ECOLOGICAL GENETICS RESEARCH ON ECOFORMS, PHYTOGEOGRAPHICAL ELEMENTS AND CYTOGENETIC KARYOTYPES IN FOREST ECOSYSTEMS AND SPRUCE FORESTS OF *SOLDANELLA MONTANA* IN THE VLĂDEASA MOUNTAINS, FOR ECOLOGICAL RESTORATION

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Abstract

Spruce forests with Soldanella montana are spread on ridges, peaks and steep slopes with various exposition, on silky rocks, on superficial very acidic and humid skeletal, oligobasic soils. From phytogeographical point of view, these forests are populated with Carpathian and Carpathian-Balkan species, Alpine-Carpathian-Balkanic microtherm and acidophilic species with the tree layer dominated by Picea abies along with rare specimens of Abies alba, Sorbus aucuparia, Pinus mugo, Juniperus sibirica.

Under the influence of environmental factors (i.e. altitude, rock, soil, duration and intensity of wind action), three local populations (stocks) were differentiated by phenotypic variability related to the shape and size of the crown (morphological variation), wood density and number of chloroplasts per mm^2 (anatomical variations), resistance to wind, snow, chick (physiological variations).

The pre-subalpine spruce forests with Soldanella montana in the Vlădeasa Mountains have a very high preservation importance because they host 13 rare, endangered, endemic, relict plant species.

Key words: populations, variability, phytocoenoses, ecosystems, ecotypes

INTRODUCTION

Spruce forests in the Vlădeasa Mountains are located on the massive cliffs and mobile and semi-mobile silicone grooves at altitudes ranging between 1,500-1,700m below the Buteasa Peak (1,792m) on high degree slopes (35-50°). These are virgin secular forests on less surveyed yet much diversified layers with high conservative value, including rare, threatened, endangered, endemic, relict species in the Natura 2000 sites: SCI ROSCI 0016, also less studied.

No ecological genetics research on spruce forests of the Buteasa Massif has been done except for the flora and vegetation studies carried out in Drăganului Valley basin by Ratiu and Gergely (1970, 1985) and on the Vlădeasa Massif by Resmeriţa (1970). Contributions to knowledge of spruce forests in the Vlădeasa Mountains were brought by Burescu (2011, 2012, 2013, 2015), and Burescu et al. (2004). Similar research has also been carried out in Romania by Abrudan et al. (2006), Bândiu and Doniţă (1988), Bândiu et al. (2001), Biriş (2004), Biriş et al. (2002,2005), Chifu, Ştefan

(1992), Chifu et al. (2014), Doniţă, Biriş (2001), Giurgiu (2001), Radu (2001), Stăncioiu et al. (2008).

MATERIAL AND METHOD

Survey location is the spruce stands from the Drăganului Valley basin with the Zârna Valley tributaries up to the Vârfuraş Peak (1,689 m), compartments (inspection districts) 9D, the Crăciunului Valley (Northeastern) to the Nimăiasa Peak (1,689 m), compartments 76B and 84E, the Buteasa Peak (1,792 m), and compartments 104C, 130E, 140A.

Material surveyed consists of the upper altitude natural forestry ecosystems - spruce forests with *Soldanella montana* that survive in extreme conditions at the borderline with the subalpine hollow.

Floral inventory of the spruce forests was carried out in the compartments of inspection districts 9D, 76B, 84E, 104C, 130E, 140A. Plant species identified with the abundance-dominance assessment for each species were introduced on the association table thus developed following the Braun-Blanquet scale (1964).

The population of spruce forests (*Picea abies*) with *Soldanella montana* were surveyed and characterized from ecological, phytocenological, and cytogenetical perspective on the basis of tables compiled with reference to the distribution of bioforms, phytogeographical elements, ecoforms and genetic cariotypes.

