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THE FORMATION OF EMBRYONIC INFLORESCENCES AND REALIZATION OF PRODUCTIVITY POTENTIAL OF COMMERCIAL GRAPE VARIETIES IN THE TEMPERATE CONTINENTAL CLIMATE OF SOUTHERN RUSSIA

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Abstract

In the Russian Federation, the main production of grapes is concentrated in the southern regions, in unstable weather conditions of a temperate continental climate. When the weather conditions deviate from the optimal values for the grape plants, they experience stress. Embryonic inflorescences are thr most sensitive to abnormal air temperatures in winter, during forced rest of plants. After wintering, the plant loses part of the inflorescence, and the expected harvest of grapes decreases. A degree of realization of the potential of economic productivity is on the average 60 %. In these conditions, the problem of preserving embryonic inflorescences during the wintering of plants, increasing the degree of realization of the potential for economic productivity in varieties of *V. vinifera* grapes is topical in the Russian viticulture. The aim of this work is to reveal the degree of setting and preservation of embryonic inflorescences during wintering and the level of realization of the productivity potential in grape varieties of different eco-geographical origin. The work was carried out in the vineyards of the Krasnodar Territory with the use of field and laboratory methods on varieties Ekaterinodarskii in the zone of covering viticulture (CJSC Novokubanskoye) and the European-Asian species *Vitis vinifera* L. — *Convar orientalis* Negr. (eastern group), *Convar occidentalis* Negr. (Western European group), *Convar pontica* Negr. (group of the Black Sea coast), as well as interspecific and intraspecific hybrids in the zone of unguided viticulture on the ampelographic collection (the city of Anapa). Minimum air temperature is the main limiting factor which impacts on grape productivity potential under environmental conditions of the Southern Russia. The dependence of embryonic inflorescence initiation and yield formation on the winter minimum air temperatures was determined on the 72 of grape varieties of different ecogeographic origin. Intergroup hybrids of the *V. vinifera* (88 %), grape varieties of the *orientalis* group (85 %), *occidentalis* group (80 %), *pontica* group (74 %) and interspecific hybrids (60 %) showed the greatest destruction of wintering buds and the smallest preservation of embryonic harvest of technical grades when the minimum temperature reduced to critical values (–27 °C). Table grape cultivars of *occidentalis* group were the most affected by cold (83 %), the *orientalis* cultivars were less affected (80 %) followed by intergroup hybrids (78 %), interspecific hybrids (68 %), and *pontica* plants (65 %). The productivity level after wintering depended closely on the number of surviving embryonic inflorescence at the beginning of vegetation ($r = 0.77$). A total of 25 % varieties studied realized their productivity traits inefficiently (only to 50 %), 35 % of the showed 50-60 % of potential productivity, the next group of 27.5 % showed a moderate efficiency (60-70 %), and only 12.5 % of the varieties ensured high (over 70 %) of productivity potential. As a result of the survey, the varieties were selected for practical use and breeding programs with a satisfactory and high adaptability. These are Pinot Franc (60 %), Aligote (61 %), Codreanka (62 %), Pearl of the Hall (63 %), Saperavi (64 %), Chardonnay (64 %), Kunlean (64 %), Bianca (65 %), Kutuzovsky (66 %), Cardinal (68 %), Sauvignon (68 %), Firstborn Magarach (69 %), Riesling (74 %), Alan (74 %), Traminer (75 %), Krasnostop Anap (83 %), and Citron Magarach (86 %).

Keywords: grapes, environment, adaptivity, embryonic inflorescences, growth, wintering, productivity

Grape fruiting is preceded by the period consisting of the successive

stages in the small (annual) cycle of the plant ontogenesis. The main stages are setting and differentiation of embryonic inflorescences in the buds of wintering eyes in the year before fruiting; differentiation and wintering of embryonic inflorescences; predifferentiation of embryonic inflorescences in the buds (eyes) after wintering; growth of inflorescences and flowering; growth and ripening. Every stage has its specific functions, the realization of which subsequently determines the economic productivity of grape [1].

