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MORPHOSTRUCTURAL DESCRIPTION OF THE SALIX OFFSHOOT SYSTEMS FROM THE MIDDLE TAIGA SUBZONE OF WESTERN SIBERIA

ABSTRACT. The comparative study of the quantitative features of biennial offshoot systems of eight species of Salix was conducted. These species are S. triandra, S. myrtilloides, S. hastata, S. pyrolifolia, S. jenisseensis, S. phylicifolia, and S. uralicola. The samples for the study were obtained from plants growing in hard to reach remote areas of the reserve "Malaya Sos'va". The modular approach and mathematical methods of analysis have been employed in the research methodology. The basic statistics, variability and correlation of seven morphostructural features of the offshoot modules of the last (AS) and previous (PS) years of vegetation are analyzed. The differences and similarities of the species as well as intra- and inter-specific statistical peculiarities of different structural and age specific offshoot modules (AS and PS) are considered and defined. The intraspecific and interspecific variability of some morphological characteristics («length of the stalk» and «the number of internodes») of the offshoot modules AS and PS does not correspond to the normal distribution law. Structural factors must explain such non-accidental character of the variability of the investigated features.

KEY WORDS. Salix, variability, morphostructure, offshoot module.

Offshoot systems are the result of the realization of the genetic program of development in certain environmental conditions. Different conditions influence on the size and structure of offshoot modules. Qualitative and structural (i.e. morphostructural) study of the changeability of offshoot systems can contribute significantly not only to the diagnostics of the species but also study of the trends of environmental changes. However, this aspect of biomorphological studies is in its initial stage of development [1-8]. There is no conventionally formalized and ergonomic methodology of morphostructural description of offshoot plant systems. This fact predetermines the necessity to construct a unified database for comparative morphostructural research of botanic species from various natural-climatic conditions.

Objective of the research: using modular approach and mathematical methods of analysis to reveal common and species-specific features in the morphostructure of offshoot plants systems of different *Salix* species from the middle-taiga phytocenosis of the West Siberian Plain. Tasks: 1) To construct a unified statistical complex for multivariate analysis of morphostructural properties of two-year offshoot systems of different *Salix* species; 2) To reveal regularities of variability and correlation of morphostructural features of offshoot modules on the intra-species and interspecies

levels; 3) Using multivariate statistical analysis to disclose the similarity degree between offshoot systems of different species.

Material and methods of the research. We have studied model samples of 8 *Salix* species: S. triandra L., S. *myrtilloides, S. hastata, S. pyrolifolia, S. jenisseensis (Fr. Schmidt) Flod., S. phylicifolia, and S. uralicola I. Belyaeva.* The samples for the study were obtained in the reserve "Malaya Sos'va" at the beginning of August 2009 in the valley of the river Malaya Sos'va (in the vicinity of the cordon Khangokrut) and in the valley of the river Em-Egan (in the vicinity of cordon Belaya Gora). The species are indicated in the tables as STr, SMyr, SPyr, SHas, SJen, Sur, SPh, and Slap.

The methodology of gathering and treating the material was published in the article [9]. It has been developed for the S. *myrtilloides* species and is suitable for the description of the structure of the offshoot system of sympodial branching woody plants. The novelty of the methodology lies in the formalization of representation of the offshoot system structure with the help of morphostructural formulae and a morphostructural matrix; implementation of the concepts «constructive and age-related type of an offshoot module» and «a four-year-old system of offshoot modules» (AS, PS, DA, GA); identification of a leaf-bearing offshoot of the last year of vegetation (AS) as a «reference point». This article presents results of the morphostructural description of two-year-old offshoot systems consisting of constructive and age-related modules of two types: AS (a leaf-bearing one-year-old offshoot) and PS — a previous-year offshoot on which AS appeared. Some researchers see the two-year system as the main structural unit of the offshoot system of woody plants [10]. The sample «a typical branch» was divided into offshoot modules of different constructive and age-related types. We have measured and calculated the following: length and width of the stem of each offshoot module, number of internodes, length of each internode, leaf, bud, and width of each bud. Results of the measurements and calculations were entered into special electronic forms developed with EXCEL software. With the help of this software we performed calculation of various morphostructural indices. We studied the features: Lst — stem length, Wst — stem width, W/Lst — relation of the stem length to its width; Nin — number of internodes; Nin/Lst — index of nodes concentration; W/L bud — index of buds proportion; Ll/Lst — leaf-bearing index. Statistical analysis was carried out with the use of STATISTICA 6.0 software.

