Linzer biol. Beitr.	39/2	707-725	18.12.2007

Vegetation of Paektu Mt. alpine tundra and changes of species composition in its ecotone

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A b s t r a c t : In total, 99 phytocoenological relevés (5 × 5 m) of alpine tundra vegetation from Changbai-shan Mts (North Korea) are synthesised. Within the association Dryado tschonoskii-Rhododendretum aurei three new subassociations are described: Dryado-Rhododendretum typicum, Dryado-Rhododendretum erigeronetosum thunbergii, and Dryado-Rhododendretum papaveretosum radicatae. In the last one two variants are distinguished: var. Bistorta vivipara and var. Bistorta incana. Also 42 relevés (20 × 20 m) from gradient alpine tundra – taiga (forest) are compared. Changes in floristic composition on transect from alpine tundra to forest and replacement of heliophilous alpine tundra species by sciophilous forest species are analysed. Cover of shrubs and individual trees has a strong impact on species composition and structure of analysed gradient.

K e y w o r d s : high mountain vegetation, hypsometric vegetation transect, Korean-Chinese boundary, Phyllodocion nipponicae, syntaxonomy of dwarf-shrub vegetation.

Introduction

MIYAWAKI (1988) and MIYAWAKI & NAKAMURA (1988) published description of the plant communities of the classes Dicentro-Stellarietea nipponicae, Asplenietea rupestria, Phyllodoco-Harrimanelletea, Cetrario-Loiseleurietea, Carici rupestris-Kobresietea bellardii, and Krummholz communities of the alliance Vaccinio-Pinion pumilae from Japan alpine meadows at elevation above 2,400m. MIYAWAKI et al. (1969) and HOLZNER & HUEBL (1988) described the occurrence of *Rhododendron aureum* in the edges of stands of the association Vaccinio-Pinetum pumilae of the Japanese Alps. The two last syntaxa are distributed also in northern Korea mountains.

More detailed studies on vegetation structure and species composition of higher belts of Paektu Mt. were recently carried out by Korean botanists. They published several lists of plant species and analysed vegetation of altitudinal zones. These information-rich papers content only a few of phytocoenological data useable for synthesis and classification of vegetation units. Special issue of the Korean Journal of Ecology, Vol. 21, No 5–2 (1998) was dedicated to results of biological (including botanical and phytocoenological) and ecological studies in Paektu Mt. area.

Phytocoenological methods for classification of plant communities of alpine and sub-alpine zone were used by KIL et al. (1998). The lowest part of subalpine tundra near timber line is occupied by *Betula ermanii* community; in higher elevation, community with *Vaccinium uliginosum* and *Therorhodion redowskianum* are distributed. The highest area is characterised by occurrence of *Dryas tschonoskii* (syn. *D. asiatica*, *D. octopetala* var. *asiatica*) community, *Rhododendron aureum* community, and *Dryas tschonoskii*, *Salix rotundifolia* and *Bistorta ochotensis* community. All plant units are described as "communities" without specification of syntaxonomical rank. Unfortunately, phytocoenological relevés and more detailed characteristics of floristic composition of stands are absent. The altitudinal distribution of plant communities is similar to the results in this study.

KIM & KYEONG (1998) characterised dominant communities of Paektu Mt. as *Rhododendron aureum-*, *Dryas tschonoskii-*, *Therorhodion redowskianum-*, and *Phyllodoce coerulea-*community and give a list of evergreen broad-leaved trees of this area.

CHANG et al. (1991) studied vertical distribution of major forest plant communities on the northwestern slope of Paektu Mt. This area they divided into five vertical zones: (1) alpine tundra vegetation with typical occurrence of *Papaver radicatum*, *Oxytropis anertii*, *Rhododendron aureum* and absence of *Dryas tschonoskii*, (2) alpine meadows and shrubs characterised by *Dryas tschonoskii*, *Rhododendron aureum*, *Vaccinium uliginosum*, (3) the upper coniferous and birch forest zone, (4) alpine shrubs and hardwood forests, and (5) pine-hardwood forest zone. Distribution of these plant communities is analogous to situation on southeastern slope (ŠRŮTEK & KOLBEK 1994).

Diffraction pattern and wave character of the timber line in the west side of Paektu Mt. were described and elucidated by CHANG (1990). Mainly pure communities of *Betula ermanii* were analysed. The mathematical theory of boundary distribution of the plants and wave character of the timber line in plant communities dominated by *Betula ermanii* on Paektu Mt. studied CHANG et al. (1998) too.

CHANG et al. (1990) compared alpine tundra flora of Paektu Mt. with alpine and subalpine zone of other mountains in Korea. 96 species occurred in Paektu Mt. were found also in subalpine and alpine belts of some other Korean mountains.

KONG (1998, 1999) presents a theory that relative sensitivity of numerous arctic-alpine and alpine plants to high summer temperatures results in their occurrence in the alpine and subalpine belts of the mountains of Korean Peninsula.

Floristic composition of three altitudinal belts and their plant communities in the caldera of Paektu Mt. were published by CHANG et al. (1992). In a lowest part Gramineae, Cyperaceae, *Chrysanthemum zawadskii*, and *Bistorta ochotensis* were found. *Astragalus membranaceus* with other alpine herbs and dwarf shrubs are dominated in middle part. Alpine dwarf shrubs (*Rhododendron aureum*, *Therorhodion redowskianum*, *Empetrum nigrum*) occur in highest part. The species composition of middle and highest belts are similar to the plant communities presented in this study.

A specific and extraordinary character of the Paektu Mt. species composition in the comparison with 48 mountains of Korean Peninsula was proved by CHOUNG (1998) using the DCA method.

YIM & SHIM (1998) applied thermal climatic approach based on meteorological data for the determination of vegetation zones of Paektu Mt. The broad ecotones between neighbouring vegetation types support the vegetation continuum concept rather than the concept of units. They suggested using information on topography or soil conditions for the definition of vegetation zones.

Quadrate method (1 m × 1 m) was used for investigation of the flora and vegetation of the alpine grasslands at Dalmoon on Mt. Paektu. In 17 plant communities 36 vascular plant taxa were analysed (LEE et al. 1998).

Species and spatial structure of vegetation on the southeastern slope of Paektu Mt. was recently described (ŠRŮTEK & KOLBEK 1994, ŠRŮTEK et al. 2003). The Paektu Mt. (2,744m) is an old volcano with caldera at 2,227 m. The last eruption in 1702 devastated large forest area. A following succession led to the differentiation of vegetation types on the southeastern slope into four forest communities and one tundra vegetation type (KOLBEK et al. 2003). At present, the tundra vegetation occurs in 1,920–2,500m. In the lowest parts it forms a mosaic pattern with forests dominated by *Larix olgensis* (ŠRŮTEK & LEPŠ 1994).

Composition of the alpine tundra vegetation of the Changbai-shan Mts on Korean-Chinese boundary was characterised by DOSTÁLEK et al. (1988). This vegetation dominated by dwarf-shrub communities with *Rhododendron aureum*, *Dryas tschonoskii*, *Rhododendron confertissimum*, etc. was described as Dryado tschonoskii-Rhododendretum aurei DOSTÁLEK et al. 1988. The description of this association was based on 6 relevés from southeastern slopes in altitudes 2,100–2,400m a. s. l. The association belongs to the alliance Phyllodocion nipponicae MIYAWAKI et al. 1968 (syn. Rhododendro-Phyllodocion BR.-BL. & SISSING in BR.-BL. et al. 1939 prov.), the order Caricetalia tenuiformis OHBA 1968, and the class Carici rupestris-Kobresietea bellardii OHBA 1974.

Total cover of herb and moss layer varies between 60–100%. Herb layer is not species-rich (11.8 species per relevé, min. 4, max. 18). In the moss layer with very various cover (5–90%) 8 species were determined (6 species per relevé, min. 5, max. 7). Heterogeneity of published phytocoenological relevés is very high. The first description of the association was not quite complete: (1) from 29 taxa presented in herb layer 10 taxa were determinated only on the rank of genus and (2) number of relevés given not comprises the variability of this unit.

In 1986 and 1988 the alpine tundra vegetation of Paektu Mt. was revised in the field and set of new relevés was collected in the open alpine dwarf-shrub communities. In addition, next vegetation relevés were collected in the light stands of park-like larch forest (association Rhododendro aurei-Laricetum olgensis DOSTÁLEK et al. 1988) and in alpine tundra vegetation. Both types of vegetation were compared.