It was found that setting and differentiation of embryonic inflorescences, as well as crop formation stages, are variable and depends on the biological peculiarities of cultivars, the environmental conditions of plants habitation, and the anthropogenic factors. In the environmental conditions of the Crimea, the Cardinal, Moldova, and Italiya varieties have setting of first generative sprouts before flowering, with the second one after flowering [2]. Differentiation of inflorescences continues during the rest period at positive air temperatures [3, 4]. The biggest and most developed embryonic inflorescences are located in the eyes of the middle part of the shoot [5-7]. The formation of the embryonic fertility in the wintering buds is closely related to the origin of grape varieties [8-11]. The phytosanitary condition of plants has a significant impact on the embryonic fertility. Even middle development of anthracnose and oidium means that shoots fertility is significantly reduced [8]. Abiotic environmental factors significantly affect the productivity of grapes at all stages of setting and harvest formation [12, 13].

The main production of grape in the Russian Federation is concentrated in the southern regions, in the conditions of a temperate continental climate. Unlike in Europe, the vineyards are affected by weather anomalies here. The greatest damage to viticulture is caused by minimum temperatures during the period of induced dormancy. If the weather conditions deviate from the optimal once every five years, the plants experience stress, the damages of reproductive organs are observed, the growth processes and the stability of fruiting are disturbed, energy is spent on their recovery. The degree of realization of the economic productivity potential of is 60% on average [14]. The main reason for poor fruiting is the low adaptability of most of the varieties used in unstable weather conditions [15], the damage of the main and additional buds by frost [16, 17]. If during the rest period, the damage of the generative organs and the decrease in productivity because of the minimum air temperatures are often observed, then, during the vegetation, a similar reaction of grape plants to high-temperature and water stresses occurs [18].

To increase the grape productivity, the awakening of buds is activated by special techniques [19, 20]. Another approaches are agrotechnical regulations, including the load with wintering eyes [21, 22], ring-barking to realize the potential productivity of buds [23], and breeding for stress-resistant varieties [24, 25]. The fruitfulness of the buds, depending on soil composition in the vineyards [26], and the influence of the plantations age on the productivity of grapes are also accounted [27].

The study of embryonic inflorescences setting and their wintering safety in terms of grape plant productivity potential is still fragmented. This paper is the first report about death rate of shoot buds and stability of grape varieties of different eco-geographical origin during wintering as influenced by extremal minimum air temperatures in a temperate continental climate of the south of Russia.

The aim of the research is to determine the dependence of the setting, the preservation of embryonic inflorescences and the degree of the potential realization of economic productivity among the grape varieties of *V. vinifera* on

minimum air temperatures in the period of forced dormancy of plants in the sever climate conditions.

Techniques. In the study we used grape variety Ekaterinodarskii (ZAO Novokubanskoe, Krasnodar Krai) and plants of European-Asian species *Vitis vinifera* L. from the Russian ampelographic collection (the city of Anapa, Krasnodar Krai) of different eco-geographical origin, i.e. *Convar orientalis* Negr. (Eastern group), *Convar occidentalis* Negr. (Western European group), *Convar pontica* Negr. (Black Sea coast group), as well as interspecies and intraspecies hybrids. Plantings of 1997 were grafted and fruiting. Observations were carried out in 1997-2012, including 2006, 2010, and 2012 with the abnormal minimum air temperatures in winter. Common field and laboratory tests were used [28].

Embryonic fertility was determined using stereoscopic microscopy (MBS-10, Opticheskie pribory, St. Petersburg, Russia) during deep (physiological) dormancy by viewing the central buds of wintering eyes on typical shootsvselected diagonally from the site of every variety [2]. The character and degree of buds damage by low temperatures during wintering were assessed visually on the longitudinal section of wintering eyes. Healthy buds had a bright green color on the section; the dead ones were dark brown or black.

The development of shoots was determined by direct calculation during active regrowth period (in May). To assess the productivity (yield) of grape bushes, grape clusters at ripening (in September) were cut, counted and weighed. The degree of realization of productivity potential was calculated as the ratio of the average to the maximum possible yield under favorable conditions.

The correlation analysis of parameters characterizing viability of wintered buds and development of shoots and grape clusters was carried out, regression equations were calculated.

Results. The investigation was carried out in the places of the greatest concentration of commercial grape plantations in the agroecological conditions of the South of Russia. In the years of setting and subsequent differentiation of inflorescences, weather conditions, in general, except for abnormal phenomena, were favorable for physiological, biochemical, and growth processes, as well as the formation of the grape harvest.