Research findings and discussion. You can see the main statistical data for the seven morphostructural features of the offshoot modules AS and PS in tables 1 and 2. The variability level is marked with variation coefficient (CV, %) (table 3). The values of the variation coefficients of AS features are higher than PS features. This can be accounted for by the different structure and other differences of AS and PS modules: 1) most of AS dies after the first year of life; 2) values of the index of buds proportion (W/L bud) for PS are relevant only for inactive buds, and for AS it is relevant for all the buds including generative. The level of intra-species

variability of the studied features is often higher than average. Features Wst and W/Lbud of offshoot module AS vary less than the others. Variation coefficients for AS can be considered extremely high in relation to features Lst, Llmx/Lst, Nin/Lst, and Wst/Lst as for some species they exceed 100%. Consequently, to study regularities of variability it is necessary to employ structural approach, in particular, development of the morphostructural description of the offshoot system elements. Salix triandra reveals the highest degree of its features variability. A significantly less degree of AS features variability is demonstrated by S. phylicifolia, S. uralicola, and S. myrtilloides. The degree of PS features variability can be characterized as medium and increased. The least variability was observed for W/L bud feature and the highest for Lst feature. As for S. hastate, it can be stated that it tends to have increased variability for PS features, as for S. phylicifolia, it is closer to a decreased degree. The level of the interspecies variability is approximately the same for both PS and AS: very high for Lst; high for Wst, W/Lst, Nin/Lst, and Llmx/Lst; medium for Nin and W/L bud.

Correlation of AS and PS morphostructural features. Interspecies level. We have calculated Spearman non-parametric correlation coefficient based on 21 pairs of AS features expressed by the median value (Me). At the level above average ($r>0.75$) five pairs of features truly correlate (23.8%): Lst and Nin/Lst; Wst and W/L bud; Wst/Lst and Nin; Wst/Lst and Nin/Lst and Nin and Llmx/Lst. We have calculated Spearman non-parametric correlation coefficient based on 18 pairs of PS features expressed by the median value (Me). At the level above average ($r>0.75$) nine pairs of features truly correlate (50%): Lst and Wst; Lst and Wst/Lst; Lst and Nin; Lst and Nin/Lst; Wst and Wst/Lst; Wst and Nin; Wst and Nin/Lst; Wst/Lst and Nin; Wst/Lst and Nin/Lst. In the interspecies correlation analysis only three pairs of features correlate at a high level both for AS and PS: Lst and Nin/Lst, Wst/Lst and Nin, Wst/Lst and Nin/Lst.

Correlation of AS and PS morphostructural features. Intra-species level. We have calculated Spearman non-parametric correlation coefficient based on 21 pairs of features for all the studied AS (table 4). Salix triandra has high intra-species correlation for 14 pairs of features (67.7%); S. hastate has such correlation for 10 pairs of features (47.6%); S. lapponum for 18 (85.7%); S. myrtilloides for 12 (57.1%); S. phylicifolia – for 16 (76.2%); S. uralicola for 16 (76.2%); S. jenisseensis for 13 (61.9%); S. pyrofolia for 18 (85.7%). Thus, over 50% of the pairs of AS features demonstrate a high level of intra-species correlation. The number of the pairs of features common for all the species, which show high correlation in each species, is 6 (28.6%): Lst and Wst/Lst; Lst and Nin; Lst and Nin/Lst; Lst and Llmx/Lst; Wst/Lst and Nin/Lst; Nin and Llmx/Lst. Out of these six pairs only 3 (14.3%) coincide with the highly correlating pairs of features in the interspecies correlation analysis, i.e. pairs of features Lst and Nin/Lst, Wst/Lst and Nin/Lst; Nin and Llmx/Lst are highly correlative for all the species both on the intra- and interspecies levels.

