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ROLE OF ALLOCHTHONOUS SUBSTANCE IN INITIAL STAGE OF SUCCESSION

Rahmonov O., Kin N. O. **Rola substancji allochtonicznej w inicjalnym stadium sukcesji**. Przedstawiono rolę substancji allochtonicznej w procesie formowania się układów ekologicznych w ekosystemach piaszczystych. Proces ten badano na przykładzie wierzby piaskowej *Salix arenaria*, która zatrzymuje substancję allochtoniczną z przyległych obszarów i w ten sposób sprzyja polepszaniu warunków siedliskowych. Na Wyżynie Śląskiej występują wielkopowierzchniowe obszary piaszczyste pozbawione – w wyniku eksploatacji piasków bądź innych surowców – pokrywy glebowej aż do skały macierzystej. Z tego powodu utrudniona jest tu inicjacja sukcesji roślinnej czy rozwój gleby. Wierzba piaskowa zatrzymuje między gałęziami cały opad własnych liści oraz nawiewane allochtoniczne substancje organiczne, które po rozkładzie wzbogacają piasek w składniki mineralne. Substancje te pochodzą najczęściej z sąsiednich kompleksów leśnych. Świadczy o tym analiza gatunkowa nierozłożonych resztek organicznych, w wyniku której stwierdzono w obrębie kęp wierzbowych obecność liści buka zwyczajnego *Fagus sylvatica,* czeremchy amerykańskiej *Padus serotina* oraz grabu zwyczajnego *Carpinus betulus.* Liście wspomnianych gatunków zawierają znacznie ilości makro- i mikroelementów niezbędnych dla rozwoju roślinności porastającej ubogie w składniki pokarmowe ekosystemy. Materiał ten wzbogaca dodatkowo lokalną warstwę ściółki glebowej i zapewnia wkraczanie innych gatunków roślin o wysokich wymaganiach ekologicznych.

Рахмонов О., Кин Н. О. **Роль аллохтонного вещества на начальной стадии сукцессии.** Показана роль аллохтонного вещества в процессе формирования экологических отношений песчаных экосистем. Процесс был исследован на примере ивы *Salix arenaria*, которая задерживает аллохтонное вещество из примыкающих территорий и, таким образом, способствует улучшению биотопных условий. В пределах Силезской возвышенности находятся обширные песчаные территории, лишенные – вследствие добычи песков или другого сырья – почвенного покрова. Такая обстановка затрудняет инициацию растительной сукцессии и развитие почв. Ива задерживает между своими ветвями всю опавшую листву, а также навеваемое, аллохтонное органическое вещество, благодаря которому песок, после его разложения, обогащается минеральными компонентами. Это вещество чаще всего поступает из соседних лесных массивов. Доказательством тому служит видовой анализ нерозложенных органических остатков: в пределах пучков ивы *Salix arenaria* набдюдается листва бука *Fagus sylvatica,* черёмухи *Padus serotina* и граба *Carpinus betulus.* Листья отмеченных видов содержат значительное количество макро- и микроэлементов, необходимых для развития растений на бедных биотопах. Данное вещество обогащает также местный слой почвенной подстилки и способствует экспансии других видов с высокими экологическими требованиями.

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Abstract

The present work describes a role of allochtonous organic matter during succession, especially in its initial phases. It was investigated on the example of *Salix arenaria* through the determination of chemical composition of plant litter of allochtonous character within willow clump in open sandy areas. The results show that nutrient compounds from ex situ are of significant importance in the rate of succession.