Classification in terms of bioforms typs was based on the system developed by Raunkiaer (1937) and the phytogeographical distribution was carried out on the basis of phytogeographical classification developed by Meusel et Jäger (1992).

RESULTS AND DISCUSSION

The flora inventory of the spruce forests - the association So*ldanello majori-Piceetum* collects 51 species (Table 1) of which 39 species are part of the basic cenotaxa (i.e. *Soldanello majori - Picenion*, *Piceion excelsae*, *Piceetalia excelsae*, *Vaccinio - Piceetea*) in which the association is included which highlights a rich biodiversity.

The layer of trees is clearly dominated by the *Picea abies* species with a 54% overall coverage, along with the species *Abies alba* and *Sorbus aucuparia*. Tree crowning coagulation ranges between 0.5-0.6, the trunk diameters ranges between 40-48 cm and the height thereof reaches 21-28 m, at the age of 100 years.

The shrubby layer is poorly developed with specimens of *Pinus mugo*, *Juniperus sibirica*, *Salix silesiaca*, *Alnus viridis*, *Sambucus racemosa*, *Lonicera nigra*, *Rosa pendulina*, *Rubus idaeus*, and *Daphne mezereum*.

The herbaceous and subshrub layers with a 50% overall coverage are dominated by *Calamagrostis villosa*, *Luzula sylvatica*, *Oxalis acetosella*, *Vaccinium myrtillus* and *Soldanella Montana*.

The well-developed moss layer covers almost all of the soil, the dominance being ensured by the following species: *Hylocomium splendens*, *Polytrichum juniperinum* and *Sphagnum girgensohnii*.

Pre-subalpine spruce forests with *Soldanella montana* in Vlădeasa Mountains have a very high preservation value because they shelter endemic, relict, endangered, vulnerable, rare plant species included on the red lists Boşcaiu et al. (1994), Oltean et al. (1994), Dihoru and Dihoru (1994) such as *Aconitum callibotrion*, *Aconitum degenii (A. paniculatum)*, *Aconitum vulparia*, *Angelica archangelica*, *Athyrium distentifolium*, *Blechnum spicant*, *Corallorrhiza trifida*, *Dryopteris cristata*, *Epilobium alsinifolium*, *Gentiana punctata*, *Gymnodenia conopsea*, *Heracleum palmatum*, *Viola dacica*. These forests contain natural forest habitats of community interest: Habitat R 4203, code 9410 - South-eastern Carpathian spruce forests (*Picea abies*) with *Soldanella montana* which need protection by being declared protected natural areas, Doniţă et al. (2005), Gafta, Mountford coord. et al. (2008) and included in the Natura 2000: SCI ROSCI 0016 sites.

From phytocenological point of view, spruce forests with *Soldanella montana* are included in the association *Soldanello majori-Piceetum*. From the point of view of the bioform types (Table 2), the phytocoenoses of the association are dominated by Hemicryptophytes (60.7%), accompanied by Phanerophytes (17.7%), Megaphanerophytes (5.9%), Mesophanerophytes (5.9%), Nanophanerophytes (5.9%) followed by Geophtyes (11.8%) and Chameephytes (9.8%). Although the phanerophytes sum up a small number of species, they shape the physiognomy of these phytocoenoses.

Table 2

The share of the bioforms in the *Soldanella* spruce forests in the Vlădeasa Mountains

Bioforms	**Ph of which:**			**Ch**	**H**	**G**	**Total species**
	MPh	**mPh**	**nPh**				
Species no	3	3	3	5	31	6	51
Share %	5.9	5.9	5.9	9.8	60.7	11.8	100
	17.7						

Legend: Ph= phanerophytes (woody plants); MPh=Megaphanerophytes; mPh=Mesophanerophytes; nPh=Nanophanerophytes; Ch=Chameephytes; H= Hemicryptophytes; G= Geophtyes.

