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Seed Reduplication of the Flowering Plants of the Disturbed Landscapes in the Northern of Far-East of Asia

Evgeny Tikhmenev[1], Pavel Evgenievich Tikhmenev[2]✉

[1]Russian Academy of Sciences, Ural Branch: Institute Botanical Garden, Ekaterinburg/RUSSIA

[2]North Eastern State University, Magadan/RUSSIA

✉***Correspondence**:* etikhmenev@bk.ru

Abstract: The results of studies of anthropogenic landscapes functioning with an assessment on the processes natural self-revegetation and effectivity of reclamation in tundra, forest-tundra, larch forest complexes are summarized. The principles of accelerated restoration of the ecological and aesthetic value of disturbed landscapes at the permafrost zone are substantiated, based on the data obtained during studying the self-revegetation and reclamation processes on disturbed complexes. Development of placer and ore deposits of mineral resources is leading to deep transformation of landscape and to destruction of soil-vegetation complexes. The processes caused by mining activity are leading to variable mechanisms of degradation of soil and vegetation often having complex impact. Results of study of sustainability of soil-vegetable complexes to the impact of mancaused activity have showed the dependence from the structure of soil profile and it characteristic, from the character of genetic horizons, frozen status of the landscape elements, form of the structure, biomass and seed productivity. The rate of fertilization and fruiting regularity of perspective some species of native flora for introduction as medical, nutritive or fodder plants was also determined.

Keywords: Pollination, Generative system, Permafrost landscapes, Disturbed sites, Soil-vegetation complexes, Rehabilitation.

1. INTRODUCTION

As a result of mining operation there are more than 124.000 hectares of disturbed lands in permafrost zone of North-eastern Asian. Especially large scale disturbances of native ecosystems have taken place in tundra and the boreal zone of basin of Kolyma river. Very cold climatic condition, when annual temperature everywhere below zero degree, predetermine imbalance of natural ecosystem under the impact of technogenic pressure. Technogenic formation range in size from 200-500 m^2 to several hectares and include flood plain, river terraces and mountain slopes. The natural landscapes of region under investigation are characterized by mountain systems. Process of self-revegetation of the diturbed sites come extremely slow and active thermokarst erosion on disturbed sites are sources of long-term pollution of the Arctic ocean basin. Exploration of reproductive biology of flowering plants started earlier on Wrangel Island was continued at the plant communities of Yakutia, continental areas of the Kolyma basin and in Kamchatka (Pugachev, Tikhmenev, 2011). The study was undertaken according to generally accepted technique developed by A. N. Ponomarev (1964, 1970). Special attention was given to ecological morphology and biology of inflorescence, effectiveness of different types of seed production, role of the flora anemophily and enthomgamy species on the natural and disturbed sites.

2. MATERIALS AND METHODS

The main aim of the research was to determine the species range of the local flora acceptable for reclamation of technogenic formations and cultivation of highly-productive artificial meadows and grass seeds in the North-Eastern Russia. Fodder production was and is hampered actually by absence of experience of recultivation and seed farming. Exploration of reproductive potential of flowering plants started earlier on Wrangel Island was continued at the plant communities of Yakutia, continental areas of the Kolyma basin and in Kamchatka (Pugachev, Tikhmenev, 2011). The study was undertaken according to generally accepted technique developed by Ponomarev A. N. (1964, 1970). Special

attention was given to ecological morphology and biology of inflorescence, effectiveness of different types of seed production, role of the flora anemophily and enthomophyly species' on the natural and disturbed sites. The rate of fertilization and fruiting regularity of perspective species for introduction as medical, nutritive or fodder plants was also determined.

3. RESULTS

The development of mineral deposits radically changes the lithogenic structure of landscapes, leads to deep deformation or destruction of their biological components, including soil and vegetation complexes. During the development of deposits, disturbances occur in the natural environment of various depths. They depend on the geochemical features of the field under development, the technology used and the level of technical equipment of the enterprise. Main researches and experimental studies of revegetation disturbed landscapes were conducting in Gold mine Kubaka, located in basin of Kolyma river in zone of larch forest. Earlier our experiments development of reclamation technology in restoration disturbed landscapes were conducting in tundra zone of Chukotka (Figure 1). Review of agrophysical and agrochemical parameters of soils of Gold ore deposit Kubaka are show in Table 1. Research conducted in the Chukotka peninsula let us possibility to evaluate a range of physical and chemical properties of technogenous formations on the Arctic coast. In particular, composition of fine soil varies from 0.0 to 16.8 %, and physical clay from 0.5 to 33.4 %. Agrochemical indicators also vary widely. The environment varies from strongly acidic to almost neutral, The presence of bases is from 28 to 95 %, the presence of mobile forms of phosphorus – from 0.0 to 30.0 mg/100 g of fine soil. There is considerable variability in the ratio of C:N and fractional humus group (Table 2).