INTRODUCTION

Open sandy areas being in initial phases of succession, especially in its zero phase, most often are devoid of vegetation or are settled by individual bushes, which distribution has a clear mosaic character. These bushes will be of essential importance in the following progress of vegetation succession and soil development. At this stage the accumulation of nutrients is strongly connected with bush canopy, which lack is noted in open areas, then to a small degree they occur in microdepressions of natural or anthropogenic origin. Areas under the canopy of willow bushes, enriched in nutrients, create separate surfaces, called islands of fertility, similar situation occurs in almost every arid and semiarid area of the world (SCHLESINGER, PILMANS 1998; NOY-MEIR 1985; SCHLESINGER et al. 1996). The mosaic distribution of microorganism biomass (HERMAN et al., 1995), eelworms (FRECMAN, MANKAU, 1986) and anthropods (SANTOS et. al., 1978) is reflected in the heterogeneous distribution of nu-

trients in desert terrains, as well as at sandy surfaces of large areas, where the pedosphere scarcely develops or it is shaped (JANKOWSKI, BEDNAREK, 2000; BEDNAREK et al., 2002; RAHMONOV, 2007). In such areas floristic and faunistic diversity is strictly connected with heterogeneity of habitat, including the soil. Functioning of ecosystems in such areas takes part under the vegetation, especially under its canopy, which fulfils the function of phytogenic field. There the most important biocenotic processes happen, whereas in zone beyond canopy weak biotic activity is observed. To biotic processes belongs among others accumulation of plant litter of different genesis (autochthonous a allochthonous), which is arrested by bushes. Wind is responsible for its translocation. Thus place of potential uptake of basic nutrients originates through introducing plant species. In sandy areas of eastern part of the Silesian Upland the largest succession link and the barrier for arrested allochthonous substance is undoubtedly made by *Salix arenaria*.

The aim of this study is an attempt to present the role of allochthonous material in enriching with nutrients areas connected with creeping willow through the determination of chemical composition of plant litter of allochthonous character within clump of *Salix arenaria* and indirectly its influence on the acceleration of processes of vegetation succession and soil development.

MATERIALS AND METHODS

At deflation fields and sandy surfaces being in initial phases of succession with singularly covering *Salix arenaria* (phot. 1), the qualitative analysis of plant litter of allochthonous origin was made. The aim was to determine its species attachment.

Under the willow clump at the end of October plant litter (*Fagus sylvatica, Padus serotina* and *Carpinus betulus*) was collected, and to compare chemical composition green leaves were also collected directly from above-mentioned species. After segregation the litter underwent laboratory analyses to determine selected nutrients. After wet mineralisation the analyses were made by means of AAS.

RESULTS

Characterised by clump form *Salix arenaria* makes the barrier for sands transported by winds (phot. 1).

Wind forming hillocks with contribution of creeping willow not only transports sand, but also allochthonous organic substance mostly originating from neighbouring forest complexes (phot. 2).

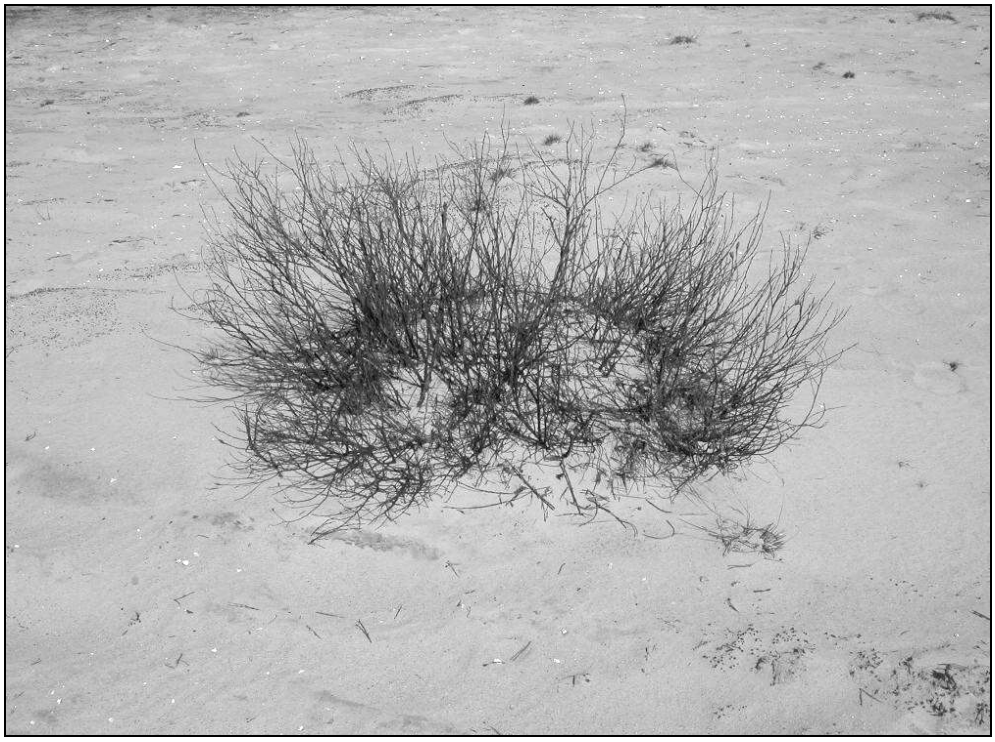
It is proved by the species analysis of undecomposed organic remains, in result of which the occurrence of leaves of *Fagus sylvatica, Padus serotina* and *Carpinus betulus* was stated within the willow clumps. The clear differences in the amount of accumulated organic matter are observed in the clump and trailing willow forms. The nearest individuals of birch and hornbeam were located in the straight line in the distance of about 1 km from deflation field, where *Salix arenaria* grows.