The optimum temperature for the beginning of blooming, formation, and differentiation of embryonic inflorescences is 25-30 °C, the sum of active temperatures is 380 °C. In case of a drop in the temperature to 15-16 °C [30], blooming is slowing down, the growth of the pollen tube stops. In Krasnodar Krai, blooming takes place most often in the first decade of June. In this and subsequent periods, the temperature conditions do not exceed the optimal values. Over the last 37 years, the average daily temperature in early June in the Black Sea open-earth grape growing area in Anapa was 19.1 °C on average, in the central cover-earth area (ZAO Novokubanskoe) was 19.3 °C. The maximum temperature during this period in Anapa went up to 32.0 °C, in ZAO Novokubanskoe to 34 °C, the minimal temperature fell respectively to 8.0 and 2.0 °C. In the period of inflorescence differentiation from the second decade of June and until the physiological dormancy (in September), the temperature in Anapa was 21.8 °C on average, in ZAO Novokubanskoe 21.2 °C. In these conditions, embryonic inflorescences of the Aligote variety were set for 89% of eyes at average, with 92% for Moldova, 94% for Ekaterinodarskii and 97% for Podarok Magaracha.

The viability of embryonic inflorescences of wintering buds is the important for the full realization of the economic productivity of grapes. Abnormal minimum air temperatures during wintering has the strongest impact on embry-

onic inflorescences and productivity of grape varieties in the coming period of plant vegetation. After wintering, as a rule, the plant loses some of the inflorescences, and the expected harvest of grape is reduced.

The assessment of the state of eyes after wintering showed a close dependence of the preservation of grape reproductive organs on the temperature regime ($r = 0.8$). With the gradual decrease in temperature, the percent of the dead eyes increased. According to the information from the curve trend line, the frost-resistant variety Ekaterinodarskii had the critical destruction of the eyes (50%) in winter at temperatures –23... –24 °C (Fig. 1).

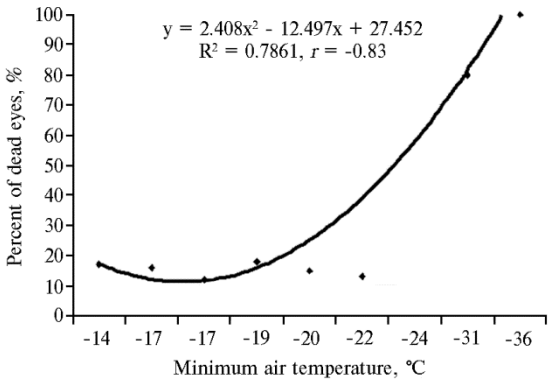

Fig. 1. The percent of dead buds in grape (European-Amur hybrid of *V. vinifera* × *V. amurensis*) Ekaterinodarskii variety in relation to the minimum temperature (ZAO Novokubanskoe, Krasnodar Krai, 2004-2012).

The decrease in air temperature to critical values in January 2006 (the city of Anapa) gave the opportunity to trace the effect of stressful wintering conditions on the safety of the eyes on grape fruit shoots in a large number of varieties. In case of the decrease in the temperature up to –27 °C, numerous damages of eyes in the group of technical varieties have been detected. The greatest death had the intergroup hybrids of *V. vinifera* (88%), then followed *Convar orientalis* Negr. (85%), *Convar occidentalis* Negr. (80%), *Convar pontica* Negr. (74%), and intraspecific hybrids (60%). In the group of table varieties, the Western European ones (83%) were the most affected, the Eastern and Eastern Mediterranean ones (80%), intergroup hybrids (78%), interspecific hybrids (68%) were less affected, and the varieties of the Black Sea basin group were the least damaged (65%).

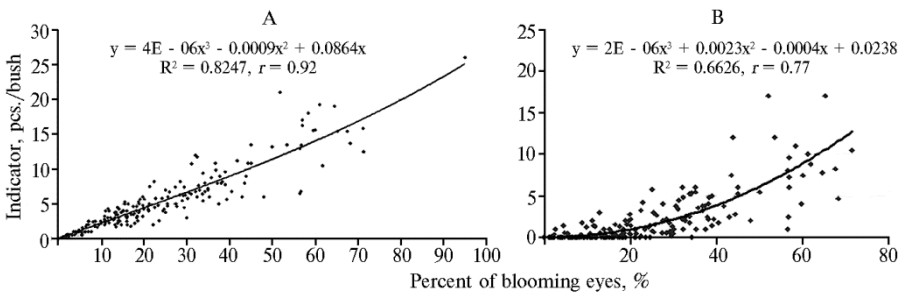

Fig. 2. The number of green shoots (A) **and formed clusters** (B) **in relation to the resistance of grape (*Vitis vinifera* L.) varieties to frost (–27 °C)** (the ampelographic collection, Krasnodar Krai, the city of Anapa, 2006).

