Comparison of climate diagrams and their modifications when interpreting botanical studies

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Abstract. The article deals with present approaches to evaluating climate diagrams of Walter-Gossen and Ball-Taylor. Climate diagrams of Ball-Taylor were modified with new methodical elements (base growth temperature line and index of aridity) showing the peculiarities of territories and the ecology of species. Analysis of the growth activity of annual shoots of J. oblonga plants and morphological and anatomical characteristics of the leaves of Platanus orientalis L., Quercus robur L., Ulmus pumila L. in Makhachkala with the use of modified climate diagrams of Ball-Taylor has allowed to get a complete picture of the adaptive mechanisms of plants of these types to weather conditions.

1 Introduction

Regularities of spatial distribution of vegetable communities or separate species of plants, their development and dynamics of growth are defined by cumulative action of ecological factors from which the most significant are climatic factors. Constantly changing ratio of duration and intensity of damp and droughty, warm and cold seasons of year also forms general idea about climate [1, 2]. The most informative way of display of this ratio within a year is drawing up climate diagrams. The consecutive arrangement climate diagrams for some years allows to receive information on longer changes of climatic factors. Such graphics are called climate diagrams [1, 3].

Climagraph and climatograph visualize dynamics of weather changes for ecological interpretation of researches, concretizing and allocating extreme years as when carrying out the introduction of works, and when studying distribution of various types of vegetation, reconstruction of a paleovegetation and paleoclimate [4, 5].

There are different approaches to construction climate diagrams, each of which has the merits and demerits. The most widespread are the ombrothermal climate diagrams of Walter-Gossen [1]. At their construction use scales of average monthly temperature and an amount of precipitation in the ratio 1:2. However in one management the logic of such ratio doesn't speak. According to G. Walther, any accepted ratio of scales conditionally. From

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here exclusive subjectivity of drawing up climate diagrams and, especially, interpretations of results of researches on their basis follows.

This approach loses the presentation and at the characteristic of climatic conditions in areas with more uniform distribution of a precipitation within a year. In this case it is offered to use a ratio 1:3 [1]. At a ratio of scales of temperature and an amount of precipitation 1:2 only damp and droughty conditions are allocated, and at a ratio 1:3 the semi-droughty zone that is also unconvincing is still in addition presented also.

Little informative such climate diagrams and at an assessment of conditions of territories with the long droughty period. For such cases the xerothermic index considering casual rains with fluctuation of an indicator from 0 to 360 [2].

Climate diagrams of Walter-Gossen aren't suitable also for comparison of territories with sufficient moistening, but with various types of vegetable communities (the wood, the forest-tundra, the tundra). For their assessment it is offered to use duration of the vegetative period that is interfaced to certain difficulties [1] as criterion.

For specification initial climate diagrams a number of authors is offered by the criteria. So, Emberzhe [2] enters plyuviotermical private which is applied and at an assessment of degree of adaptability of organisms from the point of view of classification of ecological factors by A.S. Monchadsky. Thorntwaite [2] for more exact reproduction of real weather conditions of the district a number of difficult indexes with evapotranspiration calculation that is also enough labor-consuming offered and is ambiguous.

A bit different approach is applied to an assessment of weather features of this or that territory in the climate diagrams, made on Ball-Taylor's method.

Climate diagrams on Ball-Taylor are also made in rectangular system of coordinates (abscissa axis reflects an amount of precipitation, and ordinate axis – temperature), show a real course of temperature and a precipitation according to weather features and, in our opinion, allow to interpret results of researches more precisely.

What are possible extreme versions of the image of weather conditions of territories on such the climate diagrams?

The simplest option – when temperature and an amount of precipitation on months within a year have stable indicators. In this case the field climate diagrams aspires to a minimum and the more cold and land climate, the closer climate diagrams is displaced by the beginning of coordinates. At a constant average temperature within a year and considerable fluctuation of an amount of precipitation on months climate diagrams takes a form of the narrow strip directed along abscissa axis. At uniform distribution of a precipitation within a year and considerable fluctuation of temperature on months the field climate diagrams, on the contrary, is extended along ordinate axis.

The most important, in our opinion, climate diagrams on Ball-Taylor correction of a ratio of scales as in Walter-Gossen climate diagrams and more objectively reflect a ratio of temperature and a precipitation of concrete territories don't demand.