The second way of accumulation of allochthonous matter in open areas is connected with anthropogenic depressions of different size (phot. 3), where accumulated matter can be covered with sand and after its decomposition mineral components release. It causes the formation of the following succession link, according to depression arrangement.

From bush species creeping willow as the first colonises open sandy terrains. Dynamics of recolonisation in sandy areas is strongly connected with autoecology of the given species, variety of life cycle, the possibility of dispersion and germination. Recruitment of seedlings can be limited through interactions of seeds and microhabitat availability. The main factor limiting germination and germ survivorship is probably weak water capacity of sandy substratum and the lack of soil colloids, especially in the initial phases of succession. Therefore not every species propagating in a generative way can be affixed into substratum. *Salix arenaria,* thanks to a large possibility of vegetative development, well manages under such habitat conditions. Generalising, germination of potentially occurring plant seeds in seed bank in the initial phase of communities development in sandy areas is very limited and therefore some species can start the colonisation of poor sandy deposit. The arrestment and accumulation of blown organic substance of allochthonous origin is significant for this willow clumps (phot. 2), because it enables the introduction of other species of early stage of succession.

At the surface of deflation field beyond the willow clump the lack of patches of other plants is often observed. In this case the vegetation mostly occurs in the intercanopy zone. In result of research performed within one clump of creeping willow of diameter not exceeding 1 m the occurrence of *Corynephorus canescens* and sin-

gular clumps of *Koeleria glauca* was observed. In dispersion also occur here species as follows: *Festuca ovina*, *Rumex acetosella*, *Cardaminopsis arenosa* and *Chimaphila umbellatum* – i.e.



Phot. 1. *Salix arenaria* on deflation field (phot. by O. Rahmonov)
Fot. 1. *Salix arenaria* na polu deflacyjnym (fot. O. Rahmonov)

Phot. 2. Accumulation of organic matter under clump of *Salix arenaria* (phot. by O. Rahmonov)
Fot. 2. Akumulacja materii organicznej pod kępą *Salix arenaria* (fot. O. Rahmonov)

Phot. 3. Accumulation of organic matter in anthropogenic microdepression (phot. by O. Rahmonov)
Fot. 3. Akumulacja materii organicznej w drobnych zagłębieniach antropogenicznych (fot. O. Rahmonov)

Phot. 4. *Salix arenaria* in terminal stage of succession (phot. by O. Rahmonov)
Fot. 4. *Salix arenaria* w końcowym stadium sukcesji (fot. O. Rahmonov)

species typical for communities of coniferous forests. Within the clump also individuals of *Pinus sylvestris* develop, which in terminal succession stages (phot. 4) in sandy areas creates pine coniferous forest.