The low-temperature stress and the death of embryonic inflorescences affected the development of shoots and the productivity of grape bushes. Varieties with high adaptability had more developed green shoots and formed full clusters of grapes. The dependence of the regrowth of green shoots on the adaptability of varieties (in the proportion of surviving eyes) was high, $r = 0.92$ (Fig. 2). Similarly, the increase in grape productivity with the increase in the adaptability of varieties was observed. With the increase in the resistance of varieties to frost, the number of clusters on the bushes is increased as well, $r = 0.77$ (see Fig. 2).

1. Resistance of grape (*Vitis vinifera* L.) varieties to frost (–20 °C) in relation to their origin (the ampelographic collection, Krasnodar Krai, Anapa, 2010)

Origin	Percent of blooming eyes										Total	
	0-20		21-40		41-60		61-80		81-100			
	The number of varieties											
	pcs	%	pcs	%	pcs	%	pcs	%	pcs	%	pcs	%
Interspecies hybrids	0	0	4	5	12	15	33	40	33	40	82	100
Intraspecific hybrids	0	0	10	10	17	17	40	40	34	33	101	100
Convar occidentalis Negr.	0	0	0	0	0	0	2	50	2	50	4	100
Convar orientalis Negr.	1	3	1	3	6	16	19	51	10	27	37	100
Convar pontica Negr.	0	0	3	15	0	0	11	55	6	30	20	100
Unknown origin	0	0	4	8	10	20	20	39	17	33	51	100
Total	1	0,3	22	7,5	45	15	125	42	102	35	295	100

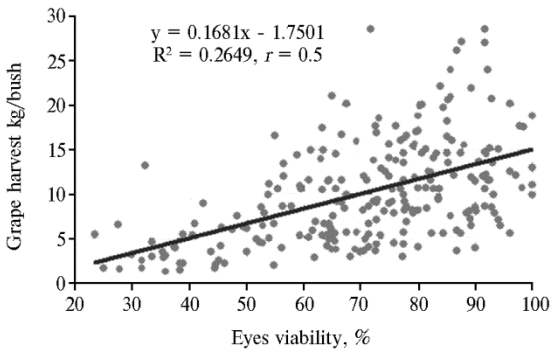

Fig. 3. The dependence of the grape yield (*Vitis vinifera* L.) on buds safety after wintering (–17 °C) (the ampelographic collection, Krasnodar Krai, the city of Anapa, 2010).

In 2010, at the decrease in the temperature up to –20 °C, the identified patterns were preserved, in general. Among interspecies hybrids, the death of eyes was insignificant (Table 1). The greatest damage was noted among the varieties of the Eastern ecological and geographical group.

The degree of the realization of potential productivity after wintering is in close dependence on the number of survived embryonic inflorescences to the beginning of vegetation. The correlation coefficient in the group of table varieties (240 pcs.) after stressful wintering in 2010 (–17 °C) showed a high dependence of the grape productivity on the safety of the eyes and was 0.513 (Fig. 3).

2. Realization of potential productivity (%) among grape (*Vitis vinifera* L.) varieties in the agro-ecological conditions of the Krasnodar Krai (the ampelographic collection, the city of Anapa, 1997-2006)

Variety	Indicator	Variety	Indicator
Biruintsa	36	Podarok Magaracha	58
Lyana	38	Pino Blanc	59
Dekabrskii	45	Viorika	59
Muscat Ottonel	46	Pino Franc	60
Rannii Magaracha	46	Aligote	61
Karaburnu	46	Codreanka	62
Strashenskii	46	Zhemchug Zala	63
Sukholimanskii	48	Saperavi	64
Vostorg	48	Chardonnay	64
Muscat Amber	48	Kunlean	64
Muscat Bessarabian	51	Bianca	65
Muller Thurgau	51	Kutuzovskii	66
Shasla	53	Cardinal	68
Italiya	54	Sauvignon	68
Tsimlyanskii chernii	55	Pervenets Magaracha	69
Krasnostop	56	Riesling	74
Kaberne	56	Alan	74
Moldova	58	Traminer	75
Rkatsiteli	58	Krasnostop Anapskii	83
Avgustin	58	Tsitronnyi Magaracha	86

The degree of realization of potential productivity varied greatly among the most popular varieties (36-86%). From their total number, 25% realized the potential of economic productivity ineffectively, up to 50%, 35% had 50-60%,

the next group of varieties (27.5%) was characterized by moderate productivity, 60-70%, and only 12.5% of varieties had a high rate, more than 70% (Table 2).

