

REPRODUCTIVE FEATURES OF WEED PLANTS OF FOREST NURSERIES

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Abstract

Floristic composition and reproductive and morphological features of weed plants of the forest nurseries are studied. The conducted researches supplement with some knowledge of seed efficiency of the weeds and it allows to improve the system of agro-technical action in the forest nurseries.

Key words: forest nurseries, weed species, weed seed reproduction, fertility, morphology, seed germination, vigor.

INTRODUCTION

As a result of the long history of weeds development, it has developed exceptional diversity of biological characteristics and adaptive features in a variety of growing conditions. Many types of weeds produce a huge amount of seeds every year. It allows the weeds to quickly populate certain areas. Seeds are stored even under intensive cultivation of the soil.

There is a large number of studies of seed plant reproduction. According to many authors (Kott 1961; Biryukov et al. 1982) annual weeds have high fertility, but it should be noted that these references are quite contradictory. The first, potential and real seed reproduction includes several elements. The elements for different types are not the same due to the morphological features of plants. Most of the elements of seed production are: the average number of generative shoots per plant, the average number of flowers per generative shoot, the average number of seeds per flower. The second, the quantitative characteristics of each of these elements depends on many interrelated external and internal factors: the climatic and weather conditions, soil fertility, pollination, pests and diseases. The third - different groups of factors have different effects on seed reproduction elements. These features make it difficult to generalize data on seed production.

The wide and rapid spread of many types of weeds is ensured by their high fertility. Fertility of weeds depends on the conditions of their habitat. In areas with a lot of vegetation weeds look depressed. In areas with few plants and well-fertilized soil weeds grow fast (if not destroyed), and form a large amount of seeds. Counting the number of weed seeds were occupied by many Russian and foreign specialists.

Weeds have a number of adaptive devices for resettlement over long distances. The small and light weed seeds are also transported over long distances. There are some adaptive devices on the top of the seed of some plant species that facilitate the transfer of wind (*Taraxacum officinale* Wigg., *Sonchus arvensis* L., *Cirsium arvense* (L.) Scop., etc.), or by animals, birds, human.

According to literature (Kott 1961; Biryukov et al. 1982; Leningrad publishing 1970) many weed seeds remain viable after passing through the digestive system of animals and birds and at the same time retaining the ability to germinate (*Chenopodium album* L., *Rumex acetosella* L.).

According to the results of many researchers weed seeds have excellent adaptation to germinate. Under favorable environmental conditions some weed seeds germinate few days after falling to the ground. Under adverse conditions (dry or excessive soil moisture) they do not germinate, but they can remain viable for several years due to seed shell. Most species have a dense shell covered cuticle protecting from environmental factors during dormancy. The air and soil temperature and the soil depth also affects the ability of seeds to germinate.

Biological adaptation weed seeds to external environmental conditions is result of a large accumulation it in the soil. It causes the difficulty of controlling weeds in forest nurseries.

Thus, it should be noted that the choice of herbicide depends on the biological features of weeds, great fertility, non-simultaneity of germination, the ability of vegetative reproduction, a wide variety of weed species.

RESEARCH METHODS

The purpose of research is the study of species diversity and reproductive properties of weeds in the northern forest nurseries. We studied biometric properties of seeds (length, width, weight of 1000 seeds), germination and seed reproduction plants to assess the reproductive properties of weeds.

Research was conducted in five permanent forest nurseries (Nyandoma, Plesetsk, Kargopol, Konosha, Ustyany) of Middle Taiga subzone of the Arkhangelsk region. We determined the species composition of weeds in each parts of nurseries (Babich & Nechaeva 2009, 2010).

It is determined seed yield at the sites of 1m² in ten replicates on fallow fields and fields with one and two year cultivation of seedlings of Nyandoma forest nursery. A large number of weed species that reproduce by seeds in these fields are spread. We calculated the average number of generating plants per 1 m² and seed reproduction plants, and then we determined the overall productivity (Rabotnov1960; Vasilevich1969).

The total number of seeds of each species is calculated and also 1000 seeds are weighed (State Industry for Standardization 1980) to determine the seed reproduction of weeds. Weight of 1000 seeds was determined to the nearest 0.01 g with an electronic balance HL-100. Seed size (length, width) of 20-25 seeds of each species was determined by measuring magnifier to the nearest 0.1 mm. Seeds were characterized according to research of V.N. Dobrokhotoy (1961).