Proceeding from the arguments given above, in the real work interpretation of results of population and anatomy and morphological researches of wood plants in the conditions of Mountain Dagestan (the Gunibsky plateau) and Makhachkala with application modified climate diagrams Ball-Taylor is presented.

2 Methods

The first part of researches is carried out on the Gunibsky plateau (1700 m above sea-level), located in northwest calcareous part of Innamountain Dagestan. Climatic indicators of a plateau continental. The average annual sum of a precipitation about 700 mm also has accurate one-topmost character, with a June-July maximum (80%). Average annual air temperature is 6,7 C °C a maximum in July-August, with average maximum 12,3 C ° and average minimum 2,8 C °.

The second part of researches is carried out in the conditions of Makhachkala (50 m above sea-level). Climate here semidesertic, moderate. Summer hot, with an average temperature over 20 With, daytime maximum temperature reaches 38 With above. Winter soft, low-snow. In separate years frosts to –25 are observed With in the winter. Precipitation drops out from 250 to 450 mm a year, it is more during the autumn period. The acute shortage of a precipitation for plants growing here is observed during the summer period. Winds in Makhachkala long, with prevalence southeast (summer) and northwest (winter) (The Dagestan TsGMS Rushydromet, Akayev, etc., 1996).

Wood plants of Platanus orientalis L were objects of research. Quercus robur L. Ulmus pumila L. growing in parks of Makhachkala and Juniperus oblonga Bieb. on the Gunibsky plateau. For carrying out accounts trees of a generative age state with the same indicators of growth and development are chosen.

On the Gunibsky plateau on J. oblonga bushes for studying of growth dynamics monthly from April to October in 2007 and 2008 measured 30 year escapes.

Anatomy and morphological features of leaves of the wood plants belonging to different ecological groups (to P. orientalis, Q. robur, U. pumila), in the conditions of Makhachkala are studied during 2009-2010.

At trees of each look and by each option it is considered on ten year growth escapes and on thirty leaves. As model on escapes for studying the fourth leaf from the escape basis was defined. Collecting leaves carried out after formation on escape of a terminal kidney.

In total it is analyzed 3 morphological and 5 anatomic signs. At leaves considered length and width of a plate and length a stake. Measurements carried out with an accuracy of 1 mm. From anatomic signs on the paradermalnykh cuts of a sheet plate considered quantity of cages, strome and the trichome top and bottom epiderm (piece on 1 mm 2).

Calculation of quantitative indices of anatomic signs of a sheet plate and stake, and also indicators of structural elements of integumentary fabric of a leaf carried out in triple frequency.

Plant material fixed in 70% alcohol with glycerin addition. Temporary micropreparations prepared by the standard technique of anatomic researches. Measurement of fabrics and cages carried out on Lomo's microscope – AT 054 with the help an eyepiece micrometer.

Work was carried out to Laboratories of an introduction and genetic resources of wood plants of GORBS of DSC Russian Academy of Sciences. Statistical processing of the obtained data carried out according to (2008), S. A. Mamayev's (1973) Sh. Sh. Gasanov's recommendations, G. F. Lakina (1990) and with use of the computer Microsoft Excel and Statistica 5.5 program. Reliability of distinctions between arithmetic averages indicators was estimated by t-criterion.

3 Results

In climate diagrams of Ball-Taylor for improvement of interpretation of results of botanical researches by us it is offered to enter two elements – the line of temperature of biological zero and the line of an index the aridities reflecting features of territories and ecology of types (Asadulaev, Sadykova, 2011).

The first element – the horizontal line (Tb), is carried out at the level of temperature of biological zero corresponding to the bottom threshold of physiological and morphogenetic activity of a vegetable organism (fig. 1) [6]. This threshold is various for plants with different ecology. For cold-resistant wood types it accept equal + 5 ºC, for the majority of cultures of a moderate zone + 10 ºC, and for more thermophilic types + 15 ºC. I.e.

temperature above this threshold intensifies the morpho-physiological processes preparing plants for spring growth [7]. According to [8], [9] and to our phenological supervision for types of P. orientalis, Q. robur, U. pumila and J. oblonga temperature of biological zero makes + 5 ºC.