For comprehensive understanding of direction of successive processes on the disturbed sites the comparative analysis of feature of pollination ecology of species in natural communities and technogenic formations have been hold. It was determined earlier, that majority of the species under investigation had self-pollination ability in case of obstructed xenogamy (Tikhmenev, 1999). Such peculiarity of reproduction system functioning at boreal and tundra plants allows them completing of ontogenenous cycles with relative regularity despite the harsh environmental conditions. At early stages of successive processes under climatic conditions of sparse vegetation cover of the disturbed sites anemophily easily occurs.

Figure 1. Reclamation of disturbed lands of the tundra zone with seeds of perennial grasses (Chukotka).

Table 1. Physicochemical properties of soils in the valley of the basin of Omolon River (basin of Kolyma}.

Horizon	Depth, cm	pH KCl	Humus, %	Nitrogen, %	Hydrolitic acidity*	Exchange Forms		V, %	Available Forms		Particle size, mm	
						Ca^{2+}	Mg^{2+}		P_2O_5	K_2O	<0,01	<0,001
					mEq/100g of soil				mg/100g of soil			
Tundra gley soil												
01_v	0-5	3,4	-	-	-	-	-	-	25	41	-	-
02	5-8	3,5	-	0,57	127,9	6,0	29,0	21	13	64	-	-
A1Bg	8-13	3,7	2,76	0,07	38,4	7,7	8,7	30	8	23	41	19
Bg	13-25	4,6	1,75	0,07	2,0	10,3	7,0	90	11	12	36	20
BG_1	40-50	5,0	1,16	-	1,6	10,6	9,0	92	-	-	40	21
BG_2	65-75	4,8	2,13	0,08	1,2	9,2	10,3	94	-	-	36	22
CG	82-92	4,2	3,21	-	-	9,8	6,7	-	-	-	38	22
Tundra underbur												
01	0-2	3,9	97,30*	-	-	22,0	6,2	-	-	-	-	-
AO2	2-6	3,9	52,02*	1,21	80,2	25,0	6,5	28	105	220	-	-
AB	6-15	4,0	2,85	0,06	7,2	13,3	6,3	73	18	4	21	6
BC_r	15-25	5,0	1,70	-	1,8	15,6	5,2	92	-	3	14	10
C	70-80	5,0	0,33	-	0,7	18,0	9,7	98	-	6	11	5
Floodplain shallow turf soil												
AO	0-2	5,2	50,95*	-	-	43,8	3,9	-	-	-	-	-
A1	2-7	4,8	3,40	3,40	32,6	14,1	2,6	34	40	14	26	12
BC	10-20	4,8	0,78	0,26	1,0	2,5	0,4	75	38	4	2	2

Note: -Not defined; * - loss on ignition;* - hydrolytic acidity; V,% is the degree of saturation with bases.

Table 2. Physicochemical properties of the overburden dump of the valley of Kolyma River.

Specimen depth, cm	pH KCl	Humus, %	Hydrolitic acidity	Exchange forms		V, %	Available forms			Particle size, mm	
				Ca^{2+}	Mg^{2+}		$N\text{-}NO_3$	$N\text{-}NO_4$	P_2O_5	<0,01	<0,001
5- 15	5,3	-	4,5	7,2	6,0	75	5,8	2,4	14,0	13	7
25- 35	4,2	4,9	7,0	6,4	5,2	62	1,1	0,8	3,0	33	17
150-160	4,2	-	36,1	8,6	5,4	28	1,3	10,2	30,0	-	-
350-360	6,1	-	1,0	3,4	2,2	85	0,3	0,6	12,0	1	0

Therefore, the disturbed sites are actively reseeded with grasses, sages and other wind pollinating species (Pugachev et al., 2004, 2005, 2011). Anthecological researches showed that regular and thick seeding is typical for species, referred to the Poaceae family: *Alopecurus alpinus, Hierochloë alpina, H. pauciflora, Poa abbreviata, xborealis, Elymus interior, E. sibiricus, E. mutabilis, E. confusus, Festuca rubra, Calamagrostis holmii, C. langsdorffii.* Many of these species are highly valuable for revegetation of the disturbed sites in permafrost condition (Tikhmenev, 2008). Regular and thick seeding on the disturbed sites is characteristic for some arboreal and shrub species of the disturbed plant communities.

Figure 2. Using of soils reserve from native communities for formation root layer on rock dumps (Gold mine Kubaka in Kolyma river basin).

Figure 3. Reclamation of gold ore deposit Kubaka.

Table 3. The biomass on overburden dumps of different ages, t/ha of dry weight.

Components of biomass	Age of dumps, years			
	2	8	14	20
Phytomass	0,04	0,54	2,67	3,59
incl. aboveground	0,03	0,23	0,31	2,53
Underground	0,01	0,31	2,36	1,06
Mortmass	-	0,05	0,06	1,23
Biomass	0,04	0,59	2,73	4,82

Overburden dumps with an age of vegetation more than 20 years are dominated by the tree and shrub layer, which already has a depressing effect on the grass cover and causes the appearance of mosses. The stock of phytomass reaches 3.59 t/ha. *Populus suaveolens* has high productivity - 1.32 t/ha, *Salix schwerinii* - 1.04 t/ha, the share of forbs does not exceed 0.01 t/ha. On 25-year-old overburden dumps, a stable vegetation cover is formed with a significant participation of a number of tree species. The layer of poplar (2.0 t/ha) and *Schwerin willow* (1.5 t/ha) is especially pronounced (Table 3).