This study has two aims:

1) Classification of alpine tundra vegetation and description of its variability.
2) Characteristics of changes in floristic composition on the ecotone between alpine tundra and forest vegetation.

Materials and methods

Two groups of data were collected using Braun-Blanquet approach (BRAUN-BLANQUET 1964). 99 phytocoenological relevés (5 × 5 m) were made in 1988 in the open alpine dwarf-shrub communities. Six relevés of original diagnosis of association, which were published by DOSTÁLEK et al. (1988), were also used to classification of vegetation. Next

42 relevés (20 × 20 m) were made in 1986 and 1988 in the ecotone between alpine tundra and larch forest of the association Rhododendro aurei-Laricetum olgensis. The stands were studied in Changbai-shan Mts, on the southeastern slopes of the volcano Paektu on the Korean side of the Korean-Chinese boundary.

Before the numerical classification values of abundance and dominance were transformed to the nine degree ordinal scale (MAAREL 1979). Cluster analysis was performed by program HIERCLUS from SYN-TAX 2000 package (PODANI 2001). β-flexible clustering method (β = -0.25), RUŽIČKA's and JACCARD's coefficients were used. Following yielded dendrograms (Fig. 1, 2) the phytocoenological tables (Tab. 1, 2) were arranged.

The names of plants follow RI & HOANG (1984) except of *Androsace capitata* WILLD. ex ROEM. & SCHULTES, *A. lehmanniana* SPRENG., *Allium chinense* G. DON, *Potentilla coreana* SOJÁK, *Salix arctica* PALL., *Rhodiola* cf. *rosea*, *Lycopodium clavatum* var. *nipponicum* NAK. These taxa are not given in the List of North Korean species names (RI & HOANG l. c.). Nomenclature of plant species was compared with Flora Coreana (ANONYMOUS 1972–1976, 1979).

Results

Vegetation classification

Dryado tschonoskii-Rhododendretum aurei DOSTÁLEK et al. 1988

Little shrubs of *Rhododendron aureum*, *Vaccinium vitis-idaea*, *V. uliginosum*, and *Dryas tschonoskii* dominate in this dwarf-shrub subalpine and alpine tundra community. Open herb layer has average cover 45.7% (min. <5, max. 80%). Low stands are 10–25cm in height, only stands with *Juniperus sibirica* are mostly higher (max. 80cm). Besides the shrubs, *Oxytropis anertii*, *Festuca ovina* var. *koreanoalpina*, *Lloydia serotina*, *Potentilla nivea*, *Bistorta vivipara*, and *B. incana* participate in the herb layer. Thin moos layer covers in average 29.8% (min. 1, max. 85%). In the collected relevés 71 species of vascular plants were found. Heterogeneity of species composition in the association is high: only 14 species belong to V and IV constancy class, however, the number of species in I and II constancy class reaches 54. The community is adapted to short vegetation period from (end of May) June to August (September) and rough climate conditions: the Chinese station located near caldera, recording a mean annual temperature of -7.4 °C and average precipitation of 1,346mm (QIAN 1992). Korean climatic station located in 1,400m a. s. l. about 30 km from the caldera recording a mean annual temperature of 0.7 °C and average annual precipitation of 909mm (ANONYMOUS 1976).

Within the association three subassociations were distinguished (see Fig. 1 and Tab. 1):

Dryado tschonoskii-Rhododendretum aurei typicum subass. nova hoc loco

Nomenclatural type: identical with the type of the association name in DOSTÁLEK et al. 1988: Tab. 3, rel. 2.

Differential species: *Rhododendron confertissimum*, *R. aureum* (higher dominancy);

differential species against the subass. Dryado-Rhododendretum erigeronetosum are *Vaccinium uliginosum*, *Lloydia serotina*, *Bistorta vivipara*.

Stands of this subassociation dominated by *Rhododendron aureum* are species-poor or medium rich. *Vaccinium uliginosum* is a dominant species and *Rhododendron confertissimum* attains high constancy. *Saxifraga laciniata*, *Parnassia palustris*, and *Orostachys malacophylla* absent or they are present very scarcely.

Average cover of tree layer per relevé is 2.2%, shrub layer 3.4%, herb layer 76.3%, and moss layer 44.8%. Number of species varies from (4)8 to 24(31), averagely 17.1. Stands are situated in the middle part of hypsometric gradient in altitudes 1955–1960m by our relevés and in highest part (2100–2400m) by relevés published in DOSTÁLEK et al. (1988).

Dryado tschonoskii-Rhododendretum aurei erigeronetosum thunbergii subass. nova hoc loco

Nomenclatural type: Tab. 1, rel. 96.

Differential species: *Luzula multiflora*, *Aquilegia japonica*, *Erigeron thunbergii*, *Allium chinense*, *Orostachys malacophylla*, *Juniperus sibirica*. In comparison with other subassociations this is negatively differentiated by absence or low constancy of species *Dryas tschonoskii*, *Oxytropis anertii*, *Saussurea alpicola*, *Tofieldia nuda*, *Androsace capitata*, *Vaccinium uliginosum*, *Lloydia serotina*.

The subassociation represents the stands with higher dominancy of *Juniperus sibirica* and some graminoids. Average cover of tree layer per relevé is 5%, shrub layer 5.6%, herb layer 38.5%, and moss layer 47%. Number of species varies from 16 to 31, averagely 19.4. Stands are situated in the lowest part of hypsometric gradient in altitudes 1920–1925m.

Dryado tschonoskii-Rhododendretum aurei papaveretosum radicatae subass. nova hoc loco

Nomenclatural type: Tab. 1, rel. 38.

Differential species: *Potentilla nivea*, *Androsace capitata*, *Papaver radicatum*, *Tilingia tachiorei*, *Pedicularis verticillata*.

The subassociation represents large stands, rich in species. *Potentilla nivea*, *Oxytropis anertii*, *Bupleurum euphorbioides*, *Papaver radicatum*, *Dryas tschonoskii*, and *Androsace capitata* occur with higher constancy against the other subassociations. High number of flowering herbs is typical feature of the unit.

Stands are situated mainly in the highest part of hypsometric gradient in altitudes 1935 to 2045m. Average cover of tree layer per relevé is 1.2%, shrub layer 1.6%, herb layer 38.8%, and moss layer 22.9%. Number of species varies from (9)13 to 28, averagely 20.9.

Within the subassociation two variants were distinguished:

a) var. Bistorta vivipara, with *Agrostis flaccida*.
   Stands are situated in the highest part of hypsometric gradient in altitudes 1980 to 2045m. Tree and shrub layers absent, average cover of herb layer is 30.4%, and moss layer 17%. Number of species varies from (9)13 to 26, averagely 19.4.

b) var. Bistorta incana, with higher constancy of *Senecio kawakami* and *Minuartia artica*.
Stands are situated mainly in the middle part of hypsometric gradient in altitudes 1935–1970(2025)m. Average cover of tree layer per relevé is 2.4%, shrub layer 3.1%, herb layer 46.9%, and moss layer 29.1%. Number of species varies from 17 to 28, averagely 22.3.

Changes in floristic composition in the ecotone between alpine tundra and forest

Classification according to RUŽIČKA's coefficient

The synthesis and classification according to RUŽIČKA's coefficient (Fig. 2) gave better knowledge and more detailed differentiation between individual clusters, than classification according to JACCARD's coefficient. Five clusters – zones – were distinguished: 1. Typical stands of Dryado tschonoskii-Rhododendretum aurei; 2. Ecotone of alpine tundra; 3. Ecotone of light-park larch forest; 4. Typical stands of Rhododendro aurei-Laricetum olgensis; 5. Rhododendro aurei-Laricetum olgensis with some penetrating species from dark taiga forest (see Tab. 2). These zones are characterised by following eight groups of differential species (A–H):

A – Alpine tundra species

Nine species occur only in primarily non-forest zone. They are heliophilous and competitively weak (Tab. 2, cluster 1) and do not exceed to lower zones (*Papaver radicatum*, *Minuartia arctica*, *Lloydia serotina*). Stands of this zone syntaxonomicaly belong to the association Dryado tschonoskii-Rhododendretum aurei.