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Thus, the natural soil-climatic conditions of the South of Russia are in general favorable for the formation of a good harvest in all periods of the small (annual) cycle of the grape ontogenesis. However, the periods of deep (physiologic) and induced dormancy are the exceptions. The embryonic inflorescences formed in the buds of the wintering eyes at this time are subjected to the destructive effect of minimal air temperatures. When the temperature drops to the critical values –27 °C, the greatest destruction of the wintering eyes and the lowest preservation of embryonic inflorescences among technical varieties are among the intergroup hybrids of *V. vinifera* (88%), and among table varieties in those of *occidentalis* group (83%). The productivity of varieties after wintering is in close dependence ($r = 0.77$) on the number of survived embryonic inflorescences to the beginning of vegetation. Preservation of embryonic inflorescences during wintering, exploitation of grape varieties highly adaptive to unstable weather and climatic conditions should be recommended to increase the sustainability and productivity of the ampelocenosis in the moderate continental conditions of the South of Russia.

REFERENCES

1. Shevtsov A.N., Popov V.I., Tolokov N.R., Aliev A.M., Arestova N.O., Mashinskaya L.P., Doroshenko N.P., Malyh G.P., Guseynov Sh.N., Muzychenko B.A., Petrov V.S., Radzhabov A.K., Kirichenko A.V., Agapova S.I., Kostrikin I.A., S'yan I.N., Hiabahov T.S. *Vinogradarstvo s osnovami vinodeliya* [Viticulture with the basics of winemaking]. Rostov-na-Donu, 2003 (in Russ.).
2. Dikan' A.P. *Osobennosti plodonosheniya vinograda i ispol'zovanie ikh v Krymu* [Features of fruiting of grapes and their use in Crimea]. Simferopol, 2005 (in Russ.).
3. Matuzok N.V., Kuz'mina T.I., *Romanenko A.A. Politematicheskiy setevoy elektronnyy nauchnyy zhurnal Kubanskogo gosudarstvennogo agrarnogo universiteta*, 2013, 92: 671-681 (in Russ.).
4. Matuzok N.V., Radchevskiy P.P., Kuz'mina T.I., Troshin L.P., Zamanidi P.K. *Politematicheskiy setevoy elektronnyy nauchnyy zhurnal Kubanskogo gosudarstvennogo agrarnogo universiteta*, 2014, 97: 747-761 (in Russ.).
5. Dikan' O.P., Bondarenko A.O., Zamors'kiy V.V., Palekha O.G. *Vinogradarstvo* [Viticulture]. Simferopol, 2002 (in Russ.).
6. Beybulatov M.R. *Nauchnye osnovy upravleniya rostom, razvitiem i produktivnost'yu vinogradgogo rasteniya agrotekhnicheskimi priemami. Avtoref. dokt. dis.* [Scientific bases of management of growth, development and productivity of a grape plant by agrotechnical methods. PhD Thesis]. Mahachkala, 2014 (in Russ.).
7. López-Miranda S., Yuste J., Lissarrague J.R. Effects of bearing unit, spur or cane, on yield components and bud productivity. *Vitis*, 2004, 43(1): 47-48.
8. Matuzok N.V., Kuz'mina T.I. *Politematicheskiy setevoy elektronnyy nauchnyy zhurnal Kubanskogo gosudarstvennogo agrarnogo universiteta*, 2013, 88: 28 (in Russ.).
9. Pavlyukova T.P., Talash A.I., Evdokimova E.A. *Vinodelie i vinogradarstvo*, 2007, 4: 44-46 (in Russ.).
10. Lisek J. Odpornosc pacow trzydziestu odmian winorosli (*Vitis* sp.) na uszkodzenia mrozowe w warunkach centralnej Polski. *Zasoby genowe roslin w ochronie roznorodnosci biologicznej. V. 2.* Warszawa, 2004: 405-410.
11. Gu S., Ding P., Howard S. Effect of temperature and exposure time on cold hardiness of primary buds during the dormant season in Concord, Norton, Vignoles and St. Vincent grapevines. *J. Hortic. Sci. Biotechnol.*, 2002, 77(5): 635-639.
12. Angelov L., Kirkova Y., Stoimenov G. Impact of climate and irrigation regime on the quantity of yield from grapes. *Nauch. Tr. Agraren univ., Plovdiv,* 2010, 55(1): 327-332.
13. Potjanapimon C., Fukuda F., Kubota N. et al. Effect of temperature on pione grapevine budbreaking at different stages of dormancy. *Sci. Rep. of the Fac. of Agriculture, Okayama Univ.*,