The second element – the vertical line (Ia) is carried out on border of change of the damp and dry periods of year. Thus across Gossen [1] dryness comes when the amount of precipitation, dropped out in a month, becomes less than the doubled average monthly temperature. According to this statement, the border of the droughty and damp periods of year on the climate diagrams is designated by the line which has been carried out perpendicular to abscissa axis through a point, where value of the doubled average temperature equally to value of an amount of precipitation in a month. The line of aridity is carried out above the line of temperature of biological zero and divides a field climate diagrams on arid and humid speak rapidly.

Thus, two lines (the line of biological zero and the aridity line) divide space climate diagrams into 3 zones. The first zone (I) – a zone of the deep and compelled rest. The second zone (II) – an optimum zone which is characterized favorable for growth and development of plants by a humidity and temperature ratio. The third zone (III) – an arid zone in which vegetative growth is slowed down or at all stops.

For plants transition of conditions to an aridity zone is critical. On the one hand, the more line extent climate diagrams in an arid zone, the more plants are subject to impact of a summer drought and are worse prepared for winter conditions. On the other hand, the earlier in the spring temperature rises to level of biological zero (at enough of a dropping-out precipitation), the it is more area of the second zone and the period favorable for growth of plants is more long.

The short description of weather conditions of the Gunibsky plateau for 2007 and 2008 on climate diagrams, presented in fig. 1 and 2 is given below.

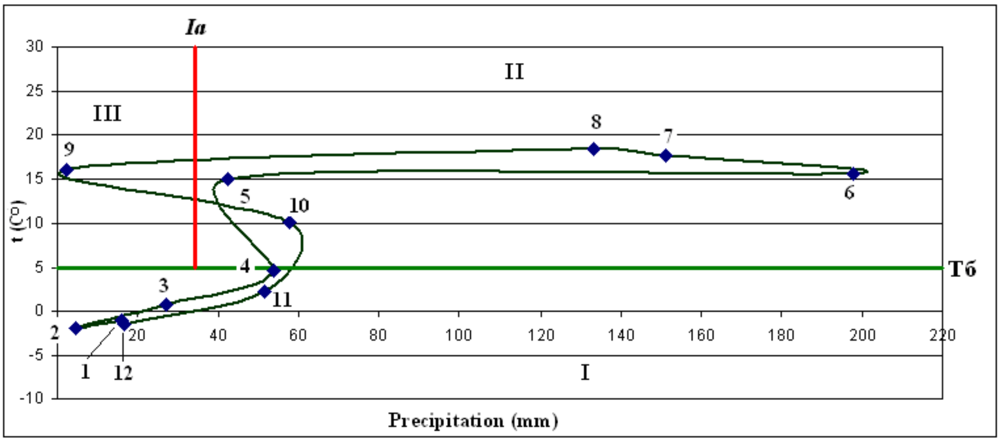

Fig. 1. Climate diagram for Gunibsky plateau, 2007.

Note: here and in Pic.2 months are indicated with Arabic numerals, ecological zones with Roman numerals: I – deep and forced rest; II – optimum; III – zone of aridity; Tб – level of base growth temperature; Ia – border of change of arid and humid conditions according to Gossen.

Average air temperature on the Gunibsky plateau didn't fall to the winter period of 2007 lower than-5,0 ºC, it isn't enough precipitation, their fluctuation in three months the insignificant. Some increase in an amount of precipitation is observed in April at air temperature at the level of 5,0 ºC that creates conditions to start growth processes at wood plants. In May average air temperature sharply increased to 15,0 ºC, but the rainfall changed slightly (line turn climate diagrams to the left side). In summer months on an amount of precipitation and air temperature developed favorable for growth and development of plants of a condition.

In September temperature remained at August level, but the amount of precipitation was sharply reduced (the line with an insignificant bias is stretched along abscissa axis) that led to formation of droughty conditions. In October air temperature decreased significantly at insignificant increase in an amount of precipitation (a descending bend of the line to the right) that promoted the best preparation of plants for winter. In November and December at gradual decrease in temperature, the rainfall (a descending bend of the line to the left) decreased also.

Climate diagram 2008 (fig. 2) shows that in January and February average temperature is higher, than in 2007, but at a smaller amount of precipitation (a steep slope of the line along ordinate axis).

The spring this year appeared warmer (in April 10ºC) and weather conditions from April to July for plants on the Gunibsky plateau developed favorable. In August the amount of precipitation sharply decreased, average air temperature increased to 19 ºC that led to establishment of arid conditions.