B – Alpine tundra species overlapping to the transition zone

The group comprises 25 species distributed prevailingly in alpine tundra and overlapping to the adjacent forest with various frequency and dominancy (Tab. 2, cluster 2). The species *Rhododendron aureum* is present only in the herb layer. *Bupleurum euphorbioides* penetrates into the forest zone along the whole transect and occupy forest clearings with lower canopy of trees. In this zone, *Vaccinium uliginosum* ordered into the group of common species, has the highest dominancy. Regular occurrence of seedlings and juvenile plants of *Larix olgensis* shows direction of probable future succession. Shifting of forest line to higher altitudes is expected (Fig. 4).

C – Species of transition zone between alpine tundra and light larch forest

This group in the table (Tab. 2) contains only five differential species. Many species overlap also into both neighbouring zones (Fig. 5).

D – Light larch forest species

Well developed thick moss layer is typical for light larch forest zone. In this zone, species of both types of vegetation (open alpine tundra and closed coniferous forest) meet. Cover of *Dasiphora fruticosa* in herb layer attains the highest values, but with less cover this species occurs scarcely in all zones.

E – Typical larch forest species

The zone of well developed forest of the association Rhododendro aurei-Laricetum olgensis is differentiated by ten species (Fig. 6). These stands represent typical larch forest vegetation of this area. Stability of this type is supported by occurrence of *Veratrum album* and shrubs *Ribes horridum* and *Juniperus sibirica*. The occurrence of typical forest species *Pseudostellaria sylvatica* is characteristic.

F – Species of transition zone between typical larch and taiga forest

Some coniferous species of the dark taiga such as *Abies nephrolepis*, *Picea koraiensis*, and *P. jezoensis* (KOLBEK et al. 2003) penetrate into the dominant larch structure of this forest. Differential group is rich in species and it is characterised also by typical forest components *Pyrola dahurica*, *Clematis ochotensis*, and *Lycopodium complanatum*. *Chamaenerion angustifolium* occurs only in closed forest stands; however, in the Europe it occupies light forest places or clearings.

G – Forest preferring species

In this group, species with clear preference to forest zone are concentrated, but they overlap with various frequency and cover into the other zones. Species *Phyllodoce coerulea* and *Sanguisorba parviflora* ordered in the group of common species have the highest dominancy in this zone. Other herbs, e.g. *Clintonia udensis* and *Maianthemum dilatatum*, prefer forest habitats. The moss *Ptilium crista-castrensis* is also typical representative species of these forests. *Gymnadenia conopsea* occurs there in lighter forest stands; however, for example in the middle Europe, it is quite a characteristic species of grasslands.

H – Common species

16 species are ordered into this group. They are distributed along the whole transect. The most frequent species are *Vaccinium vitis-idaea*, *V. uliginosum*, *Festuca ovina* var. *koreanoalpina*, *Larix olgensis*, and *Juniperus sibirica* in the herb layer.

Classification according to JACCARD's coefficient

JACCARD's synthesis (Fig. 3) divided the set of relevés into four basal clusters. The first cluster is characterised by open vegetation with dwarf-shrub communities and extrazonal occurring of trees in tree layer, however, these woody species are present also in herb layer. In this group the maximum of heliophilous species are concentrated, such as *Dryas tschonoskii*, *Chrysanthemum zawadskii*, *Oxytropis anertii*, *Tilingia tachiorei*, *Hedysarum alpinum*, both *Bistorta* species, and *Papaver radicatum*. *Rhododendron aureum* is presented in the herb layer and in shrub layer absent absolutely. *Larix olgensis* is present mainly as a shrub; *Abies nephrolepis* and forest sciophilous herbs are absent.

The second cluster represents stands in the contact zone tundra – forest. The floristic composition is characterised by medium values of cover of *Larix olgensis* and its full presence in shrub layer. *Rhododendron aureum* in shrub layer yet absents. Dominancy of the typical heliophilous plant of the group, *Dryas tschonoskii*, decreases; helio-sciophilous forest plants such as *Calamagrostis langsdorfii*, *Linnaea borealis*, *Dasiphora fruticosa*, *Lonicera edulis*, *Hieracium umbellatum*, *Gymnadenia conopsea*, and *Anthoxanthum nipponicum* are present for the first time.

Third and fourth clusters represent larch forests with typical forest species, such as *Clintonia udensis*, *Linnaea borealis*, *Calamagrostis langsdorfii*, *Potentilla coreana*, *Abies nephrolepis*, *Viola sachalinensis*, and *Pleurozium schreberi.*

The third cluster is characterised by occurrence of many sciophilous forest plants and with fully developed, but yet open, tree layer. *Rhododendron aureum* is present in 1–2m high shrub layer with highest dominance and constancy. Heliophilous plants absent, however, constancy and/or dominancy of *Ribes horridum*, *Lonicera edulis*, *Geranium eriostemon*, etc. increase. Occurrence of species *Veratrum album*, *Aconitum coreanum*, and *Trifolium lupinaster* is limited only to this group. Some lichen and moss species (*Cladonia rangiformis*, *C. stellaris*, *Rhytidium rugosum*) have the highest cover.

The fourth cluster is characterised by higher share of species penetrated from dark taiga, such as *Abies nephrolepis*, *Picea koraiensis*, *P. jezoensis*, *Lycopodium complanatum*, *Allium thunbergii*, *Pyrola dahurica*, *Prunella vulgaris*, *Orthilia secunda*, *Clematis ochotensis*, *Geranium eriostemon* etc.

Discussion

Syntaxonomical classification is based on floristic similarity of distinguished units and it does not follow strictly altitudinal gradient. Beside the complex altitudinal factor the vegetation pattern is probably conditioned by other ecological factors (substrate and/or soil structure, microrelief, content of organic matter, etc.) or succession. Consequently the stands of the subass. Dryado-Rhododendretum papaveretosum occupy large altitudinal range from the highest altitude (2045m) to relatively low altitude (1935m). Stands of the subass. Dryado-Rhododendretum typicum are situated in the middle part of the altitudinal gradient. Based on results of floristic analysis they are ordered among the relevés of the Dryado-Rhododendretum papaveretosum var. Bistorta incana, which comprise stands from 1935m to 1970(2025)m. Stands of the Dryado-Rhododendretum typicum attain notably higher cover of herb layer (76.3%) than stands of the Dryado-Rhododendretum papaveretosum var. Bistorta incana (cover 46.9%).

Ecological differentiation of these three subassociations is based only on terrain microgeomorphology and properties of (soil) substrate, which were observed in the field. The subass. Dryado-Rhododendretum papaveretosum occupies habitats on the raw volcanic ash without differentiated soil profile. This ash is of various granularity and often fluffy. Some parts of surface are not occupied by plants, on other places competitively weak species, such as *Papaver radicatum*, *Androsace capitata*, *Pedicularis verticillata*, and *Minuartia arctica* occur. Herb litter is mostly blows away by wind and initial humus layer starts to form only in the clump hemicryptophytes (*Potentilla nivea*, *Carex rupestris*, *Chrysanthemum zawadskii*) and especially in the clump of *Dryas tschonoskii*, *Oxytropis anertii*, and around the clumps of *Festuca ovina* var. *koreanoalpina*. Stands of this subassociation are under strong influence of erosion and deflation processes.

In the stands of subass. Dryado-Rhododendretum typicum more species forming clump polycormons grow. These species are able to retain a plant litter. Consequently, forming humus layer is of several centimetres thick. This primitive soil composes suitable properties for ecesis of next clump species. Typical is an occurrence of broad-leaved species *Rhododendron aureum*, *Vaccinium uliginosum*, *V. vitis-idaea*, and commonly *Dryas tschonoskii*, *Oxytropis anertii*, and *Festuca ovina* var. *koreanoalpina*. *Salix arctica* and

Phyllodoce coerulea occur clearly more frequently, however competitively weak species of subass. Dryado-Rhododendretum papaveretosum markedly decrease. Stands grow in compact substrate with more or less continuous humus layer on slightly (several centimetres) elevated isles with interspaces denudated up to raw volcanic ash. Stands of both subassociations form mosaic pattern in broken microrelief and ecotones between them are very frequent.

Stands of the subass. Dryado-Rhododendretum erigeronetosum occupy the most stabile and relative homogeneous substrata. Mosaic pattern of vegetation is conditioned more by penetrating shrubs than differentiation of microrelief. The surface is more compact and flat, places without humus layer are presented exceptionally. Forming of soil profile is accompanied by occurrence of nutrients and stability of ecological conditions demanding species. These differential species (see Tab. 1) may be found also in neighbouring light larch forest. Stands are characterised by decreasing of light demanding species (*Dryas tschonoskii*, *Oxytropis anertii*, *Lloydia serotina*) of alpine tundra vegetation. *Phyllodoce coerulea* and *Dasiphora fruticosa* occur with higher values of dominancy. More stabile layer of litter underlies arising of developed soil profile.