2010, 99: 35-42.
14. Egorov E.A., Petrov V.S., Pankin M.I. *Vinodelie i vinogradarstvo*, 2007, 3: 7 (in Russ.).
15. Egorov E.A., Serpuhovitina K.A., Petrov V.S., Pankin M.I., Guguchkina T.I., Pavlyukova T.P., Talash A.I., Ulitin V.O., Nud'ga T.A., Vorob'eva T.N., Hvostova I.V., Hudaverdov E.N., Il'yashenko O.M., Kovalenko A.G. *Adaptivnyy potentsial vinograda v usloviyah stressovyh temperatur zimnego perioda* [Adaptive potential of grapes in conditions of stress temperatures of the winter period]. Krasnodar, 2006: 33-35 (in Russ.).
16. Krumov S. Degree of injury on the vain and additional buds of vine cultivars caused by the winter frosts in 2005. *Cel'skostop. Nauka*, 2006, 39(4): 49-53.
17. Dobreva S., Slavtcheva T., Donchev A. Vine resistance to low winter temperatures and its relation to the main agrobiological and physiological characteristics. Pt 3. Resistance and recovery from frost damages. *Bulg. J. Agr. Sc.*, 2006, 12(3): 393-404.
18. Palliotti A., Petoumenou D., Vignaroli S. et al. Reazioni delle varieta di vite agli stress climatici estivi. *Inform. Agr.*, 2008, 21: 41-50.
19. Potjanapimon C., Fujioka N., Fukuda F., Kubota N. Physiological aspects of bud associated with breaking dormancy in grapevines. *Sci. Rep. of the Fac. of Agriculture, Okayama Univ.*, 2008, 97: 41-47.
20. Botelho R.V., Pires E.J.P., Terra M.M. Efeitos de surfactantes e da cianamida hidrogenada na brotacao de gemas de videiras cv Niagara Rosada. *Rev. Ceres.*, 2004, 51(295): 325-332.
21. Dinchev I., Ivanov A. *Lozarstvo i vinarstvo*, 2006, 1: 14-18 (in Bulg.).
22. Pandeliev S., Angelov L. Study on the yield and quality of the grape cv. Tempranillo depending on loading with winter buds. *Bulg. J. Agr. Sc.*, 2005, 11(3): 289-301.
23. Braikov D., Roytchev V., Botjansky P. Influence of girdling on the potential bud fertility and technological characteristics of grape in the table cultivar Armira. *Rasten. Nauki*, 2007, 44(3): 276-283.
24. Dobreva S., Slavcheva T., Donchev A. *Lozarstvo i vinarstvo*, 2007, 2: 13-19 (in Bulg.).
25. Slavcheva T. *Lozarstvo i vinarstvo*, 2008, 2: 11-19 (in Bulg.).
26. Hronsky S., Pinter E. The influence of different soil treatments on maturation of one-year old wood and fertility coefficient of Muller Thurgau grapevine cultivar. *Acta Hortic. Regiottcturae*, 2006, 9(1): 25-28.
27. Zuffereey V., Maigre D. Age de la vigne. Pt 2. Influence sur la qualité des raisins et des vins. *Rev. Suisse Vitic. Arboric. Hortic.*, 2008, 40(4): 241-245.
28. *Metodicheskoe i analiticheskoe obespechenie organizatsii i provedeniya issledovaniy po tekhnologii proizvodstva vinograda /Pod red. K.A. Serpukhovitinoi* [Methodical and analytical support for the organization and conduct of research on the technology of grapes production. K.A. Serpukhovitina (ed.)]. Krasnodar, 2010 (in Russ.).
29. Petrov V.S., Pavlyukova T.P., Talash A.I. *Nauchnye osnovy ustoychivogo vyrashchivaniya vinograda v anomal'nyh pogodnyh usloviyah: Monografiya /Pod. red. V.S. Petrova* [Scientific foundations of sustainable grapes cultivation in abnormal weather conditions: Monograph. V.S. Petrov (ed.)]. Krasnodar, 2014 (in Russ.).