Germination and vigor of weed seeds were determined in a special climate chamber "Phytotron 30" at 23 ° C and constant illumination of 40,000 lux. 100 seeds of each species are germinated in four replicates on moistened filter paper (State Industry for Standardization 1984). Germinated seeds were counted after 5, 10 and 15 days after lying. Well germinated seeds are those which have developed healthy root with length not less than the seed.

RESULTS

We established that there are 109 species of plants (86 genera and 29 families) of weed flora in the forest nurseries of Middle Taiga subzone of the Arkhangelsk region. This is about 10% of the total flora of the Arkhangelsk region (Babich & Nechaeva 2011), which includes 1098 species (Schmidt 2005).

Based on the studies and statistical data set that to obtain reliable information on the size of seeds enough to use 20-25 seeds. The main results for the mass 1,000 seeds, their surface, color and other features are shown in Tables 1, 2.

Seed surface is extremely diverse. Often the main structural features of the surface (tuberculated, ribbed, etc.), which are sustainable, complemented by shine, matte, waxy coating, etc. Shiny surface is due to the surface structure of shells and degree of ripeness of seeds; rough surface is formed by small spines, grooves; smooth surface is devoid of any outgrowths; pubescent surface is characterized by having of hairs of different length and thickness.

Color of seeds are weakly sustainable feature. Pigment substance which determines the color of seeds are easily changed depending on the ripeness of the seeds. It is considered that ripe seeds have a typical color. Seed color can be extremely diverse within the same species and even plant. Especially diverse color of seeds of dicotyledonous plants. Cereal seed color within plants is more uniform.

Table 1. Weight of 1000 seeds of annual weeds

Name of annual weed	Weight 1,000 seeds, g			Morphological features of seeds
	our data		literature data [6, 11, 14]	
	min-max	X±m		
<i>Polygonum hydropiper</i> L.	1,00-1,40	1,16±0,04	-	Triangular nut; shiny surface; the color is dark brown
<i>Viola arvensis</i> Murr.	0,33-0,40	0,36±0,01	0,65 [14]	Obovoid; oily shiny surface; the color is light brown
<i>Spergula arvensis</i> L.	0,30-0,40	0,31±0,02	0,5 [14]; 0,5 [11]	Spherical, covered with tubercles; surface tubercles; the color is black; boxes are broadly, 9-24 seeds are in a box

<i>Viola tricolor</i> L.	0,24-0,40	0,31±0,02	0,5 [11]	Obovoid; oily shiny surface; the color is from light yellow to dark brown, ovoid capsule, 20-50 seeds are in a box
<i>Chenopodium album</i> L.	0,15-0,20	0,19±0,01	1,15 [14]; 2-1,5 [11]	Rounded, slightly convex, smooth and shiny surface; intense black coloring
<i>Stellaria media</i> L.	0,10-0,11	0,11±0,00	0,5-0,6 [14]; 0,5 [11]	Rounded, covered with small tubercles; the color is dark brown with a red tint; elongated box has 2-9 seeds
<i>Chamomilla recutita</i> L.	0,05-0,10	0,07±0,00	0,07 [6]; 0,08 [11]	Cylindrical, slightly glossy surface; the color is generally light yellow; 50-470 seeds are in a flower
<i>Capsella bursa-pastoris</i> L.	0,06-0,07	0,07±0,00	0,1 [14]; 0,1-0,15 [11]	Oval, rounded at the top, the base has a recess, smooth surface, the color is from yellow to brown, 20-25 seeds are in a pod with length of 3-5 mm.
On the average	0,28-0,39	0,32	-	-

Notes: Latin names of the species are given by V.M. Schmidt (2005); $X \pm m_x$ - average $\pm$ error.