Unfortunately, phytocoenological relevés from alpine tundra vegetation of other parts of Paektu Mt. is not available. Published papers KIL et al. (1998), KIM & KYEONG (1998), CHANG et al. (1992) content list of plant species and communities. Compare and synthesis of whole alpine tundra vegetation of this area are not realisable.

Cover of shrubs and individual trees has a strong impact on species composition and structure of alpine tundra stands. These species form conditions for following succession and development of light larch taiga.

Species composition of stands in forest zone depends not only at decreasing elevation. The composition of herb layer is highly influenced by cover of shrubs and mostly trees which limit light conditions in lower layers. Also at clearings in forest zone can be found heliophilous species which have their ecological optimum in the alpine tundra.

Acknowledgements

The paper was supported by a project of Grant Agency of the Czech Republic no. 206/05/0119 "Plant communities of the Korean Peninsula: the first vegetation synthesis of less known area". The authors are grateful to Dr. M. Šrůtek, I. Ostrý, and colleagues from the Institute of Botany of D. P. R. K., Pyongyang, for help in the field and scientific cooperation.

Zusammenfassung

Es wurden 99 phytozönologische Aufnahmen (5 × 5 m) der alpinen Tundra-Vegetation des Changbai-shan Gebirges in Nord Korea erhoben. Innerhalb der Assoziation Dryado tschonoskii-Rhododendretum aurei wurden drei neue Subassoziationen beschrieben: Dryado-Rhododendretum typicum, Dryado-Rhododendretum erigeronetosum thunbergii und Dryado-Rhododendretum papaveretosum radicatae. Die letzte Subassoziation wurde in zwei Varianten gegliedert: var. Bistorta vivipara und var. Bistorta incana. 42 Aufnahmen (20 × 20 m) wurden aus dem Transekt Tundra-Taiga (Wald) verglichen. Die Änderungen der floristischen Zusammensetzung wurden von der Tundra bis zum Lärchenwald (von den lichtliebenden Tundra-Arten bis zu den Schattenwaldarten) analysiert. Die Beschattung durch Sträucher und einzelne Bäume hat einen grossen Einfluss auf die Artenzusammensetzung des Transekts.

References

ANONYMOUS (1972-1976): Flora Coreana. Vols. 1-7. — Pedagogical Publishing House, Pyongyang, 2849 pp. (in Korean).

ANONYMOUS (1976): Geographical atlas of Korea. — Pedagogical Publishing House, Pyongyang, n.v. pp. (in Korean).

ANONYMOUS (1979): Flora Coreana. Appendix. — R.P.D.C., Pyongyang. 685 pp. (in Korean).

BRAUN-BLANQUET J. (1964): Pflanzensoziologie. Grundzüge der Vegetationskunde. — 3rd ed. Springer, Wien. 865 pp.

CHANG N.-K. (1990): Wave character of the timber line on Paektusan. — Korean J. Ecol. **13(4)**: 321-329.

CHANG N.-K., SHIM K.-CH., LEE H.-U., KANG K.-M. & K.-H. SO (1998): The theory of boundary distribution of the plant and wave character of the timber line on Mt. Paektu. — Korean J. Ecol. **21(5-2)**: 491-499.

CHANG N.-K., YEAU S.-H. & S.-K. LEE (1992): A study on distribution of plant communities around Chunji in crater on Mt. Paektu. — Korean J. Ecol. **15(3)**: 209-220.

CHANG N.-K., YEAU S.-H., LEE S.-K. & H.-R. KWON (1991): Vertical distribution of forest types on the north-western slope of Mt. Paektu. — Korean J. Ecol. **14(4)**: 435-448.

CHANG N.-K., YOO H.-M. & E.-J. EO (1990): A comparison of the alpine tundra floras of the alpine tundra zone on Paektusan with the alpine and subalpine zone in Korea. — Korean J. Ecol. **13(3)**: 237-245.

CHOUNG Y. (1998): Characteristic species distribution of the Baekdoo Great Mountain Chain at Kangwon Province, Korea. — Korean J. Ecol. **21(1)**: 105-112.

DOSTÁLEK J. SEN., DOSTÁLEK J. JR., MUCINA L. & H.D. HOANG (1988): On taxonomy, phytosociology, and ecology of some Korean Rhododendron species. — Flora **181**: 29-44.

HOLZNER W. & E. HUEBL (1988): Vergleich zwischen Flora und Vegetation der subalpin-alpinen Stufe in den japanischen Alpen und in den Alpen Europas. — In: MIYAWAKI A. & E. LANDOLT (eds.), Contributions to the knowledge of flora and vegetation of Japan. Veröff. Geobot. Inst. ETH, Stiftung Rübel **98**: 299-329.

KIL B.-S., KIM Y.-S., KIM CH.-H. & H.-G. YOO (1998): The vegetation characteristics of the upper area of timber line in Mt. Paektu. — Korean J. Ecol. **21(5-2)**: 519-529.

KIM J.-H. & K.W. YUN (1998): Evergreen broad-leaved trees in Mt. Paektu and North Korea. — Korean J. Ecol. **21(5-2)**: 531-539.

KOLBEK J., JAROLÍMEK I. & M. VALACHOVIČ (2003): Forest vegetation of the northern Korean Peninsula. — In: KOLBEK J., ŠRŮTEK M. & E.O. BOX (eds.), Forest vegetation of Northeast Asia, pp. 263-361. Geobotany **28**, Kluwer Academic Publishers, Dordrecht, Boston, London.

KOLBEK J., ŠRŮTEK M. & E.O. BOX (2003): Forest vegetation of Northeast Asia. — Geobotany **28**, Kluwer Academic Publishers, Dordrecht, Boston, London. 462 pp.

KONG W.-S. (1998): The alpine and subalpine geoecology of the Korean Peninsula. — Korean J. Ecol. **21(4)**: 383-387.

KONG W.-S. (1999): Global warming and alpine vegetation. — Korean J. Ecol. **22(6)**: 363-369.

LEE H.-S., PARK H.-W., RIM Y.-D. & S.-K. LEE (1998): Flora and vegetation of alpine grassland at Dalmon on Mt. Paektu. — Korean J. Ecol. **21(5-2)**: 541-547.

MAAREL E. VAN DER (1979): Transformation of cover abundance values in phytosociology and its effects on community similarity. — Vegetatio **39**: 97-114.

MIYAWAKI A. & Y. NAKAMURA (1988): Überblick über die japanische Flora in der nemoralen und borealen Zonen. — In: MIYAWAKI A. & LANDOLT E. (eds.), Contributions to the knowledge of flora and vegetation of Japan. Veröff. Geobot. Inst. ETH, Stiftung Rübel **98**: 100-128.

MIYAWAKI A. (1988): A general survey of Japanese vegetation. — In: MIYAWAKI A. & E. LANDOLT (eds.), Contributions to the knowledge of flora and vegetation of Japan. Veröff. Geobot. Inst. ETH, Stiftung Rübel **98**: 74-99.

MIYAWAKI A., OHBA T. & S. OKUDA (1969): Phytocoenological study of alpine and subalpine zones of the Norikura-dake Mts in Central Japan. — Cons. Soc. Jap. **36**: 50-103 (in Japanese).

PODANI J. (2001): SYN-TAX 2000. Computer Program for Data Analysis in Ecology and Systematics for Windows 95, 98 & NT. User's manual. — Scientia Publ., Budapest. 53 pp.

QIAN H. (1992): Alpine tundra vegetation of Changbai Mountains. — Bot. Res. **3**: 97-118 (in Chinese).

RI J.-D. & H.-D. HOANG (1984): List of plant names. — Goahakbaekgoasadzon-Tschulpansa. Pyongyang. 544 pp. (in Korean).

ŠRŮTEK M. & J. KOLBEK (1994): Vegetation structure along the altitudinal gradient at the treeline of Mount Paektu, North Korea. — Ecol. Res. **9**: 303-310.