Salicaceae family species (*Chosenia arbutifolia, Populus suaveolens, Salix shweriny;* Betulaceae family: *B. exilis, B. middendorffii, B. platyphilla, Duschekia fruticosa),* which are consist of typical anemophilous group of disturbed sites. Plenty of free-flowing pollen enriching ground-level air for 24 hours, close growing of trees and shrubs and long-lasting fertility of generative system contribute greatly to successful pollination and seeding at different succession stages. Among typical species of revegetating floral communities there is rather extensive group of species, mostly from the Fabaceae, Scrophulariaceae and Salicaceae families, which are characterized as obligatory entomophilous plants. For successful seed reproduction of this group species visitation of anthophilous insects is obligatory. Due to this fact occurrence of the majority of enthomophilous species, which are obligatory xenogamous ones, is rather rare in the rehabilitate plant communities and their use for revegetation purposes has relatively small efficiency (Tikhmenev, 1999). In the blooming phase of plants pollen of these species is usually mature and characterized by high fertility level lasting up to 2-3 days and more, thus, microsporogenesis of the most studied species at the disturbed sites is successful. These species can use self-pollination easily in case of obstructed xenogamy. This provides relatively regular seeding during possible lack of pollinating insects (Tikhmenev, 2001). Typical growing in clumps and dense groups also supports “efficiency” of pollination activity of anthophilous insects on the disturbed landscapes.

Among typical species of recovering floral communities there is rather extensive group of species, mostly from the Fabaceae, Scrophulariaceae and Salicaceae families, which are characterized as obligatory entomophilous plants (Tikhmenev and others, 2020). For seed reproduction of this group species visitation of anthophilous insects is obligatory. Due to this fact occurrence of the majority of enthomogamy species, which are obligatory xenogamous ones, is rather rare in the rehabilitate plant communities and their use for revegetation purposes has relatively small efficiency.

Determination of seed viability of some pioneer species showed that intensity of germination of species most common for floodplain forests and pioneer species of recoverable sites are rather comparable, and in some cases this parameter can be even higher at plants of pioneer species. Thus, *Salix pulchra, S. schwereni, Populus suaveolens* and *Saxifraga funstonii* on the disturbed sites showed high productivity and seed vitality comparing to the plants of natural communities. Due to higher level of warmth supply on the disturbed landscapes more species complete ontogenesis successfully including seeds maturation and dissemination. Quality

Wide spectrum of conditions for settling and development of introduced plants on the disturbed sites are reflected in structure and productivity of the vegetation cover of such habitats (Pugachev, Tikhmenev, 2011; Kapelkina and others, 2014).

Figure 4. Revegetation stone dump with seeds of local flora species (*Larix cajanderi*, *Pinus pumila*) and grasses.

Figure 5. Revegetation site (waste) with seeds of local flora species.

Quantity of the thin soil material, wetting regime of substratum and distance to the natural floral societies (as source for seeds) play the determinative role for successfulness comparing to natural communities, which have more severe conditions for seasonal development (Tikhmenev, 2008). Effectiveness seed transportation of anemochorous species, which contribute the main portion of "seed rain" to the disturbed sites, rarely exceeds 100-120 meters from the adjacent natural plant communities. The animals' activity determines success of zoohores species seed distribution, including Siberian dwarf pine (Khomentovsky, 1995). Observation have shown that artificial reclamation by native species more effective and in short time to increase of an erosion process (Tikhmenev, 1999)

Experimental studies on plants introduction in the region showed that the seeds range for cultivation of artificial meadows and recovering of the disturbed landscapes should be drawn up using resources of local flora under estimation of its ecological peculiarities, level high seed reproduction. On the bases of field experiments, an effective technology of the reclamation of disturbed sites in Arctic and Subarctic has been developed (Patent #2711926, date of Russian Federation registration 23.01.2020). Some species of native flora are being used: *Arctagrostis latifolia* and *A. arundinaceae*, *Elymus*

sibiricus, E. mutabilis, Calamagrostis purpurea, Trisetum spicatum, Beckmania syzigachne and others grasses. Seed material of Larix *cajanderi* and *Pinus pumila* are very perspective to be introduce to the disturbed landscapes.

Thus, research of reproductive biology of phanerogams and principles of revegetation of disturbed permafrost landscapes let us determine rather large group of anemophilous and entomophilous species perspective for introduction to the disturbed sites. In number of cases performance of the assisted land reclamation measures is necessary; therefore, the data obtained on reproductive potential of species, which are dominants of the forming vegetative complexes, are valuable for development of efficient anti-erosien restoration of vegetation cover and creation of artificial meadows on the disturbed landscapes.

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