Table 2. Weight of 1000 seeds of perennial weeds

Name of perennial weed	Weight 1,000 seeds, g			Morphological features of seeds
	our data		literature data	
	min-max	X±m		
<i>Elytrigia repens</i> L.	1,74-2,60	2,15±0,10	3,9	Elongated; surface is not smooth, brown; spikelet have 5-10 flowers, hard fall, 1-4 seeds are in a flower
<i>Phleum pratense</i> L.	0,42-0,46	0,44±0,00	0,6	Ovoid shape, the surface is not smooth and shiny, light-brown coloration
<i>Plantago major</i> L.	0,17-0,25	0,21±0,01	0,3	Multifaceted; slightly shiny surface; coloration dark brown, ovoid boxes
<i>Sonchus arvensis</i> L.	0,11-0,14	0,12±0,00	0,6 -2,0	Oval, elongated, slightly curved, has long blond soft fluff, easy to fall off; the surface is not smooth and shiny, the color is from dark brown to light brown; 60-90 seeds are in a flower
<i>Deschampsia caespitosa</i> L.	0,10-0,12	0,11±0,00	-	Triangular, smooth surface, color ranges from yellow to green, up to 350 seeds are in a panicle
<i>Achillea millefolium</i> L.	0,09-0,11	0,10±0,00	0,08 -0,15	Elongated, slightly curved; the surface is not smooth and shiny; grayish-brown color
<i>Cerastium holosteoides</i> Fries	0,05-0,06	0,06±0,00	0,1	Rounded, covered with tubercles; not shiny; color ranges from yellow to brown, darker tubercles; boxes have 25-50 seeds.
<i>Chamerion angustifolium</i> L.	0,02-0,04	0,03±0,00	0,075	Elongated, slightly compressed; the surface is not shiny, the color is brown
<i>Linaria vulgaris</i> L.	0,02-0,03	0,03±0,00	0,15	Rounded, flat, surface with small tubercles; color is black
<i>Rumex acetosella</i> L.	0,01-0,016	0,01±0,00	0,25-0,3	Nuts triangular, slightly convex faces; the surface is smooth, shiny; the color is light brown
On the average	0,27-0,38	0,33	-	-

Notes: $X \pm m_x$ - average $\pm$ error.

Length and width of seed are shown in Table 3. *Sonchus arvensis* L., *Polygonum hydropiper* L., *Phleum pratense* L., *Viola arvensis* Murr., *Viola tricolor* L., *Deschampsia caespitosa* L., *Capsella bursa-pastoris* L., *Rumex acetosella* L. have a small variation in length of the seed (up to 10%).

Table 3. Sizes of weed seeds

Name of weed	Length of seeds, mm			Width of seeds, mm		
	our data		literature data	our data		literature data
	min-max,	X±m		min-max	X±m	
<i>Elytrigia repens</i> L.	3,1-6,7	5,2±0,17	4-5	0,5-1,4	1,1±0,03	-
<i>Sonchus arvensis</i> L.	3,0-3,4	3,2±0,04	2,5-3,25	0,3-0,4	0,3±0,01	0,75-1,25
<i>Polygonum hydropiper</i> L.	2,5-3,2	2,8±0,05	-	1,8-2,4	2,1±0,05	-
<i>Phleum pratense</i> L.	1,7-2,1	1,8±0,02	1,5-2,25	0,8-1,1	0,9±0,02	0,75-1
<i>Viola arvensis</i> Murr.	1,45-1,9	1,6±0,02	-	0,8-1,1	1,0±0,05	-
<i>Viola tricolor</i> L.	1,3-1,6	1,5±0,02	1,25-1,75	0,6-0,9	0,8±0,02	0,75-1
<i>Deschampsia caespitosa</i> L.	1,3-1,7	1,4±0,03	-	0,4-0,6	0,5±0,01	-
<i>Achillea millefolium</i> L.	1,0-1,9	1,4±0,05	1,75-2,25; 1,5-2	0,3-0,6	0,4±0,02	0,5-0,75
<i>Chamomilla recutita</i> L.	1,2-1,5	1,3±0,03	0,8-1,25	0,3-0,5	0,3-0,5	0,25
<i>Plantago major</i> L.	1,0-1,5	1,3±0,04	0,75-1,25	0,6-0,8	0,7±0,02	0,5-0,75
<i>Chenopodium album</i> L.	1,0-1,6	1,3±0,04	1,5-1,75	0,9-1,5	1,2±0,04	1,5-1,75
<i>Spergula arvensis</i> L.	0,6-1,3	1,0±0,04	1-1,25	0,6-1,3	1,0±0,04	1-1,25
<i>Capsella bursa-pastoris</i> L.	0,7-1,1	0,9±0,02	0,75-1	0,3-0,6	0,5±0,02	0,5
<i>Rumex acetosella</i> L.	0,8-1,0	0,9±0,02	0,75-1,25; 0,8-1,1	0,4-0,5	0,5±0,01	0,75-1,25; 0,8-1,1
<i>Chamerion angustifolium</i> L.	0,7-1,1	0,9±0,03	1-1,25	0,1-0,2	0,1±0,01	0,3
<i>Stellaria media</i> L.	0,5-0,8	0,7±0,02	0,75-1,25; 0,9-1,3	0,5-0,8	0,7±0,02	0,75-1,25; 0,9-1,3
<i>Cerastium holosteoides</i> Fries	0,3-0,5	0,5±0,02	0,5-0,75	0,3-0,5	0,5±0,01	0,5
<i>Linaria vulgaris</i> L.	0,3-0,6	0,4±0,02	1,75-2,25	0,3-0,5	0,4±0,01	1,75-2,25