ŠRŮTEK M., KOLBEK J. & J. LEPŠ (2003): Species and spatial structure of forests on the southeastern slope of Paektu-san, North Korea. — In: KOLBEK J., ŠRŮTEK M. & E.O. BOX (eds.), Forest vegetation of Northeast Asia. pp. 383-408. Geobotany **28**, Kluwer Academic Publishers, Dordrecht, Boston, London.

ŠRŮTEK M. & J. LEPŠ (1994): Variation in structure of Larix olgensis stands along the altitudinal gradient on Paektu-san, Chanbai-shan, North Korea. — Arctic Alpine Res. **26(2)**: 166-173.

YIM Y.-J. & J.-K. SHIM (1998): On the vegetation zone of Mt. Paektu. — Korean J. Ecol. **21**(5-2): 501-518.

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Tab. 1. Syntaxonomical classification of the association **Dryado tschonoskii-Rhododendretum aurei**.
Explanation: Numbers 3 and 2 following names of plants respond to occurrence of taxa in tree and shrub layer, respectively.

Unit	typicum		erigeronetosum		papaveretosum var. *Bistorta vivipara*		papaveretosum var. *Bistorta incana*		
Number of relevé	45555555655566		9999999999		122212322 1122233332333344131111		14444444877666777666767788877888888		
	12634590213456278901		0451623798		7515074626890937942018578901133862		42478356689386134497552710806325947		
Number of species	1 11121111321211112	C1	1111122321	C2	1211222122111121222222222222211111	C31	21122111222222222222222222222222222	C32	CC
	44852807855146275974	%	6866710136	%	8389601901877608431306001421354499	%	08913897444336015211010724263385126	%	
Differential species of the subass. typicum									
Rhododendron confertissimum	.a1.3++.+r....a.....	40	....	0	....	0	..r.+..............................	6	10
Differential species of the subass. erigeronetosum thunbergii									
*Erigeron *glabratus*	........r...........	5	1++r++++11	100	..........................r.......	3	..........r.............+r....+r...	14	17
Aquilegia japonica	...........+r.r....1	20	111++++1+1	100	.....................+............	3	.......................+r.....r++..	14	20
*Luzula *sibirica*	........+...+.......	10	111+++++..	80	....	0	+....1..+.r.....r.......1.+...+1+++	34	22
Juniperus sibirica	.+.........r.....1..	15	++.r.aaaa.	70	....+..............+.r............	9	......r.rr+.....r.+rr..r.a1+...a+11	46	29
Allium chinense	...........+.......+	10	+++..+.1.1	60	.................+................	3	....r........+............r........	9	12
Differential species of the subass. papaveretosum radicatae									
Potentilla nivea	...r.r........+r..+.	25	..r++.....	30	a111111111+a1++11++1+11+++11+11+1+	100	+1++++++++++a1+1a1+1111a+11+a1+++11	100	78
Androsace capitata	..............+.....	5	....	0	a+1111111+1+111++++1111++11+1r++.	97	11111111+1+1111111111111r1+111r1.1+	97	69
Papaver radicatum	.....+..............	5	....	0	1++++++1++++1++1+++1+++1+r1+111++1	100	+..r..1....+1+1++++++++..+.++......	51	54
Tilingia tachiroei	...........r.++.....	15	.......+..	10	r+++.+1.+1.rrr++++.+11+++r+r..+.r.	76	.+......+..+++.++..+.....rr..r++rrr	46	46
Pedicularis verticillata	..............r.....	5	....	0	r++++r+++++.r+...r......+.++....r.	53	+++++..+...++++++++1+11++..+1+.....	66	42
Differential species of the var. *Bistorta vivipara*									
Bistorta vivipara	...+++1111.11.....++	55	.......+..	10	++++1111++++11++++++++11++1++11111	100	1............+.......+........+....	11	51
Agrostis flaccida	.......++1+....++1..	35	.......1..	10	................a+1a1a+r++.1......	32	.........+1..................+.....	9	22
Differential species of the var. *Bistorta incana*									
Bistorta incana	............11+1++++	40	++r+r+r+++	100	....	0	.+1+++1++rr11++++++1++1+1++++++++++	97	53
Senecio kawakami	....	0	.....r....	10	....	0	........++++++++++++++++r..+++....+	60	22
Minuartia arctica	....	0	....	0	.r..........r.....................	6	........+..+++r++...+.++r+.++......	40	16
Characteristic species of the ass. Dryado tschonoskii-Rhododendretum aurei									
*Festuca *koreanoalpina*	+111.11a11+aa+1a1111	95	bbb3baaa+a	100	aaaaaa11111+111a111+++1+1aaa+a+1++	100	11a1a1111+111111a++++11aaaa1+aaaa1a	100	99
Dryas tschonoskii	+a4113aaabaaa1aaaaaa	100	....1.....	10	3333b3bbb33ba1aabaaabbab33a311aaa.	97	343433b3aab33bb3b333b3ba+aabbbaa1aa	100	90
Oxytropis anertii	.+++11.1+.++++1+1+11	85	..++......	20	aaaaaa11111a11aa+++1+1++1+++r+1+1+	100	1++++++1+++aa+1a1111111++1r++1++++r	100	89
Zygadenus sibiricus	......+++r..r+1++++1	60	1++1r11+11	100	1++1++1+11....+1+++++11++++1..+++.	79	....++..+++1++11++1+++11++++111++++	83	79
Lloydia serotina	....11+1+1+.+1.+++..	60	....	0	11aaa++1aa11.a111+++11+11+1....r.	82	.+1++1r.+++.r..+r..1..+....+.......	43	56
Hedysarum alpinum	......+r...+r......+	25	.......r..	10	+r..r++++.1+..+.....+.............	32	+..+............+......r...+.r.....	17	23
Others									
Bupleurum euphorbioides	......+++++1+++1++1+	70	++...++++.	60	.+.++++++++r.r+++++++++++++1r+..+.	82	+11+++++++++++++1++1++++1+++++1++++	100	84
Saussurea alpicola	......+.r..++1+1+1++	55	....1...+.	20	111111+11a+1+a1111+1111++++1.1++11	97	111++1..+++11111111++a1++1+111++.11	91	79
Carex rupestris	.............++11+++	35	1...+...+b	40	aaaaaaa111a1a111a1+11111111a111a1.	97	aaaaaa11aaa1aaaaaaaaa11a11+111++..1	94	78
Tofieldia nuda	....11+++.1+++1..+1+	65	...+..+...	20	+1aa1++11a1...111.1aa1.1aa11+.+++.	79	111111+1+11++++1+++11..+r1+11++1+11	94	76
Chrysanthemum zawadskii	...+.......++.+.....	20	a11111a1..	80	.++++++.+++11++++++++++++++++++11+	94	+.++.+++++r+++++++++++++++++..+++++	89	76
Saxifraga laciniata	............+.......	5	+++++++...	70	+111+111++++11111111++11+++.11a111	97	+11+++1++..++11+1+11+11.+++++.++.++	86	72
Vaccinium vitis-idaea	.1.1.+aaabaaaab3a333	85	r+rr+a+++.	90	a...1.........a1aaa+ra..aa1a+1....	47	....1.1a1aaa.11aar...1+11+1a1aaaaba	74	69
Vaccinium uliginosum	.a.b3433334ab4334333	90	....	0	..1+1a11bb....b1ab..1aaa.3........	50	a+aaababb3bb1+1.++.1a..r.a.ab3b1a13	83	65
Parnassia palustris	...........+..+.....	10	+1++.+1+++	90	r+++++++r++++........rr+++......r.	56	.++.+.+.++++++.++1++.+.+++++r+11++.	77	58
Rhododendron aureum	43.411baaaabbabbaaa.	90	.r.a+aa33.	70	.1..+...........r.r..a11aaaa......	32	.++1r.aaa....+................+a1.1	34	48