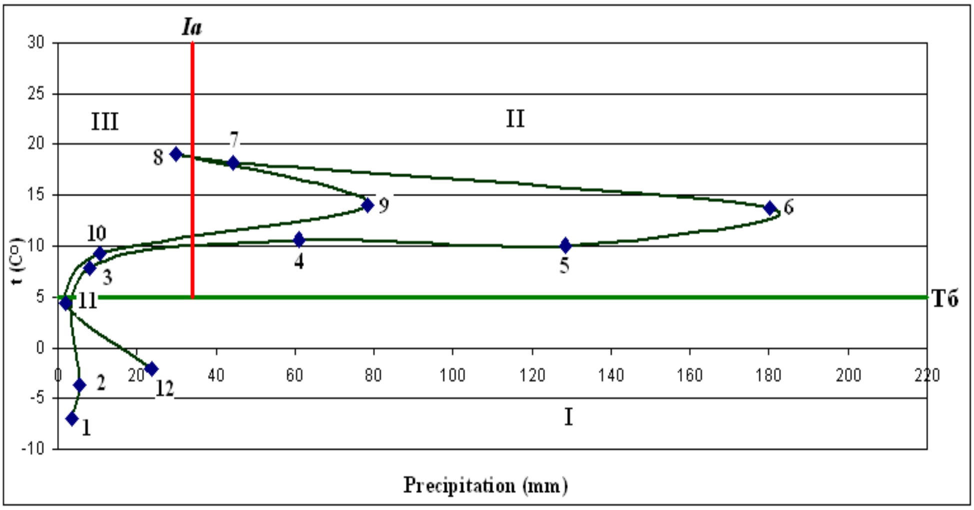

Fig. 2. Climate diagram for Gunibsky plateau, 2008.

In September a precipitation increased again, air temperature decreased a little, and the line climate diagrams returned to an optimum zone. From October to December temperature decreased smoothly without sharp differences, and the amount of precipitation decreased considerably, as well as in 2007.

On climate diagrams we used an assessment of weather conditions for interpretation of growth activity of year escapes of female and man's plants of J. oblonga on the Gunibsky plateau (fig. 3).

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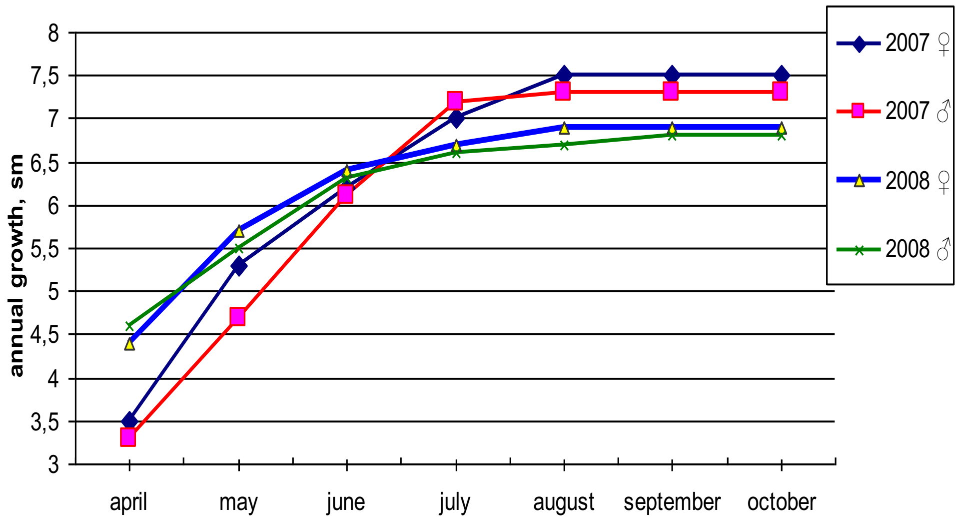

Fig. 3. Dynamics of growth shoot of male and female bushes of J. oblonga in 2007 and 2008 years (n – 30 shoots).

In 2007 length of year escapes of female and man's bushes of J.oblonga is more, than in 2008. It is explained by that during the spring period of 2007 a significant amount of a precipitation though the vegetative period and came to the end earlier (in September) dropped out. It is visible that growth of escapes of this look in the conditions of the Gunibsky plateau depends more on humidity, than on temperature. It is shown and in researches [9].