The analysis of the phytogeographical elements (Table 3) reveals the dominance of the circumpolar species (31.6%), followed by the Central European (19.6%), Eurasian (15.8%), European (13.9%), Balkan-

Carpathian (7.8%), and Alpine-Carpathian-Balkan ones (3.9%), which is phenomenon that may be explained considering the pedoclimatic conditions in which these forests are planted, and the floral ties with the Southern and Oriental Carpathians.

Table 3

Share of phytogeographical elements in the *Soldanella* spruce forests in the Vlădeasa Mountains

Phytogeographical elements	**Cp**	**Eua**	**E**	**Ec**	**Carp-B**	**Alp-Carp-B**	**End**	**Cosm**	**Total species**
Species no	16	8	7	10	4	3	1	2	51
%	31.6	15.8	13.9	19.6	7.8	5.9	1.9	3.9	100

Legend: Cp=Circumpolar; Eua=Eurasian; E=European; Ec=Central European; Carp-B= Balkan-Carpathian; Alp-Carp-B=Alpine-Carpathian-Balkan; End=endemic; Cosm=Cosmopolitian.

The ecoforms (Table 4) reveal that the spruce forests with *Soldanella monatana* in the Vlădeasa Mountains have a behaviour ranging from mesophilic (60.7%) to a slightly mesophilic behaviour (21.5%) in terms of humidity. With regard temperature, the microtherm species (58.8%) are dominant followed by micro-isotherms (17.5%), euriterms (15.6%) and cryophiles (7.8%). Soil chemistry favours the development of Acidophiles (27.4%), acid Neutrophils (23.5%) followed by Euriionic species (17.6%), and strong acid Acidophiles (13.7%).

Table 4

Distribution of ecoforms (ecological indices HTR) in the phytocenosis of *Soldanella* spruce forests in the Vlădeasa Mountains

Ecological indices	**Value category**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**0**	**Total species**
H	Species	.	.	4	15	16	11	5	51
	no %	.	.	7.8	29.4	31.3	21.5	9.8	100
T	Species	4	15	15	8	1	.	8	51
	no %	7.8	29.4	29.4	15.6	1.9	.	15.6	100
R	Species	7	14	.	12	.	9	9	51
	no %	13.7	27.4	.	23.5	.	17.6	17.6	100

Legend: H=humidity; H(2.5)=Xeromesophils; H(3-3.5)=Mesophils; H(4)=Meso-hygrophila; H(0)=Eurihide; T(1.5)=Cryophyte; T(2-2.5)= Microtermes; T(3-3.5)=Micro-mesoterms; T(0)=Euriterms; R(1,5)= strong Acidophiles; R(2) = Acidophiles; R(3)= acid Neutrophils; R(4)= weak acid Neutrophils; R(0)= Euriionic.

Regarding the genetic constitution in the spruce population (Table 5), diploid and polyploid plan species are found in equal shares (45%), followed by diplo-polyploid species (5%).

Table 5

Distribution of genetic categories by karytype in the *Soldanella montana* spruce forests in the Vlădeasa Mountains

Genetic categories	Diploid (D)	Polyploid (P)	Diplo-polyploid (DP)	Total species
Species no	23	23	5	51
%	45.09	45.09	5.09	100

The analysis of *Soldanella montana* spruce forests from the perspective of genetic constitution (Table 5) suggests the predominance of polyploid ecoforms that have made miraculous adaptations to rocks and groves at altitudes ranging between 1,600m and 1,800m exposed to strong winds. With regard to the resistance to wind, snow, ice, altitude distribution, soil and rock requirements, there are genetically differentiated 3 phenotypic varieties in the spruce population in terms of crown shape, tree branching, tree straightness, bioaccumulation of wood mass, wood density and resistance, the number of chlorophylls with chlorophylls a and b per unit area (mm^2) of the leaf mesophylls.