Larix olgensis	....r.11.+.....1++1a	45	.......r..	10	.r..1.........+.11r......ar..a..1.	29	a..++.+++a........+..1.+.r+.1a11.aa	51	38
Orostachys mallacophylla	...................r	5	++r+++....	60	.+..r....+++++..+rr+.......r...r.+	41	..........+..+.+r......+r1r...r.r..	29	31
Adenophora verticillata	.......+...11+++.+.1	40	.......+11	30	.......+.........+..+.++..+.+......	21	.++++.......1....r+.............r..	23	26
Larix olgensis 2	......1....a1..+111a	40	.....b....	10	....	0	.........+..................baaab1ba	26	18
Larix olgensis 3	......1....a.....1ab	25	.....bab3.	40	....	0	............................aaaababa	23	17
Salix arctica	......1++1.11.......	30	.rr...+.+.	40	......+.........r..r..............	9	...................r......r.......	6	15
Phyllodoce coerulea	3a......1..11.......	25	......+a31	40	................+...+.............	6	.........................a......aa	9	14
Sanguisorba parviflora	..........r+.++....+	25	......++++	40	....	0	...r...+.r.............r..........	11	13
Gentiana jamesii	...........+.......r	10	.....+.11a	40	...r....+.........................	6	.............+r......r.......r....	11	12
Rhodiola rosea	......+.............	5	....	0	............+.....+..1....+..+....	15	....r....+.......r..r.....+......	14	11
Taraxacum sp.	...........+........	5	.+....r++.	40	...r..............................	3	.........r.............r+..........r	11	10
Dasiphora fruticosa	...........1........	5	....r+1+..	40	....	0	.........rr.............r..........r	11	9
Adenophora polyantha	.......+...11......+	20	....	0	....	0	...........+1..........r......r....	11	8
Anthoxanthum nipponicum	.........1..........	5	.......+11	30	....	0	....	0	4
Silene oliganthella	....	0	r.........	10	....	0	..........r.......r........+.........	9	4
Salix sp. A	.++3.+..............	20	....	0	....	0	....	0	4
Gentiana algida	....	0	....	0	..................r.....r.........	6	....+r............................	6	4
Chimaphila japonica	......a..+11........	20	....	0	....	0	....	0	4
Dasiphora fruticosa 2	...........1........	5	........a3	20	....	0	....	0	3
Senecio kirilowii	...++r..............	15	....	0	....	0	....	0	3
Picea jezoensis 2	..........3a1.......	15	....	0	....	0	....	0	3
Hierochloë sibica	...111..............	15	....	0	....	0	....	0	3
Gymnadenia conopsea	....	0	.......+11	30	....	0	....	0	3
Androsace lehmanniana	...+++..............	15	....	0	....	0	....	0	3
Diphasiastrum complanatum	....	0	.aa.1.....	30	....	0	....	0	3

In one or two relevés:
Achnatherum sibicum 3: 1; *Botrychium lunaria* 99: r; *Campanula cephalotes* 92: r, 97: 1; *Carex* sp. 2: +; *Dianthus morii* 14: r, 82: r; *Dianthus superbus* 97: 1, 98: +; *Gentiana* sp. 5: 1; *Juncus* sp. 3: 1; *Linnaea borealis* 97: +; *Lloydia triflora* 14: +; *Luzula* sp. 2: +, 6: +; *Pedicularis* sp. 6: r; *Picea jezoensis* 49: +, 53: a; *Picea jezoensis* (tree layer) 53: a, 54: +; *Rhodiola elongata* 61: r; *Salix* sp. B 2: +; *Sanguisorba* sp. 5: +; *Saxifraga* sp. 2: 1, 6: +; *Solidago virga-aurea* 97: +.

Relevé data follow this order: relevé number in bold, cover (in %) of tree layer, cover of shrub layer, cover of herb layer, cover of moss layer, and slope (in º). Exposition of all relevés is southeastern.
1: -, -, 80,10, 25; **2**: -, -, 70, 20, 10; **3**: -, -, 80, 10, 5; **4**: -, -, 70, 90, 5; **5**: -, -, 65, 20, 5; **6**: -, -, 60, 5, 10; **7**: -, -, 50, 20, 5; **8**: -, -, 35, 15, 5; **9**: -, -, 20, 10, 5; **10**: -, -, 10, 10, 5; **11**: -, -, 5, 5, 5; **12**: -, -, <5, 1, 5; **13**: -, -, 10, 10, 5; **14**: -, -, 45, 20, 15; **15**: -, -, 40, 20, 15; **16**: -, -, 15, 5 15; **17**: -, -, 45, 20 15; **18**: -, -, 10, 5, 15; **19**: -, -, 10, <5, 15; **20**: -, -, 40, 30, 15; **21**: -, -, 50, 30, 10; **22**: -, -, 45, 20, 10; **23**: -, -, 30, 20, 10; **24**: -, -, 20, 10, 10; **25**: -, -, 45, 20, 10; **26**: -, -, 60, 25, 10; **27**: -, -, 20, 20, 10; **28**: -, -, 50, 40, 10; **29**: -, -, 30, 15, 10; **30**: -, -, 20, 10, 10; **31**: -, -, 25, 15, 10; **32**: -, -, 15, 10, 10; **33**: -, -, 10, <5, 10; **34**: -, -, 40, 25, 10; **35**: -, -, 15, 10, 10; **36**: -, -, 20, 20, 10; **37**: -, -, 30, 20, 10; **38**: -, -, 45, 25, 10; **39**: -, -, 75, 20, 10; **40**: -, -, 20, 15, 10; **41**: -, -, 75, 30, 10; **42**: -, -, 75, 20, 10; **43**: -, -, 70, 40, 10; **44**: -, -, 60, 24, 10; **45**: -, -, 30, 20, 10; **46**: 10, 10, 70, 30, 10; **47**: -, -, 70, 25, 10; **48**: -, -, 65. 30, 10; **49**: 5, 5, 85, 30, 10; **50**: -, -, 70, 30, 10; **51**: -, -, 85, 40, 10; **52**: -, -, 75, 60, 10; **53**: 5, 25, 85, 65, 10; **54**: 5, 10, 60, 30, 10; **55**: -, 5, 70, 50, 10; **56**: -, -, 80, 60, 5; **57**: -, <5, 85, 60, 5; **58**: -, <5, 80, 55, 5; **59**: <5, <5, 85, 60, 5; **60**: 10, <5, 85, 70, 5; **61**: 15, 10, 80, 70, 5; **62**: -, -, 75, 60, 5; **63**: -, -, 55, 35, 5; **64**: -, -, 45, 35, 5; **65**: -, -, 40, 30, 5; **66**: -, -, 30, 20, 5; **67**: -, -, 50, 25, 5; **68**: -, -, 40, 30, 5; **69**: -, -, 45, 30, 5; **70**: 10, 15, 50, 35, 5; **71**: -, -, 20, 10, 5; **72**: -, -, 20, 25, 5; **73**: -, -, 45, 40, 5; **74**: -, -, 45, 35, 5; **75**: -, -, 35, 30, 5; **76**: 5, 5, 50, 30, 5; **77**: -, -, 45, 60, 5; **78**: -, 1, 70, 50, 5; **79**: -, -, 50, 60, 5; **80**: -, -, 35, 20, 5; **81**: -, -,15, 5, 5; **82**: 5, 5, 30, 15, 5; **83**: 10, 10, 75, 50, 5; **84**: 15, 20, 50, 25, 5; **85**: 15, 20, 40, 25, 5; **86**: -, -, 60, 20, 5; **87**: 10, 10, 70, 50, 5; **88**: -, -, 15, 5, 5; **89**: 5, <5, 30, 15, 5; **90**: -, -, 30, 70, 5; **91**: -, -, 35, 50, 5; **92**: 20, 15, 35, 75, 5; **93**: 5, -, 30, 40, 5; **94**: -, -, 25, 60, 5; **95**: -, -, 30, 60, 5; **96**: -, -, 25, 45, 5; **97**: -, -, 60, 50, 5; **98**: -, 30, 40, 10, 5; **99**: 25, 10, 75, 10, 5.

Tab. 2. Vegetation zones of transition between alpine tundra and larch forest characterised by five groups of relevés and differential groups of species.
Explanations: 1. Typical stands of Dryado tschonoskii-Rhododendretum aurei; 2. Ecotone of alpine tundra; 3. Ecotone of light-park larch forest; 4. Typical stands of Rhododendro aurei-Laricetum olgensis; 5. Rhododendro aurei-Laricetum olgensis with some penetrating species from dark taiga forest. Numbers of relevés are identical with ones in the dendrogram (Fig. 2). Numbers 3, 2, 0 following names of plants respond to occurrence of species in tree, shrub and moss layer, respectively.