Note: bold – annual weeds; min-max - minimum and maximum values; X±m_x - average ± error.

Elytrigia repens L., *Achillea millefolium* L., *Chamomilla recutita* L., *Plantago major* L., *Chenopodium album* L., *Spergula arvensis* L., *Chamerion angustifolium* L., *Stellaria media* L., *Cerastium holosteoides* Fries, *Linaria vulgaris* L. have an average variation in length of the seed (from 10.1 to 30%). Species have mostly average variation in the width of the seed. Accuracy and reliability of output experience in all cases are proved ($p < 5\%$; $t > 4$). The maximum length of seeds is observed in *Elytrigia repens* L., *Polygonum hydropiper* L., minimum length of seeds – in *Linaria vulgaris* L., *Cerastium holosteoides* Fries, *Chamerion angustifolium* L.

The size distribution of the seed (in length) is shown in Table 4 in according to the classification V.N.Dobrokhotoy (1961). The largest number of species that are distributed in the forest nursery have a small and very small size of the seeds (83%) allowing them spread easily. Smaller and lighter seeds spread over large areas according to some authors (Kott 1961; Birukov et al. 1982, etc.).

Table 4. Seed distribution of size

Category of seeds	Dimensions seed of length (mm)	The number of weed species			
		annual		perennial	
		amount	%	amount	%
Very large	Over 8	-	-	-	-
Large	4 - 8	-	-	1	12
Average	2 - 4	1	10	1	12
Small	1 - 2	5	50	4	50
Very small	To 1	4	40	2	26
In total	-	10	100	8	100

Small seeds contain a small amount of nutrients, which is why the bulk of the plants, especially dicotyledonous die in the soil before reaching the surface. Dicotyledonous weeds a much greater die from moisture deficit than cereals (Samsonova 2006).

Thus, the sizes of seeds in forest nurseries of Middle Taiga subzone are lower than in the same species of plant in the Southern regions according to the literature (Biryukov et al. 1982; Dobrokhotoy 1961).

It should distinguish between the average productivity of plants and seed yield. The average productivity of plants is the average number of seeds per individual or per generative branch. Seed yield (total productivity) - is the number of seeds produced by plants per unit area. Seed yield depends on the number of generative plants per unit area and the average seed production. Both vary significantly by year.

Table 5 shows that the fertility of some weeds species changes brightly. As a result, of research established that the seed production of annual weeds is from 190 (*Viola arvensis* Murr.) to 15 thousand seeds per plant (*Stellaria media* L.) (average 5.2 thousand). The seed production of perennial plants is 15 (*Elytrigia repens* L.) to 21.7 thousand seeds per plant (*Cerastium holosteoides* Fries) (average 4.8 thousand). Low seed fertility of some species of weeds (*Elytrigia repens* L., *Linaria vulgaris* L.) is caused by biological features of plants, as these species reproduce mainly vegetative way.

Most seeds production of annual weeds were observed in *Stellaria media* L. (15 thousand of seed), *Chenopodium album* L. (13.2 thousand of seeds), *Chamomilla recutita* L. (8.6 thousand of seeds). Most seed productivity of perennial weeds were observed in *Cerastium holosteoides* Fries (21.7 thousand of seeds), *Sonchus arvensis* L. (18 thousand of seeds), *Rumex acetosella* L. and *Deschampsia caespitosa* L. (1.2 thousand of seeds).