1. Variety - flag biotypes - poorly developed crown, branches oriented horizontally in a single plane, opposite to the wind direction, poorly developed trunk with low heights and small diameters, slow growth, high density wood. It has a large number of chloroplasts (600-800)/ mm^2. It is resistant to wind, snow, yet poorly resistant to ice. It survives in rankers, rocks, scree on highs and high peaks – i.e. on the upper third of the slopes, where they are slowly regenerating.

2. Variety - flat biotope, pyramidal crown, standard diameters and height, suitable growth, resistant to wind and snow but poorly resilient to ice. The cell plastidom counts between 400-600 chloroplasts/ mm^2. Hard wood of medium density colonizes the middle and lower thirds of the slopes.

3. Variety - columnar biotype, cylindrical crown at the pyramid peak. Thick trunk (80cm) with high heights (30-35m). Low density soft wood. Resistant to snow and ice, poorly resistant to wind. Plastidom is relatively rich i.e. 400-600 chloroplasts/ mm^2. It grows on deep, fertile soils along mountain valleys and brooks in the Vlădeasa Mountains.

Economic importance

Solidanella montana spruce forests gives a lower quality wood due to the growing conditions it develops. These forests are included in the functional categories 1-2a, 1-2c, 1-3f, 1-1c, 1-5j, 1-5i, being virgin secular forests that provide environmental services in critical situations, soil erosion control, climate control, protection of river basins and drinking water in the

Floroiu-Drăganu lake (400,000m^3) directed to the Munteni-Remeti hydroelectric plant with a capacity of 150 MW, producing 300,000,000 KWh each year.

In order to protect the flora and biodiversity of spruce forests with *Soldanella montana* containing rare wood ecosystems, open word of spruce trees on rocks and grooves, it is necessary to completely prohibit any cuttings that could affect the stability - already too fragile - of the rocks and grooves included in the forest environment.

Depending on the preservation status of the habitat and the rare, endangered species, preservation works can be approved to ensure species preservation in the ecosystem and their natural regeneration, to avoid the erosion processes triggered by these forests.

CONCLUSIONS

1. The research has resulted in a floral inventory of 51 plant species of which 13 species are rare, endangered, relict, endemic, vegetating in a habitat included in a natural, rare forest ecosystem, which needs protection.
2. The phytocoenoses of spruce forests with *Soldanella montana* are dominated by the hemicrypthophites (60.7%), due to the appurtenance of the surveyed territory to the temperate continental region climate.
3. Phytogeographical analysis shows the predominance of circumpolar species (31.6%) favoured by the colonization and development of spruce stands specific to some cold and wet forest site types in the mountain and sub-alpine floors of the Vlădeasa Mountains.
4. Regarding the action of ecological factors, spruce forests are dominated by ecoforms of a mesophilic (60.7%), microterm (58.8%) acidophil (27.4%) up to acido-neutrophil (23.5%) types.
5. There has been demonstrated the existence of genetic variability within the spruce population depending on the area (altitude, edaphic factors) that generated the differentiation of 3 biotypes (varieties) adapted to different forest resorts. The most relevant is the flag biotype based on edaphic ecotypes that can generate a clinal species – clinal variability in time.

Table 1

Ecology of *Soldanella* spruce forests gathered in the association *Soldanello majori - Piceetum* Coldea et Wagner 1998