Vegetation zone	**1**	**2**	**3**	**4**	**5**
Number of relevé	111	11111	112223	22222223	33333333444
	123456901278	34567	890565	12347890	12346789012
Number of species	232323334443	35322	232223	23323323	33343334544
	517495634376	42714	677036	32885191	51295658264
A – Alpine tundra species					
Lloydia serotina	+1a111+++++1	.....	......	....	....
Pedicularis verticillata	+++r++11+..r	.....	......	....	....
Papaver radicatum	a++1++11+r..	.....	......	....	....
Rhodiola rosea	1.+++r++..+.	.....	......	....	....
Minuartia arctica	+r...r+++r..	.....	......	....	....
Rhododendron confertissimum	..a..+....+1	.....	......	....	....
Gentiana squarrosa	..+...+rr...	.....	......	....	....
Gentiana algida	...rr+....r.	.....	.....+	....	....
Chimaphila japonica	.....++..+1.	.....	......	....	....
B – Alpine tundra species overlapping to the transition zone					
Potentilla nivea	11111+1111r+	+....	......	....	....
Saxifraga laciniata	a1111+11+++.	1....	......	....	....
Androsace lehmaniana	111111111+r+	.r...	......	....	....
Oxytropis anertii	aaa11+11++++	+r...	......	....	....
Tilingia tachiroei	+++++++r++r+	.++..	......	....	....
Zygadenus sibiricus	++111++111++	++1..	......	....	....
Chrysanthemum zawadskii	11++++1+11++	11+..	......	....	....
Carex rupestris	aaa1aaaa11.1	+r1..	......	....	....
Hedysarum alpinum	+++++.r+r.++	.+r..	......	....	....
Bistorta vivipara	11111.+.r.1+	.+r..	......	....	....
Senecio kawakami	......+1++..	r....	......	....	....
*Luzula *sibirica*	.+...+.r+1+.	11...	......	....	....
Adenophora tetraphylla	...++++..+1+	.11..	......	....	....
Adenophora polyantha	......+.r.1+	.++..	......	....	....
Rhododendron aureum	.+.+a1+.+1ba	ab3..	......	....	....
Bistorta incana	.....+1++1++	+1+..	......	....	....
Allium chinense	...+.r+.rr++	+11..	......	....	....
Salix arctica	..++.r.r.r1.	++r..	......	....	....
Callistephus chinensis	....r...+++.	++1..	......	....	....
Dryas tschonoskii	abbb433bbaaa	+r..+	+.....	....	....
Orostachys malacophylla	1+++r.++++.r	+...+	++....	....	....
Tofieldia nuda	1+11a1+1111+	+++++	+1....	....	....
Bupleurum euphorbioides	+++++11+11+1	+1+..	..1..+	....	++++.......
Larix olgensis	r1+1++++11++	.++11	..+...	.++....r	...+....+..
Parnassia palustris	+++r++1+11++	111+1	+11...	....	........+.+
C – Species of transition zone between alpine tundra and light larch forest					
Campanula cephalotes	....	r1...	......	....	....
Solidago virga-aurea	....	.1+..	......	....	....
Pyrola japonica	....	.++..	......	....	....
Botrychium lunaria	....	.+r..	......	....	.......r...
Botrychium ternatum	....	...rr	......	....	....
D – Light larch forest species					
Polytrichum alpinum 0	....	.....	3+1...	....	....
Cladonia rangiferina 0	....	.....	..ba+.	....	....
Cladonia stellaris 0	....	.....	aa3b.1	....	...+.......
Cetraria laevigata 0	....	.....	111a+.	....	...+.......
Hieracium umbellatum	....	.+...	111..+	....	....
Dasiphora fruticosa	........rr+.	+++1+	a.4+a1	+1+.....	...+....r.+
E – Typical larch forest species					
Aconitum coreanum	....	.....	......	+...11+1	....
Veratrum album	....	.....	......	...rr.++	....

Ribes horridum 2	....	.....	......	**....++1+**	....
Trifolium lupinaster	....	.....	......	**....++++**	....
Juniperus sibirica 2	....	.....	......	**....+11+**	....
Hylocomium splendens 0	....	.....	......	**111.....**	....
Pseudostellaria sylvatica	....	.....	......	**....++.1**	....
Ribes horridum	....	.....	....++	**++++1a11**	....
Rhytidium rugosum 0	....	.....	......	**...1aa1.**	........1..
Lonicera edulis	.........r..	.....	....+.	**+++1++11**	.......r.r.
F - Species of transition zone between typical larch and taiga forests					
Pyrola dahurica	....	.....	......	....	**11++..+.11+**
Clematis ochotensis	....	.....	......	....	**....+++++++**
Chamaenerion angustifolium	....	.....	......	....	**....++++++.**
Galeorchis cyclochila	....	.....	......	....	**......+++11**
Ligusticum tenuissimum	....	.....	......	....	**.....+.++++**
*Cladonia *fusca* 0	....	.....	......	....	**3a11.......**
Astragalus uliginosus	....	.....	......	....	**....+.1++..**
Gentiana scabra	....	.....	......	....	**+++........**
Bupleurum longeradiatum	....	.....	......	...+....	**.......+1++**
Abies nephrolepis 3	....	.....	......	..+.....	**+++....+11a**
Picea koraiensis	.........r..	.....	......	....	**+1+++...+..**
Orthilia secunda	....	.....	......	...+..1.	**....+1+.+1+**
Abies nephrolepis	....	.....	.....+	..+.....	**1+11111+111**
Allium thunbergii	....	.....	.+....	.....+..	**+.++.1+++.+**
Picea koraiensis 2	........a...	.....	.....b	....	**aama.++r.1a**
Abies nephrolepis 2	....	.....	.....b	.1a.....	**111a+...a1a**
Picea koraiensis 3	....	.....	.....a	.1r.....	**1a+1..+a.1a**
Lycopodium complanatum	....	.....	...1..	.1m.....	**a1aaaaaaaaa**
Geranium eriostemon	....	.+...	......	......+1	**...+11+111+**
G - Species prefering forest					
Picea jezoensis	...r......+.	...r+	++..++	..+.....	+1+1+11.11+
Picea jezoensis 2	.........11.	....r	+++.+a	.+r.....	maa1+++.11a
Calamagrostis langsdorfii	.........r.+	.111.	.11+1.	3a11a333	aamma+aaaa1
Picea jezoensis 3	..........1.	.....	...+.3	.11.....	11a3++..aa3
Gymnadenia conopsea	....	.11..	..++..	..+.++..	+.+.++.++++
Linnaea borealis	....	.1...	.....m	aamaaa1a	aa1ma11a1a1
Lonicera edulis 2	....	.r...	......	+1+a+m1a	...+.++++..
Rhododendron aureum 2	....	...1a	aba44b	334a4333	++.r...a1+3
Pleurozium schreberi 0	....	...33	.+....	a343a3a3	44433333455
Solidago japonica	....	...++	....++	a+11111a	1+111m1a111
Potentilla coreana	....	.....	+.....	+++..+.+	++++.++++++
Cladonia uncialis 0	....	.....	11....	.1a.....	aa+a.......
Ptilium crista-castrensis 0	....	.....	.a1433	33334333	...a3333a..
Clintonia udensis	....	.....	...++1	..+.11+1	1++.1+m11++
Prunella vulgaris	....	.....	.....+	....	++.+...++.1
Viola sachalinensis	....	.....	......	+++.+.1+	1+++11+111+
Carex peiktusani	....	.....	......	+.+.....	.......1+1.
Majanthemum dilatatum	....	.....	......	...11++.	....+1.+...
H - Common species					
Vaccinium vitis-idaea	++1aa11aaaa3	1a1a+	+++..1	a1a11aaa	aaaaa11111a
*Festuca *koreanoalpina*	aaa1a111aaaa	ba133	+ba+.1	.++1....	11aa+m111a+
Vaccinium uliginosum	+abbbbaabb33	++.1+	111aa1	.a1+....	11+1+++r1a1
Saussurea alpicola	1111111111+1	+++++	......	....	...++1++1+.
Juniperus sibirica	.r.+.r++a1++	aaaab	a1+a1a	+1a3aaaa	arabaaaa1aa
Taraxacum sp.	.r.....rrr+.	r1+..	......	....	....+++1+++
Gentiana jamesii	.r........+r	+11++	..+..+	...r....	...++111+++
Phyllodoce coerulea	...+..r.+1+.	aab11	aaab3b	+a33+1a1	33a11aaaaaa
Aquilegia japonica	...r....++++	111..	......	....+.++	....11+11++
Agrostis flaccida	...1+...1.+a	.+...	.1a++1	..1.....	1aa1.......
Larix olgensis 3	.....1.ab31a	3443a	aaabab	3b33a3a3	3aa333333aa
Sanguisorba parviflora	.....+..r.++	r1+..	..++++	1+++1111	...+1++11++
Larix olgensis 2	.....a.aabaa	a++11	.+aa+1	.111....	...+...r.+1
Anthoxanthum nipponicum	..........+.	.11..	.1+...	....	....+1+11+m
Dasiphora fruticosa 2	..........1.	.aa..	......	...1+m++	.........+.
Dianthus superbus	....	.a+.+	......	....++..	........r..
Number of other species			1		
	020000102211	24022	632147	34347424	20192106443

Fig. 1. Numerical classification of 99 relevés (5 × 5 m) of alpine tundra vegetation from Paektu Mt. (North Korea). RUŽIČKA's coefficient and β-flexible clustering method was used (β= -0.25).