Table 1

Basic statistical data on morphostructural features of AS offshoot modules

	SPyr	SJen	SHas	STr	SLap	SPh	SUr	SMyr
Height of species, m	2,50-3,00	2,00-2,50	0,80-1,20	0,80-1,20	0,70-1,30	0,50-1,20	0,40-0,70	0,30-0,60
Nin (min-max)	3,00-13,00	4,00-17,00	3,00-24,00	3,00-30,00	4,00-20,00	4,00-12,00	4,00-12,00	3,00-12,00
Nin, Me	7,00	8,00	8,00	11,00	9,00	8,00	8,00	8,00
Nin, CV, %	36,70	36,80	53,50	49,50	27,80	21,10	22,40	21,10
L st, cm (min-max)	0,40-17,00	0,40-25,20	0,46-40,00	0,37-80,00	0,43-24,00	0,50-8,50	0,40-8,70	0,20-8,00
Lst, cm Me	3,40	5,50	4,55	9,40	4,25	2,80	3,20	2,00
Lst CV, %	92,80	83,60	105,7	117,4	77,10	61,00	50,80	64,30
W st, cm (min-max)	0,08-0,14	0,06-0,15	0,07-0,20	0,05-4,00	0,05-0,17	0,04-0,14	0,04-0,10	0,04-13,00
Wst, cm Me	0,10	0,10	0,12	0,10	0,07	0,07	0,06	0,07
Wst, cm CV, %	10,00	18,20	25,00	60,00	37,50	28,6	28,60	28,60
Wst/Lst (min-max)	0,82-20,00	0,55-20,00	0,36-28,00	0,45-24,32	0,70-11,60	1,23-10,00	0,95-10,00	1,40-24,00
Wst/Lst Me	2,94	2,08	2,03	1,17	1,80	2,61	1,88	3,2
Wst/Lst CV, %	93,70	108,60	128,40	155,40	87,70	51,30	64,70	90,70
W/L bud (min-max)	36,90-91,00	41,30-100,00	35,00-111,0	36,00-128,00	38,00-101,00	54,20-100,00	49,40-100,00	56,00-106,00
W/L bud Me	48,50	54,50	63,50	66,00	64,50	74,10	77,50	76,00
W/L bud CV, %	23,90	22,90	29,30	31,60	26,40	17,80	15,40	15,9
Nin/Lst (min-max)	0,80-24,00	0,60-10,00	0,50-8,70	0,40-10,90	0,80-14,00	1,40-8,00	1,30-7,50	1,00-22,00
Nin/Lst Me	2,40	1,50	2,59	1,10	2,25	3,00	2,30	3,90
Nin/Lst CV, %	111,70	77,60	83,80	117,40	78,20	47,90	44,50	77,30
Llmx/Lst (min-max)	38,80-825,00	46,10-850,00	18,80-485,00	13,10-700,00	29,20-360,00	61,20-257,10	58,80-328,60	35,00-450,00
Llmx/Lst Me	194,10	138,45	112,35	71,30	104,55	74,10	126,50	77,30
Llmx/Lst CV, %	75,00	81,90	81,40	117,80	52,10	33,70	38,10	72,80
Amount of AS	42,00	80,00	64,00	77,00	76,00	39,00	55,00	81,00

Table 2

Basic statistical data on morphostructural features of PS offshoot modules

	SPyr	SJen	SHas	STr	SLap	SPhyl	SUr	SMyr
Height of species, m	2,50-3,00	2,00-2,50	0,80-1,20	0,80-1,20	0,70-1,30	0,50-1,20	0,40-0,70	0,30-0,60
Nin (min-max)	6,00-15,00	7,00-13,00	6,00-24,00	8,00-19,00	8,00-14,00	7,00-9,00	6,00-14,00	5,00-12,00
Nin Me	9,00	10,50	12,00	12,50	12,50	8,00	8,00	8,00
Nin, CV, %	27,00	15,60	44,20	27,60	13,40	7,90	25,70	20,50
L st, cm (min-max)	3,50-19,30	4,00-23,00	3,70-29,00	18,50-38,00	3,00-14,50	3,00-14,30	2,70-13,50	1,20-7,70
Lst, cm Me	10,70	12,15	13,00	25,85	5,90	4,20	5,30	2,55
Lst CV, %	49,70	37,90	64,50	26,60	65,80	62,70	52,70	52,70
W st, cm (min-max)	0,14-0,30	0,12-0,28	0,17-0,35	0,19-0,35	0,08-0,25	0,10-0,15	0,08-0,19	0,08-0,18
Wst, cm Me	0,16	0,19	0,25	0,25	0,16	0,13	0,11	0,10
Wst, cm CV, %	22,20	22,20	24,00	19,20	31,30	15,40	25,00	30,00
Wst/Lst (min-max)	0,98-4,00	0,91-3,50	0,9-5,41	0,72-1,62	1,40-3,90	1,05-4,00	1,25-3,33	2,20-9,20
Wst/Lst Me	1,96	1,53	1,82	0,89	2,40	3,33	2,15	3,75
Wst/Lst CV, %	45,40	37,10	84,10	32,70	28.80	27,80	30,00	37,80
W/L bud (min-max)	22,60-90,60	15,00-103,20	48,00-91,00	71,00-106,60	63,00-100,00	76,50-100,00	71,10-112,30	76,00-133,00
W/L bud Me	69,50	74,80	82,00	93,50	69,00	85,50	87,75	89,50
W/L bud CV, %	22,30	24,70	14,90	12,40	15,50	8,30	13,10	14,70
Nin/Lst (min-max)	0,70-1,90	0,50-1,80	0,50-1,90	0,50-0,80	0,90-3,70	1,60-2,70	1,00-2,20	1,40-5,40
Nin/Lst Me	1,00	0,95	1,00	0,65	1,85	2,00	1,55	3,30
Nin/Lst CV, %	34,20	33,00	41,00	18,50	44,30	16,00	26,70	29,50
Amount of PS	15,00	20,00	11,00	8,00	16,00	11,00	14,00	26,00