Bio	Phyt. el	U	T	R	2n	Compartments surveyed	9D	76B	84E	104C	130E	140A	K
		(ecological indices)				Altitude (m)	1550	1500	1600	1600	1700	1550	
						Exposition	N	NV	NE	N	NV	S	
						Slope (°)	30	38	26	30	30	50	
						Tree layer consistency	0,6	0,6	0,6	0,5	0,5	0,5	
						Tree height (m)	28	24	23	26	21	21	
						Diameter (cm)	48	44	48	40	40	46	
						Herbaceous layer covering (%)	50	60	80	50	60	15	
						Surface (ha)	6,5	8	19	19	6,9	6,2	
H	Ec(alp)	3.5	2	1.5	P	*Soldanella montana*	+	+	+	+	+	+	V
MPh	Eua	0	0	0	D	*Picea abies*	3	4	4	4	4	3	V
Soldanello majori – Picenion, Piceion excelsae													
H	Carp-B	3	0	0	D	*Hieracium transsylvanicum*	+	+	.	+	+	+	V
H	Eua	4	2.5	1.5	P	*Calamagrostis villosa*	2	2	.	2	1	2	V
H	Carp	4	2	3	D	*Leucanthemum waldsteinii*	.	.	.	+	+	.	II
H	E(Alp)	3.5	2.5	2.5	P	*Homogyne alpina*	1	+	+	+	+	+	V
H	Ec	4	2	4	P	*Gentiana asclepiadea*	+	+	.	+	+	+	V
H	Cp	3.5	2	1.5	P	*Blechum spicant*	+	+	.	+	+	.	IV
H	Cp	3.5	0	0	P	*Dryopteris dilatata*	+	+	+	.	.	.	III
G	Cp	3.5	2	2	P	*Phegopteris connectilis*	.	.	.	+	+	.	II
mPh	E-A	0	2	0	D	*Pinus mugo*	.	.	.	.	+	+	II
Mph	Ec	4	3	0	D	*Abies alba*	.	.	.	.	+	+	II
Piceetalia excelsae													
H	Cp	0	0	1	P	*Dechampsia flexuosa*	1	+	+	+	.	+	IV
G	Cp	3	2.5	2	P	*Gymnocarpium dryopteris*	.	+	+	+	+	.	IV
						Sphagnum girgensohnii	+	1	.	1	1	.	IV
						Pleurozium schreberii	+	.	.	.	2	.	II

Table 1 (continuation)

Bio	Phyt. el	U	T	R	2n	Compartments surveyed	9D	76B	84E	104C	130E	140A	K
		(ecological indices)											
mPh	Cp-A-a	2.5	1.5	4	D	*Juniperus sibirica*	1	.	.	.	+	.	II
H	E	2.5	2.5	2	D,P	*Luzula luzuloides*	1	.	.	.	.	+	II
H	Eua	2.5	3	2	P	*Calamagrostis arundinacea*	.	.	1	.	.	.	I
Vaccinio Piceetea													
H	End	3.5	2	2	P	*Campanula abietina*	+	+	.	+	+	.	IV
H-G	Cp	4	3	3	D	*Oxalis acetosella*	1	1	+	+	1	+	V
Ch-nPh	Cp	0	2	1	D	*Vaccinium myrtillus*	2	3	4	3	3	2	V
H	Cosm	4	2.5	0	P	*Athyrium filix-femina*	+	+	+	1	+	.	V
H	Cp-A-a	3	1.5	4.5	D	*Polystichum lonchitis*	+	.	+	+	+	+	V
						Polytrichum juniperinum	.	3	1	+	+	1	V
						Hylocomium spendens	4	3	.	4	.	1	IV
G	Cp	4	2	2	P	*Streptopus amplexifolius*	+	+	.	+	+	.	IV
H-Ch	Ec	3	0	4	D	*Lamium galeobdolon*	+	+	.	+	+	.	IV
nPh	Ec	3	2.5	3	P	*Rosa pendulina*	+	.	.	+	+	+	IV
Ch	Cosm	3.5	2	2	P	*Huperzia selago*	+	+	+	.	+	.	
mPh	Ec	3	2	3	P	*Lonicera nigra*	+	.	.	+	.	+	III
MPh	E	3	2.5	2	D	*Sorbus aucuparia*	+	.	.	.	+	+	III
Ch	Cp	4	2.5	2	P	*Lycopodium annotinum*	+	+	.	.	.	.	II
Ch-nPh	Cp	3	2	1	D	*Vaccinium vitis-idaea*	+	.	.	.	.	+	II
nPh	Eua	3.5	3	3	D	*Daphne mezereum*	+	.	.	.	.	.	I
H-G	Cp	3	2	2.5	D	*Moneses uniflora*	+	.	.	.	.	.	I
Ch	Cp-Bo	3	0	0	D	*Orthilia secunda*	+	.	.	.	.	.	I
G	Cp-Bo	3	0	3	P	*Corallorhiza trifida*	+	.	.	.	.	.	I
G	Eua	4	2.5	4	D,P	*Veratrum album*	+	.	.	.	.	.	I
H	Alp-Carp-B	0	0	3	D	*Laserpitium krapfii ssp. alpiaum*	.	.	.	.	+	.	I
H-G	Alp-Carp	3	1.5	1.5	P	*Gentiana punctata*	.	.	.	.	+	.	I