Active growth of year escapes at J.oblonga generally happens in spring months therefore moisture security during this period at a favorable temperature has crucial importance. In April, 2008 the gain of escapes of female plants made 1,3 cm, and escapes of man's plants – 0,9 cm that is much lower (72% and 64% respectively) than indicators of 2007. In May the picture significantly didn't change. In the next months growth of escapes in 2007 decreased a little, but surpassed indicators of 2008. The assessment of growth activity of escapes of J.oblonga on climate diagrams shows that in 2007 there were more favorable conditions for growth both on temperature, and on humidity. In 2008 within two spring months (April and May) temperature was up to standard 10 °C whereas in May, 2007 it reached 15 °C. That is in May, 2008 the low temperature, and weak growth of the last affected intensity of growth of escapes during the summer period of 2008. it is connected with rainfall reduction to 44,3 mm and simultaneous increase of average temperature (18,2 °C).

However growth of escapes in 2008 proceeded rather more long (on female bushes – until the end of August, and on man's – until the end of September) as at the end of summer and there were more favorable conditions (the line climate diagrams doesn't go beyond the second, optimum zone) in the fall. Growth of escapes of a juniper in 2007 stopped at the end of August that was connected with an insignificant amount of precipitation (the line climate diagram passes into an arid zone).

We see that climate diagrams features of growth of escapes of wood plants not only depending on change of weather conditions for the vegetative period, but also depending on a condition of conditions during the whole year allow to estimate Ball-Taylor. It is important as moisture security of deeper layers of earth is of great importance for growth of escapes of trees during the winter period. As a whole conditions of 2007 were more favorable for the active growth of escapes of plants of J. oblonga, than a condition of 2008 though in the first case the autumn drought and caused a premature stop of their growth. I.e. climate diagrams Ball-Taylor visualize ecological information, and makes it available at interpretation of adaptive reactions of a vegetable organism.

4 Discussion

Morphological and anatomic adaptive changes of leaves at the types relating to different ecological groups (to Platanus orientalis L. – mesophyte, Quercus robur L. – xeromesophyte, Ulmus pumila L. – xerohalophyte) by us are estimated on climate diagrams, made for conditions of Makhachkala.

First of all, the analysis of the overall picture presented on rice 4 and 5, shows that 2009 was more damp and cool though distribution of a precipitation on months was the extremely adverse. Especially droughty the spring and the first half of summer (the line climate diagrams for all this period is placed in an arid zone) were.

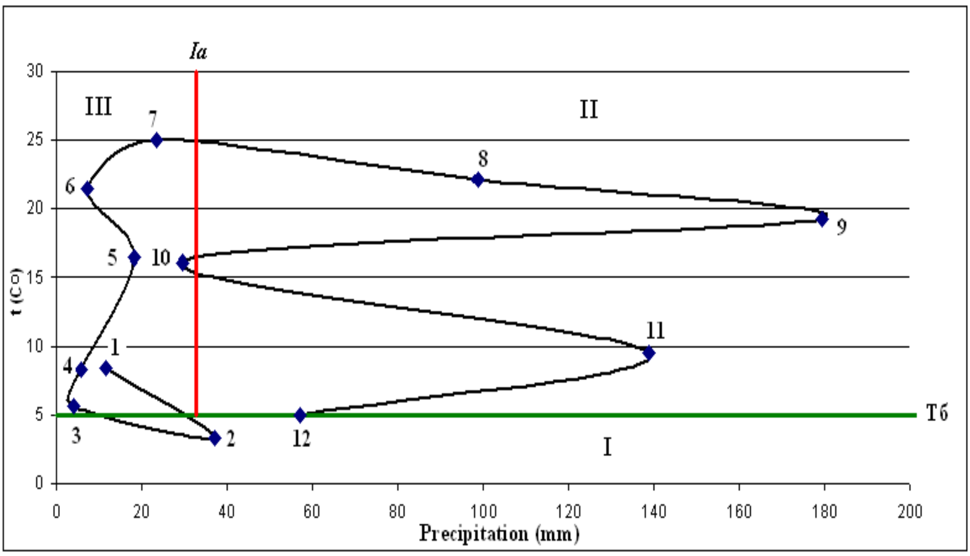

Fig. 4. Climate diagram for Makhachkala, 2009.