From cryptogamous species within willow clump often occur the species as follows: *Cladonia cervicornis* subsp. *verticillata***,** *C. subulata, C. phyllophora, C. mitis, Cetratria aculeata, Politrychum piliferum, P. juniperinum, P. formosum,*

whereas the borders of willow clumps and the top parts of hillocks at uncovered places are occupied by *Algae*, forming biological soil crust. The term Biological Soil Crusts should be understood as the mosaic, composed of cryptogamous plants, and especially algae, bryophytes, lichens and liverworts, making highly specialised plant communities (BELNAP, 2001). As research by RAHMONOV (2007) indicate, the relation C:N as the indicator of mineralisation processes and in consequence deciding of nutrient availability for plants is more advantageous in the case of fragments of surfaces covered with biological soil crust and in clumps of creeping willow. At this stage of succession such species diversity is among others conditioned by soil fertility within willow clumps.

Litter of these species additionally enriches interclump areas, which are essential from the point of view of plant nutrition. In chemical composition of these species the essential role is played by ash elements as follows Ca, Mg, Na, K, Na and others (tab. 1). One of tasks of these elements is maintenance of soil pH-reaction in the state of weakly acid in sandy deposits. In leaves investigated in the case of phosphorous the phenomenon of retranslocation is observed. At open sandy surfaces the additional portion of organic and mineral matter is of significant importance in initiation and acceleration of systems development.

DISCUSSION

Salix arenaria between branches arrests the whole litter of its own leaves and blown allochthonous and autochthonous organic substance, which undergoes covering up with sand. Processes of formation of succession chains at open sandy surfaces in eastern part of the Silesian Upland are mostly initiated by *Salix arenaria* and *S. acutifolia,* and to a less degree by *Pinus sylvestris*. Therefore the problem investigated will be discussed for the example of *Salix arenaria*. This species as the first after algae mostly introduces at sandy surfaces of large contribution of dusty-clayey material, as well as at loose and bare sands at open surfaces. Thus it makes the barrier for the wind. In the following years of development it increases its canopy and fixes sand. In the shadow of its canopy microhabitats of specific microclimate are formed. Then it favours occupancy by other species. Other tree-bush species create biogroup (RAHMONOV, 2000). Developing singular willow at open terrain also makes specific trap for plant litters transported by wind and for fine dusty-clayey fractions, originating from blown soils, located at neighbouring areas. Apart from organic substance produced by biogroup and its components, the above-mentioned allochthonous organic matter makes the essential material for soil forming and it influences the communities maturation. Thus in open areas scattered soil and plant islands can create, which will become the place of acceleration of plant-soil succession in neighbouring areas through increasing in its range or through propagules providing in the case of plants. After sand stabilising species of small nutrition requirements still occur. In dunes some species show high viability resulting from decomposing buried organic matter. Just these favouring conditions allow formation of more advanced and extended vertical structure of plant communities.

The lack of seeds source, disadvantageous habitat conditions, anthropogenic disturbances or other biotic factors stop tree species introduction, and then the lack of shadow and the area of plant litter, especially leaves, can delay processes and changes occurring in the process of shaping of plant-soil succession in open areas devoid of vegetation, on contrary to areas covered with willows. In the majority of dunes or hillocks soils are characterised by better content of nutrients. It is possible to observe here clear relations between vegetation and soil, which provide arguments, explaining the occurrence of plant species in areas of significant thickness of organic-humus horizon, at formation of which the substance of allochthonous origin is of large importance. Together with increasing in the area of vegetation-soil clump processes of organic matter decomposition also occur, in result of which the nutrient releasing follows. Its occurrence is, as research by SCHLESINGER et al. (1998) and our prove, limited into the canopy. Therefore this zone is called island of fertility. Enriched areas under willows canopies are characterised by largest species richness than other areas (RAHMONOW, KRĘCIAŁA, 2001).