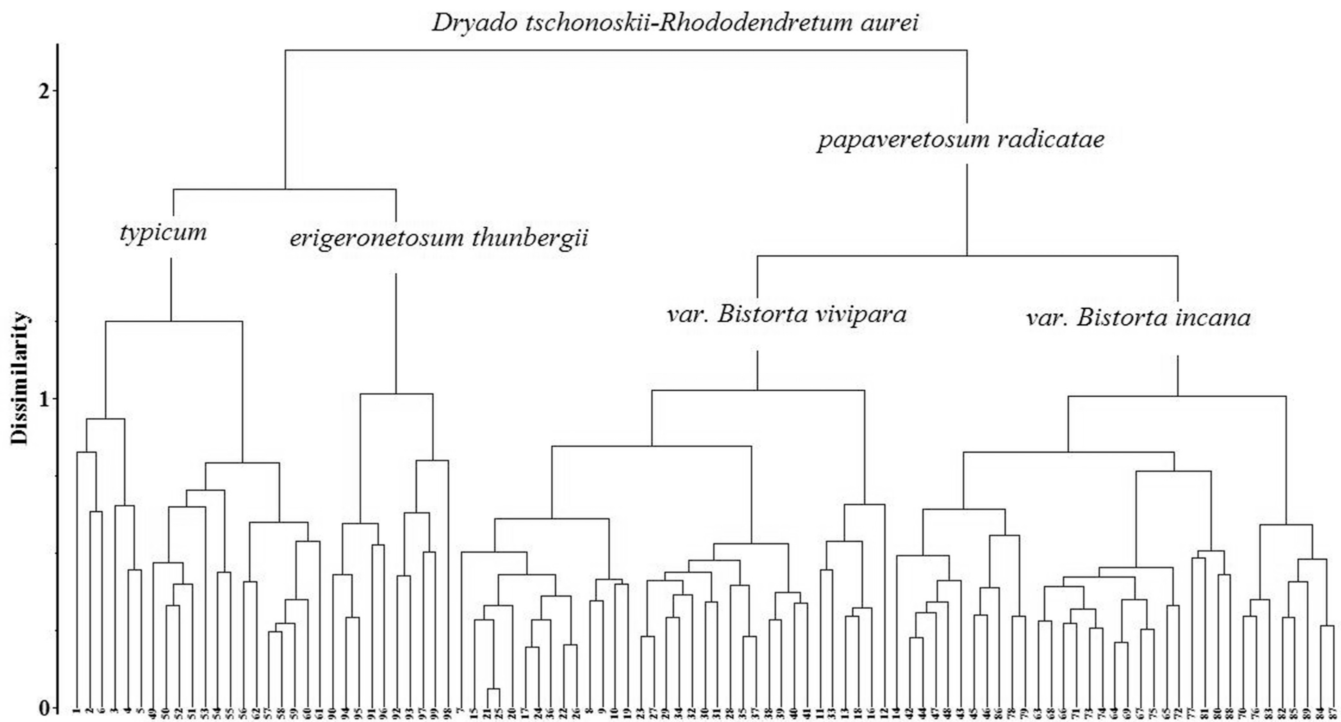

Fig. 2. Numerical classification of 42 relevés (20 × 20m) of alpine tundra and adjacent larch forest vegetation from Paektu Mt. (North Korea). RUŽIČKA's coefficient and β-flexible clustering method was used (β= -0.25).

Explanations: 1. Dryado tschonoskii-Rhododendretum aurei; 2. Transition zone of alpine tundra; 3. Transition zone of light-park larch forest; 4. Typical stands of Rhododendro aurei-Laricetum olgensis; 5. Rhododendro aurei-Laricetum olgensis with some penetrating species from dark taiga forest.

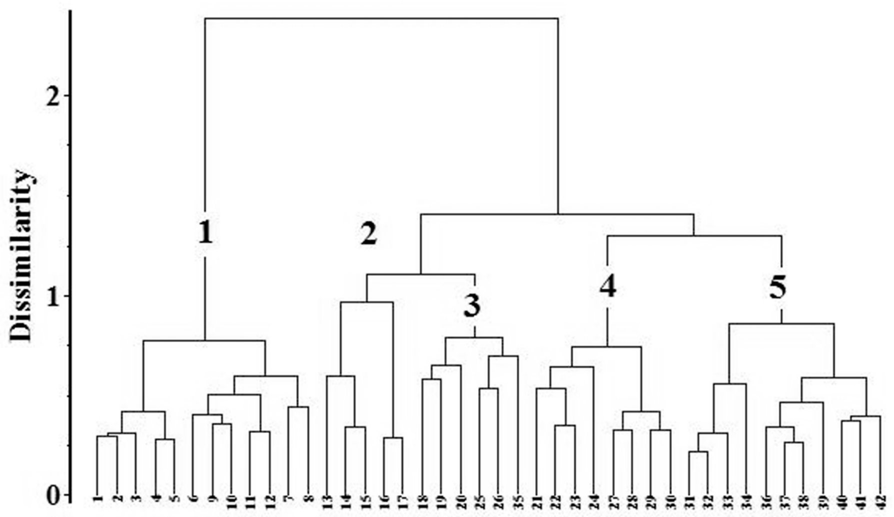

Fig. 3. Numerical classification of 42 relevés (20 × 20m) of alpine tundra and adjacent larch forest vegetation from Paektu Mt. (North Korea). JACCARD's coefficient and β-flexible clustering method was used (β= -0.25). Explanations: see page 7–8.

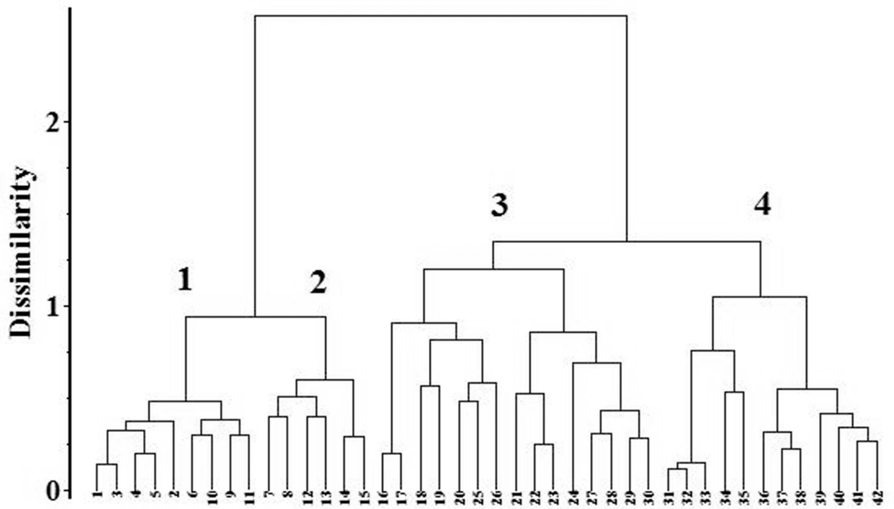

Fig. 4. Timber-line on Paektu Mt. – transition zone between alpine tundra and light-park larch forest (*Larix olgensis*) (photo I. Jarolímek).

Fig. 5. Timber-line on Paektu Mt. – contact zone of alpine tundra and light-park larch forest (Rhododendro aurei-Laricetum olgensis) (photo I. Jarolímek).

Fig. 6. Light-park larch forest (Rhododendro aurei-Laricetum olgensis) – ground layer contents species of alpine tundra, e.g. *Rhododendron aureum*, *Bupleurum euphorbioides*, and *Juniperus sibirica* (photo I. Jarolímek).