	0.11± 0.006	92	0.41± 0.042	98
Elytrigia repens	2.8± 0.08	62	21.7± 0.34	91 0.017	0.13±	43	0.06± 0.003	50	0.19± 0.009	45

Table 7. *Effect of weeds on the growth of 1-year-old Scots pine seedlings.*

Variant	Biomass of 100 absolutely dry Scots pine seedlings					
	Above-ground part		Roots		Total	
	g	% of control	g	% of control	g	% of control
Control	5.12	100	1.89	100	7.02	100
Spergula arvensis	2.45	48	0.94	50	3.39	48
Cirsium setosum	3.66	71	1.45	77	5.10	73
Elytrigia repens	2.25	44	1.03	54	3.28	47

Table 8. *Effect of* Rumex acetosella *on the growth of Scots pine seedlings in the Segezha forestry enterprise nursery.*

***Rumex acetosella* air-dried above-ground biomass**	**Seedling height**		**Biomass of air-dried seedlings**					
			Above-ground part		Roots		Total	
g/m²	cm	% of control	g	% of control	g	% of control	g	% of control
0	5.7± 0.17	100	0.13± 0.0150	100	0.04± 0.001	100	0.17± 0.016±	100
115	7.2± 0.019	127	0.11± 0.012	85	0.03± 0.001	75	0.14± 0.013	82
287	5.9± 0.26	104	0.06± 0.009	46	0.01± 0.001	25	0.07± 0.010	41

Elytrigia repens produces the heaviest effect on the performance of Scots pine seedlings. The percent cover may reach 80-100 percent, and above-ground biomass of up to 500 g in m^2. The principal reason for the powerful effect of *Elytrigia repens* on pine growth is the well-developed rootstock system lying in the upper soil layer, which also contains a significant part of active pine roots. The biomass of quackgrass rootstocks at a depth of 20 cm may reach 4,000 g in m^2.

The study of the relationship between pine seedling survival and performance, and the distance from the growing quackgrass rootstock showed the rootstock impact zone to cover 3-4 cm (figure 1). On the other hand, substances excreted by *Elytrigia repens* roots were not found to affect the germination of pine seeds. The growth of the seedlings could not be observed because of abundant mould growth in variants with extracts from quackgrass roots.

Conclusion

Survival of Scots pine seedlings in the first year of cultivation depends on the species composition of weeds. The greatest threat are rhizomatous *Elytrigia repens* and *Equisetum arvense,* which enhance the development of pathogenic fungi of the genus *Fusarium* resulting in the seedling damping-off.

Survival of pine seedlings in the second year of cultivation depends both on the species composition and percent cover of weeds. The major reason for seedling death is the lack of nutrients. The heaviest damage is produced by rhizomatous plants, particularly *Elytrigia repens* and *Equisetum arvense*.

The major manifestation of the adverse effect of weeds on Scots pine seedling growth is reduction in the seedlings' biomass.

All weeds may be formally joined into three groups with regard to morphological characteristics and damaging capacity in respect of pine seedlings: (1) annual, biennial grasses, (2) perennial grasses with deeply lying root system, and (3) perennial grasses with the bulk of the belowground organs in the upper soil layer. The latter are the most harmful for the growth and survival of both 1- and 2-year-old pine seedlings.

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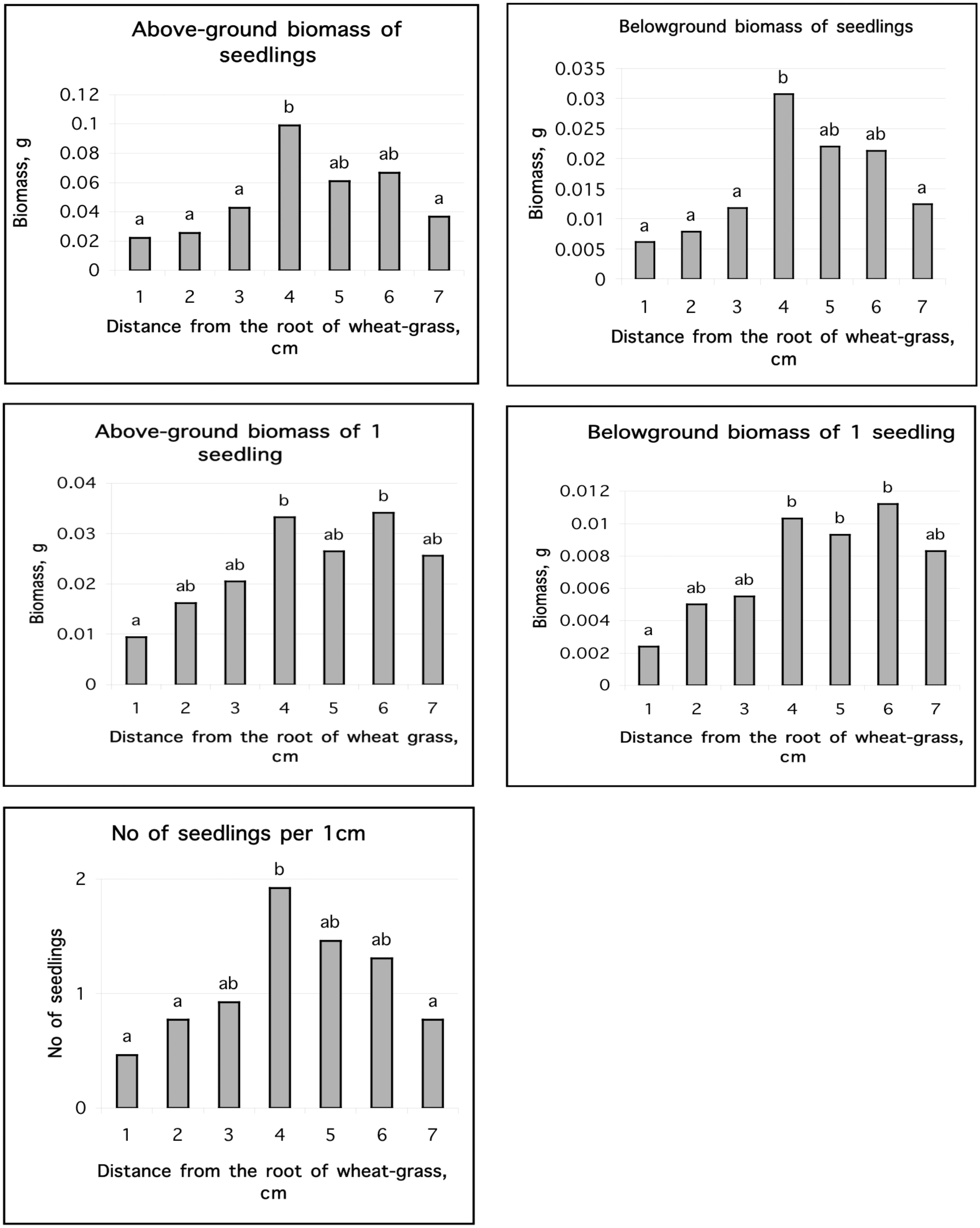
Figure 1. *Relationship between growth and survival of 1 year-old pine seedlings and distance to the wheat-grass rootstocks*



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