Table 3

Comparison of variation coefficients of AS and PS morphostructural features

	Nin	Lst	Wst	W/L st	W/L bud	Nin/Lst	Llmx/Lst
PS	8-44	27-66	15-31	28-84	8-25	16-44	-
AS	21-54	51-117	10-60	51-155	15-32	45-117	34-118

We have calculated Spearman non-parametric correlation coefficient based on 18 pairs of features for all the studied PS (table 5). S. jenisseensis has high correlation for three 916.7%) pairs of features; S. phylicifolia for two (11.1%); S. uralicola for 10 (55.6%); S. pyrolifolia for 6 (33.3%); S. hastata for 5 (27.8%); S. lapponum for 6 (33.3%); S. triandra for two (11.1%); S. myrtilloides for 5 (27.8%). Thus, the share of highly correlating pairs of features on the intra-species level for PS is significantly lower than for AS modules and does not exceed 30% (except S. uralicola). Only one (5.6%) pair of PS features (lst and Wst/Lst) show high correlation for each of the eight species. 7 species have the same highly correlative pair of features: Lst and Nin/Lst; five species have the same highly correlative pairs of features: Lst and Nin; Wst/Lst and Nin; Wst/Lst and Nin/Lst.

Comparison of the results of the intra- and interspecies correlation analysis demonstrates that on the interspecies level the share of the pairs with high correlation of features for AS is smaller than for PS; on the intra-species level the regularity is reverse; only one pair of features (Lst and Wst/Lst) reveals a similarly high level of correlation in all the variants of PS and AS analysis, both in intra- and interspecies comparison.

Results of the multivariate statistical analysis of AS and PS offshoot modules. There are different ways of qualitative estimation of phenotypic similarity of the objects under study. One of them is Eucledian distance which is calculated in the process of cluster analysis. The results of the cluster analysis of AS and PS offshoot modules are shown in fig. 1-4 and table 4.

Table 4

Results of the dispersion analysis of AS cluster (numerator) and PS clusters (denominator)

	Intergroup dispersion	df	**Intragroup dispersion**	df	F	p
Lst	35,4 / 388,6	3	1,60 / 6,6	4	29,5 / 79,0	0,00 / 0,00
Wst	0,2 / 1,9	3	0,13 / 0,5	4	1,9 / 0,5	0,28 / 0,07
W/Lst	2,1 / 4,8	3	0,92 / 1,5	4	3,1 / 1,5	0,15 / 0,09
Nin	9,2 / 25,2	3	0,67 / 4,5	4	18,4 / 4,5	0,01 / 0,04
Nin/Lst	4,0 / 3,6	3	1,62 / 1,6	4	3,3 / 1,6	0,14 / 0,16
W/L bud	6,1 / 5,4	3	0,63 / 0,9	4	12,9 / 0,9	0,02 / 0,04
Llmx/Lst	0,8 / -	3	0,24 / -	4	4,2 / -	0,10 / -