Table 5. Seed reproduction of weeds on the fields with biennial seedlings of spruce

Name of weed	The average number of generating plants		The average number of seeds		
	units / m2	thousand / ha	thousand / m2	million units / ha	units / plant
<i>Viola arvensis</i> Murr.	4,5	45,0	0,855	8,55	190
<i>Deschampsia caespitosa</i> L.	1,1	11,0	1,265	12,65	1150
<i>Stellaria media</i> L.	0,7	7,0	10,5	105,0	15000
<i>Rumex acetosella</i> L.	0,7	7,0	0,84	8,4	1200
<i>Achillea millefolium</i> L.	0,6	6,0	0,24	2,4	400
<i>Chamerion angustifolium</i> L.	0,6	6,0	-	-	-
<i>Spergula arvensis</i> L.	0,5	5,0	0,963	9,63	1925
<i>Viola tricolor</i> L.	0,4	4,0	0,68	6,8	1700
<i>Plantago major</i> L.	0,2	2,0	0,18	1,8	900
<i>Chenopodium album</i> L.	0,2	2,0	2,64	26,4	13200
<i>Chamomilla recutita</i> L.	0,1	1,0	0,86	8,6	8550
<i>Elytrigia repens</i> L.	0,1	1,0	0,002	0,02	15
<i>Phleum pratense</i> L.	-	-	-	-	130
<i>Cerastium holosteoides</i> Fries	-	-	-	-	21700

Very few annual weeds form up to 1000 seeds. These are *Polygonum hydropiper* L., *Viola arvensis* Murr., *Capsella bursa-pastoris* L. Among the perennial weeds such as *Plantago major* L., *Achillea millefolium* L., *Phleum pratense* L., *Elytrigia repens* L., *Linaria vulgaris* L. have up to 1000 seeds per plant.

Low fertility of seeds of some species is compensated by saving them well. Weeds, the seeds of which are adapted to spread by itself by wind, are sharply distinguished by their fertility. Their seeds have different facilities. These include: *Sonchus arvensis* L., *Chamerion angustifolium* L., etc.

Several weeds form many small seeds that are easily spread by wind, water, soil particles, transport, animals. Such weeds are *Capsella bursa-pastoris* L., *Plantago major* L.

Thus, the rapid spread of weeds contributes to their high seed production. Therefore, they should not be allowed to develop weed seed-up phase in the fields of forest nurseries to save crops from persistent weeds.

The density of growing cultivated plant influences on the growth of weeds. Weed seeds grow worse under the cover of intense growing, strongly drying soil crops than on fields with rare cultures. For example, the conditions for the development of young weeds is much worse in crops of well-developed three-year spruce seedlings than in the fallow field and fields with annual and biennial seedlings of spruce.

Determination of weed seed germination was carried out in laboratory conditions. The seed germination of weeds of Nyandoma forest nursery was identified. Seeds of *Spergula arvensis* L. are characterized by almost absolute germination (Table 6).

Seeds of *Phleum pratense* L. (95%), *Plantago major* L. (94%), ***Viola tricolor* L.** (79%), ***Viola arvensis* Murr.** (61%), *Cerastium holosteoides* Fries (88%), *Deschampsia caespitosa* L. (73%), *Sonchus arvensis* L. (57%) well germinated. Seeds of *Chamerion angustifolium* L., *Sonchus arvensis* L. germinate not simultaneously unlike most weed seeds.

Table 6. Germination of weed seeds

<i>Name of weed</i>	Vigor, %	Germination, %
<i>Chenopodium album</i> L.	0	4
<i>Viola tricolor</i> L.	70	79
<i>Viola arvensis</i> Murr.	51	61
<i>Spergula arvensis</i> L.	9	12
<i>Capsella bursa-pastoris</i> L.	1	6
<i>Stellaria media</i> L.	97	99
Annual weeds	38	44
<i>Cerastium holosteoides</i> Fries.	85	88
<i>Sonchus arvensis</i> L.	24	57
<i>Plantago major</i> L.	88	94
<i>Chamerion angustifolium</i> L.	19	49
Perennial dicotyledonous	54	72
<i>Deschampsia caespitosa</i> L.	57	73
<i>Phleum pratense</i> L.	90	95
Perennial monocotyledonous	74	84
Perennial weeds	61	76

According to the literature germination of freshly ripe seeds of *Chamerion angustifolium* L. reaches 90%, but decreased to 35% in the spring. Seeds of *Deschampsia caespitosa* L. able to germinate without a period of winter dormancy. Seed germination is high (80-100%).