Table 1 (continuation)

Bio	Phyt. el	U (ecological indices)	T (ecological indices)	R (ecological indices)	2n	Compartments surveyed	9D	76B	84E	104 C	130E	140A	K
H	E	3.5	2.5	0	D	*Ranunculusplatanifolius*	.	.	.	.	+	.	I
						Betulo-Adenostyletea							
H	Ec	3.5	2	3	P	*Doronicum austriacum*	+	+	.	+	+	+	V
H(G)	Carp-B	3.5	2	0	D	*Adenostyles alliariae*	+	+	.	+	+	+	V
H	Eua	3.5	3	3	P	*Senecio germanicus*	+	+	.	+	+	+	V
H	Eua	4	3	2	D	*Hypericum maculatum*	+	+	.	+	+	+	V
nPh	Cp-Bo	3	3	3	D,P	*Rubus idaeus*	+	.	.	+	+	+	IV
H	Ec	3	2.5	4	D	*Veronica urticifolia*	+	+	.	.	.	.	II
H	Alp-Carp-B	3.5	1.5	4	D,P	*Aconitum degenii*	.	.	.	.	+	+	II
H	Carp-B	2.5	2.5	4.5	P	*Aconitum callibotrion*	.	.	+	+	.	.	II
						Querco-fagetea							
G	E	3	2.5	2.5	P	*Polygonum verticillatum*	+	+	.	+	+	+	V
H	E	3.5	3.5	3.5	P	*Polystichum aculeatum*	.	+	.	+	+	.	III
H	Eua	3.5	3	3	D	*Actaea spicata*	+	+	.	.	.	.	II
H	Ec	4	2.5	4	D	*Aconitum vulparia*	.	.	.	.	+	+	II

Place and date of survey: Compartment 9D-Zara Valley, 02.07.2013; Compartment 76B - Crăciunului Valley, 02.07.2013; Compartment 84E – Crăciunului Valley 10.07.2013; Compartment 104C - Buteasa Peak, 10.07.2013; Compartment 130E - Buteasa Peak, 10.07.2013; Compartment 140a Moara Dracului Waterfall under Buceasa Peak, 23.07.2013.

Bio = Bioform; Phyt. el = Phytogeographical elements; U = humidity; T = temperature; R = Chemical soil reaction; K = Constancy of species; Abundance and dominance of species: 5 = 87.5%; 4 = 62.5%; 3 = 37.5%; 2 = 17.5%; 1 = 5%; + = 0.5%.

In a single survey the following species were included: *Angelica archangelica* (84E); *Athyrium distentifolium* (76B); *Heracleum palmatum* (140A); *Crocus heufelianus* (104C), *Scila bifolia* (104C); *Leucojum vernum* (84E), *Sambucus racemosa* (130E), *Alnus viridis* (130E); *Geum montanum* (9D); *Luzula multiflora* (9D); *Hypericum montanum* (84E), *Cherophyllum hirsutum* (84E), *Salix silesiaca* (130E), *Thalictrum aquilegiifolium* (84E), *Salix capraea* (140A).

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