Change of arid conditions with the humid happened only in August, to increase an amount of precipitation in September to 179,3 mm. In October it became again dry (29,3 mm), at fluctuation to average air temperature from 19,2 to 16,4 ºC, (at most in July – 25,0 ºC). In November the amount of precipitation increased again that could promote only to the best preparation of trees for winter conditions.

Thus, the line climate diagrams for 2009 has big extent in an arid zone (from March to July and in October) and only in August, September and November occupies an optimum zone. Such picture reflects a considerable environmental pressure which was tested by wood plants at the beginning of the vegetative period, as was the reason of rather low growth activity of escapes of trees of the studied types.

The line climate diagrams, reflecting conditions of 2010 has big elongation along ordinate axis, and smaller along abscissa axis in comparison with 2009 that is connected with temperature drops and rather smaller rainfall.

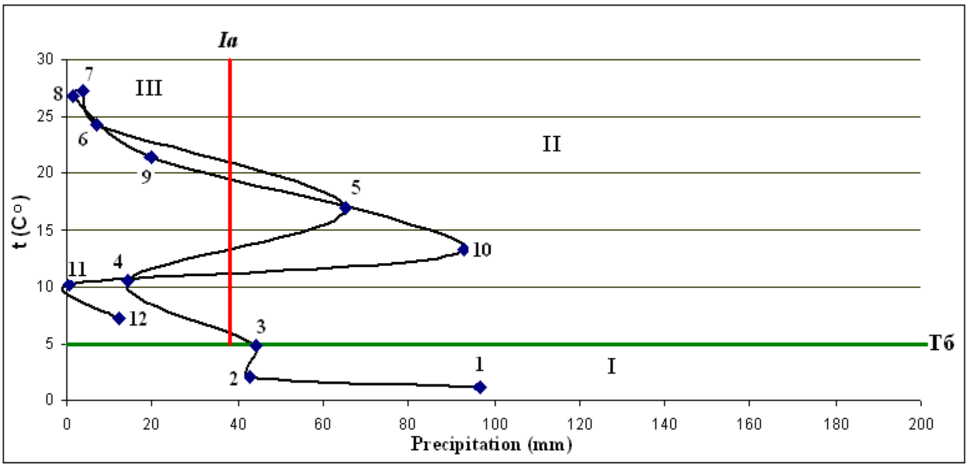

Fig. 5. Climate diagram for Makhachkala, 2010.

In 2010 especially adverse conditions for wood plants of Makhachkala developed during the summer period (the line climate diagrams from the middle of June to the middle of September is placed in an arid zone). Besides, there was few precipitation (at a low temperature) and in April that was reflected not only in the sizes, but also in structure of leaves though in May favorable weather conditions were observed. As a whole the sizes of leaves at U. pumila, showed to P. orientalis big dependence on weather conditions when passing vegetative cycles in two years, than those at Q. robur (tab. 1).

At P. orientalis for these years length of a sheet plate changed slightly while width in 2009 decreased significantly (by 4,5 cm). Such morphological reaction of leaves of this look, we connect with dryness of conditions (a low index of aridity) spring of 2009 during most their intensive growth.

Besides, on growth of spring leaves though it is process short [10], took place not only influence of the current weather situations, but also the prolonged influence of winter conditions with a low indicator of an index of aridity (fig. 4). It is known that in similar weather conditions of a plant of various ecological groups behave differently.

Table 1. Comparative analysis of morphological and anatomical structure of the leaves of P. orientalis, Q. robur, U. pumila in Makhachkala in years.

Characteristics	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
	P. orientalis		**U. pumila**		**Q. robur**	
Length of leaf, cm	14,4±0,70 15,4	15,0±0,51 10,8	6,4±0,23** 11,3	5,3±0,21** 12,8	9,8±0,66 21,5	9,5±0,31 10,2
Width of leaf, cm	13,9±1,46* 13,9	18,4±0,9* 16,9	3,4±0,08* 7,1	3,1±0,09* 9,4	5,4±0,31 18,2	4,9±0,14 8,9
Length of stem, cm	5,7±0,69* 38,4	3,9±0,41* 33,5	0,8±0,05 17,0	0,7±0,02 10,7	0,8±0,05 20,5	0,8±0,08 31,8
Number of cells u/e, pcs.	993,3±41,66** 13,3	786,6±51,01** 20,5	906,6±34,39 12,0	915,6±25,83 8,9	1444,4±68,61* 15,0	1203,8±95,12* 25,0