Seeds of following weeds have not germinated because of their biological features: *Linaria vulgaris* L., *Achillea millefolium* L., *Chamomilla recutita* L., *Rumex acetosella* L., *Elytrigia repens* L., *Polygonum hydropiper* L. Many of them have either a longer period of dormancy or a solid structure of the seed coat, which prevents the entry of water and air in the seeds - factors that activate livelihoods of seeds.

As a result of researches identified a 1.5 times increased germination of cereal weeds in comparison to dicotyledonous (germination of cereal weeds is 84 % but dicotyledonous weeds - 55%). Perennial weed germination is 1.7 times higher than seeds of annual weeds (germination perennial weeds is 76% and the one-year - 44%). Correlation analysis showed that the number of seeds per plant has following regularity: the smaller the seeds, the more seeds per plant, and the higher the percentage of seed germination ($r = -0,745; -0,801$).

CONCLUSIONS

To successfully control weeds it is necessary to know their biological features and use agro-technical measures during mass appearance of persistent weeds. Weed control measures should be based on species and quantitative representation of plants and taking into account their biological characteristics.

The first investigated range of weeds in the forest nurseries of Middle Taiga subzone of Arkhangelsk region counts 109 species of plants belonging to 86 genera and 29 families. The sizes of seeds (length, width, weight of 1000 seeds) in forest nurseries of Middle Taiga subzone are lower than in the same species of plant in the Southern regions.

Most species (83%) have small and very small size of the seeds. Perennial weed germination (76 %) is 1.7 times higher than seeds of annual weeds (44 %). Correlation analysis showed that the number of seeds per plant has following regularity: the smaller the seeds, the more seeds per plant, and the higher the percentage of seed germination ($r = -0,745; -0,801$).

REFERENCES

- Babich, NA, Nechaeva, IS 2009, 'Weeds of forest nurseries', *News of Higher educational institutions 'Forest Magazine'*, Arkhangelsk, no. 2, pp. 15-17 (Russian).
- Babich, NA, Nechaeva, IS 2010, 'Reproductive features of weeds of forest nurseries', *'Herald Mari State Technical University'*, Yoshkar-Ola, no. 2(9), pp. 57-67 (Russian).
- Babich, NA, Nechaeva, IS 2011, 'Systematic structure of weeds in the forest nurseries of Middle Taiga subzone of the Arkhangelsk region', *'Coniferous boreal'*, Krasnoyarsk, vol. XXVIII. - pp. 72-77 (Russian).
- Biryukov, VI, Biryukov, VV, Polyakov, V, Rai, VF, Strekalovskaya, RN 1982, *Weeds of Nechernozemie permanent nurseries and their control measures*, Bryansk (Russian).
- Dobrokhoto, VN 1961, *Weed seeds*, Moscow, *Selhozizdat* (Russian).
- Kott, SA 1961, *Handbook on weed control*, Moscow (Russian).
- Leningrad publishing 1970 'Weeds', *Useful and harmful plants of Leningrad region*, pp. 165-174 (Russian).
- Rabotnov, TA 1960, Study Methods of seed reproduction of grassy plants in communities, *Field geobotany*, Moscow- Leningrad, USSR Academy of Sciences, vol. 2. pp. 20-40 (Russian).
- Samsonova, VP, Annunciation YN, Kondrashkina MI 2006, Accounting and mapping of weeds, *Publishing and Trading Corporation "Darya and K °*, Moscow (Russian).
- Schmidt, VM 2005, *Flora of Arkhangelsk region*, St. Petersburg (Russian).
- USSR State Standard 1980, SIST 12042-80, *Crop seeds. Methods for determining the mass of 1000 seeds*, State Industry for Standardization, Moscow (Russian).
- USSR State Standard 1984, SIST 12038-84, *Crop seeds. Methods for determination of germination*, State Industry for Standardization, Moscow (Russian).
- Vasilevich, VI 1969, *Statistical Methods in geobotany*, Leningrad (Russian).