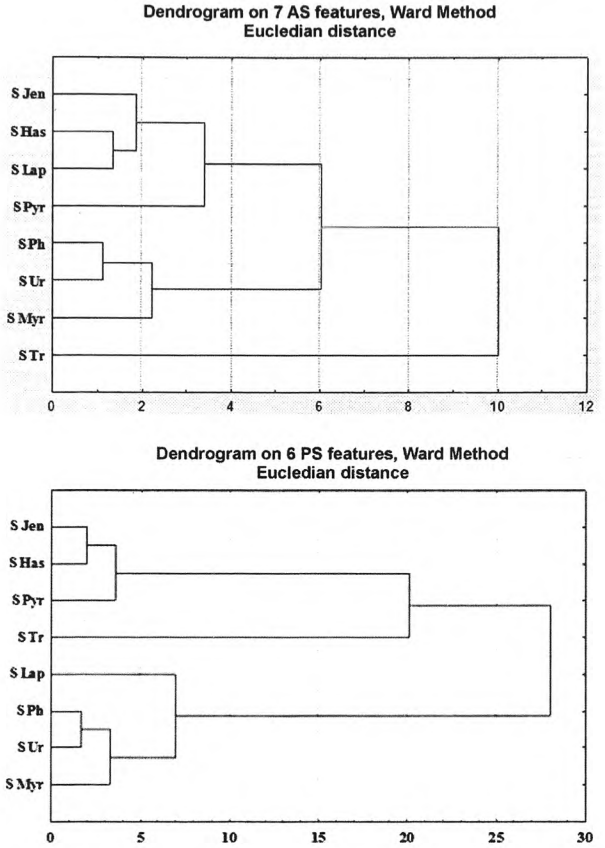

Fig. 1 Dendrograms of similarity of AS (left) and PS (right) offshoot modules

Evaluation of the species similarity based on the complex of morphostructural features with the use of cluster analysis has shown that the species group differently according to AS and PS features. Leaf-bearing AS modules fall into two big clusters one of which includes only *S. triandra*. Intra-group dispersion turns out to be bigger than intergroup one for all the features but for Lst and Nin. The species which are the closest in their morphostructure are *S. phylicifolia* and *S. uralicola*: in all the variants of clusterization they stably enter the same small cluster. In different variants of clusterization one small cluster unites species *S. jenisseensis and S. hastata*. Similarity of AS and PS, while estimation of closeness of different species, shows itself in that the established clusters on AS and PS truly differentiate for the same features: Lst, Nin, W/L bud of Salix species from the middle taiga phytocenoses of West Siberia.

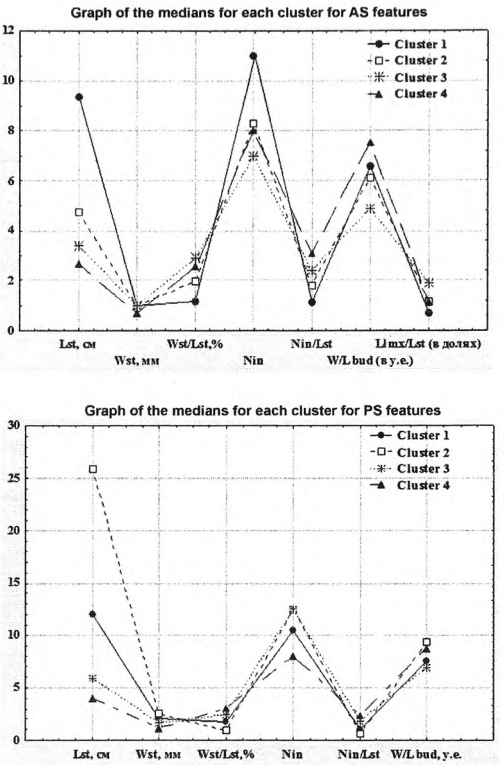

Fig. 2 Graph of the differences of AS clusters (top) and PS(bottom) on the meadian values of morphostructural features

Conclusion. Analysis of the qualitative data on the morphostructure of two-year-old offshoot systems of plants of *Salix* species from the middle taiga families of the Severo-Sos'vinskaya province of West Siberia, organized into one statistical complex, has shown that there is no uniformity in the variability and correlation of the morphostructural features of different species. We have disclosed differences in the variability and correlation of these features for the offshoot modules of different constructive and age-related types (AS, PS). Certain features display similar tendencies in the norm of distribution of the AS and PS values for the majority of the species under study. They are two AS features AS (W/L bud and Llmx/Lst) and three PS features (Nin/Lst, Wst, W/Lst). On the interspecies level the share of the pairs with a high correlation of the features for AS is smaller than for PS; on the intra-species level there is a reverse regularity. Two-year-old offshoot systems *S. phylicifolia* and *S. uralicola* on the one hand and *S. jenisseensis* and *S. hastata* are the closest in their morphostructure. The features which distinguish the two-year-old offshoot systems of different species *Salix* are Lst, Nin, and W/L bud.

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