Important ecological factor in areas of loose sands is treading, which can be considered in two aspects – positive and negative. In the first case the treading causes the break up of dead, overground plant organs, which consequence is the increase in contact area of organic remains with soil and the acceleration of its mineralization rate. Most often it also causes mechanical stabilisation of seeds in the ground, what increases the probability of their germination. On the other hand

Table 1. Chemical composion of leaf-litter *Prunus serotina, Fagus sylvatica* and *Carpinus betulus*
Tabela 1. Skład chemiczny liści *Prunus serotina, Fagus sylvatica* i *Carpinus betulus*

Nazwa próby	C	N	P	Si	Mn	Mg	Na	K	Ca	Mo	Co	Fe	Al	Zn	Cd	Pb	Sr	pH	
	[%]		[mg/kg]															H_2O	KCl
Padus serotina																			
Liście zielone	56,5	2,03	884	904	306	2184	1244	7638	13306	20	0	246	132	30	0	4	50	5,16	4,94
Liście opadłe	53,9	0,59	184	606	180	3232	1604	10712	23450	18	0	374	172	94	0	4	45	4,27	4,07
Fagus sylvatica																			
Liście zielone	53,7	2,14	1052	888	522	1456	592	9510	9710	8	4	416	0	78	0	10	26	5,00	4,75
Liście opadłe	48,4	0,76	488	1624	912	1156	854	6526	2384	6	2	754	862	110	0	26	24	4,98	4,54
Carpinus betulus																			
Liście zielone	48,4	0,94	1384	398	1014	2514	1750	9518	16420	0	4	314	328	110	0	12	29	5,01	4,80
Liście opadłe	48,5	1,09	644	660	1242	2602	678	7218	15280	0	6	886	750	104	0	16	30	3,98	3,73

negative influence of treading reveals in disturbing of vegetation cover. It is especially marked at borders of eastern and northern part of the area investigated, which is connected with easy access and touristic use of this terrain. One should also emphasise that psammophytes are very sensitive to mechanical factors, which in this respect to significant degree hinder vegetation succession.

Dead plant organs – penetrating the soil or occurring at its surface – enrich substratum in nutrients. One of the most important forms of habitat-forming plant activity is the accumulation of dead remains and falling leaves in soil and its surface, which secures saprophytic components of biocoenosis basic food (matter and energy). On the other hand saprophytes activity has a bearing on edaphic conditions of plant growth, i.e. humidity relations, the content of mineral nutrients, soil aeration and its pH-reaction.

Leaves and decomposing timber and the accumulation of humus along willow bushes and pioneer tree species are very important elements differentiating ecological niches. The development and rate of succession depends on topographic conditions, water relations and the substratum. Sands in area investigated are mostly built of quartz. There very important biological processes happen, which change this environment. Accumulation of organic matter not only directly increases nutrient resources, nitrogen and others elements, but also modifies humidity, aeration and the capacity of exchangeable cations. Alcaline cations seem to be especially important for nutrient reserves of metallic cations (RAHMONOV, 2007), which are of large importance during the succession.

From study by RAHMONOV (1999) results, that in the process of ecosystems development on open sandy areas the essential role is played by the neighbouring biochores and artificial plantings, especially of broad-leaved species, because broad-leaved species produce large amount of phytomass, which is transported by wind towards open areas. It is very important phenomenon in the process of succession in areas which are poor in nutrients. The role of plantings in the initiation of succession generally can be considered in two aspects: positive and negative. The positive role of them consists in this, that areas of drift sands were decreased and simultaneously edaphic conditions were improved. On the other hand the negative role of plantings reflects in disturbances in processes of natural succession. Then in such places during 30 years poor pine monoculture has created, which has not any similarity with nature pine coniferous forest. The consequence of these processes is artificial pine plantation, in the opposite case climax systems for the given ecoregion are created.

CONCLUSIONS

The rate and development of succession on sands and dunes initially is conditioned by the accumulation of organic matter and allogenic factors.

Forest complexes surrounding sandpits and open sandy terrains are the potential source securing the organic material providing, enriching sand with humus compounds and tree seeds. The role of pioneer vegetation is extremely essential in open sandy areas, because it is the living barrier in the process of arrestment of allochthonous substance, brought by wind from the neighbouring terrains. In initial phases of succession the role of wind is very important, not only in the propagules providing, which decides of succession rate, but also in the allochthonous organic matter providing.

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