Number of cells l/e, pcs.	1517,7±70,88 14,8	1613,3±69,68 13,6	2753,3±53,22* 6,1	2484,4±89,40* 11,3	2317,7±39,33 5,4	2209,9±77,58 11,1
Number of stomata l/e, pcs.	176,1±12,50*** 22,5	290,5±16,08*** 17,5	293,9±16,44 17,7	254,4±13,25 16,6	448,9±26,44 18,6	471,6±23,26 15,6
Number of trichoma l/e, pcs.	37,2±9,66 63,9	17,7±3,95 70,3	57,8±7,89* 43,0	36,1±5,28* 46,0	36,7±5,28 45,3	46,6±6,33 43,0

Note: u/e – upper epidermis; l/e – lower epidermis; differences are significant under: * - P>0,95, ** - P>0,99, *** - P>0,999. In numerator – ; in denominator - CV,%.

It is thus noticed that at the xeromorphic of plants the size of a leaf changes more considerably.

At U. pumila in 2010 we connect reduction of the linear sizes of a leaf with its xeromorphic, and adaptive reaction to emergency weather conditions at the beginning of spring (an insignificant precipitation), at later and less long, in comparison with mesophytes types (P. orientalis, Q. robur), growth of leaves.

Relative dryness of conditions of spring of 2009 detained vegetation approach at mesophyte P. orientalis that led and to later formation of leaves to what their smaller sizes testify. Spring conditions of 2010 on distribution of a precipitation were more favorable that respectively led and to increase in the sizes of a sheet plate of this look. Xerohalophyte – Q. robur, being intermediate between two ecological groups, I showed the greatest resistance to fluctuation of weather conditions of year. Rather large sizes of leaves it is observed at xerohalophyte – U. pumila in droughty 2009. I.e. ecological preferences mesophytes and xerophytes considerably disperse that, first of all, is reflected in growth and development of leaves in different weather conditions. It is possible to note that formation of structural elements of leaves at wood plants has the difficult nature, dependent not only from ecological preferences, age and vitality trees, but also from the prolonged influence of conditions of the last months.

Distinction of conditions of different years made a certain impact and on an anatomic structure of leaves of P. orientalis, Q. robur, U. pumila.

For example, in 2010 quantity of cages top epiderm at P. orientalis and Q. robur leaves and the quantity of cages bottom epiderm at U. pumila authentically decreased by surface unit. Formation of leaves with more xeromorphous signs was promoted by arid conditions, first of all, during the spring period though these distinctions were reliable only for P. orientalis – a mesophytic look.

As for number the trichome, their quantity is significantly more only at U. pumila leaves in 2009 that connect as it was noted above, with stronger adaptive reaction to adverse conditions of the environment at steadier types.

Thus, in spite of the fact that as a whole 2010 droughty, the cold and dry spring of 2009 had a greater impact on morpho-anatomic features of leaves of the studied wood views of Makhachkala.

5 Conclusion

Dynamics of growth of escapes of J. oblonga on the Gunibsky plateau has high dependence on the prolonged action of autumn-winter weather conditions, than conditions of the vegetative period, and during the summer period – from an amount of precipitation, than from temperature fluctuation.

Wood plants of different ecological groups at change of weather conditions get various adaptive morpho-anatomical changes. P. orientalis (mesophyte) adapts to severe constraints of year due to reduction of width of a leaf, quantity of strom bottom epidermis, increases in quantity of cages top epidermis and strom. At Q. robur (xeromesophyte) at deterioration of weather conditions the quantity of cages top epiderm increases, at more constant values of the sizes of a leaf, and at U. pumila (xerohalophyte), at deterioration of conditions of year, indicators of morfologo-anatomic signs increase.

Application modified climate diagram Ball-Taylor in the analysis of growth activity of year escapes of plants of J. oblonga and morfologo-anatomic features of leaves of wood types of P. orientalis, Q. robur, U. pumila allowed to receive a better understanding about mechanisms of adaptation to various conditions with more profound ecological interpretation of the received results.

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