Estimation of an adaptation potential of vine and methods of its increase in Kazakhstan

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Abstract: The analysis of vine buds deaths as a main biological factor of wintering of the culture and agricultural and meteorological conditions in autumn and spring period in main wine-growing zones of Kazakhstan have been conducted. The features of agricultural and meteorological conditions have been discovered in that period. The results of the study of productivity and a condition of wine-growing plantations after an implementation of top-dressings are presented. In case of an influence of micro and macro elements on plants, a general pattern of a productiveness increase due to an intensive work of an assimilation mechanism was noted. Higher content of macro elements had led to an increase of an embryonic fertility of studied varieties.
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Introduction

Wine-growing zones of Kazakhstan are situated in southern and south-eastern parts of country, where vine requires winter covering. In case of a culture, requiring covering on plantations, where vine plants are seriously damaged by spotty necrosis and a frost damage leading to a significant decrease of a harvest which happens not more often than three four times in ten years, it is practical to start growing cultures requiring half-covering. Vine covered in winter with a soil loses its endurance and decreases frost resistance.

A solution to a problem of a vine culture covering methods selection requires in a case of each separate plantation a thorough consideration of micro climate conditions of a territory. An influence of a relief on a distribution of minimal air temperature is so high that in regions where it is possible not to cover vineyards, a very dangerous, in negative temperatures context, places can be found, which requires a protection of vine, and in a case of zones of cultures, requiring covering, places with a good discharge of cold air, which allows not to cover especially frost resistant varieties in winter, can be found.

In winter month vine buds on well-ripen shoots of frost resistant varieties can sustain without a visible damage negative temperatures from -15^{0}C to -18^{0}C. As a result, an implementation of high hilling of vine with a soil bank is becoming worth of considering. The most effective measure, in a rootage damage prevention is covering of vines with cane mats [1,2]. During a study of vine frost resistance an attention was concentrated on an accumulation and a conversion of carbohydrates. A depth and a speed of starch conversion in sugars of various types in varieties with different frost resistance is different and it depends on changes of temperature. Even first insignificant negative temperatures (about -3-5^0) lead to a drastic shift in a direction of starch hydrolysis in shoots of frost resistant varieties and after a certain time of not frost resistant ones. In frost resistant varieties the major part of starch converses in sugar. It is known, that sugars significantly increase a resistance of a plant tissue to negative temperatures. A protective mechanism is based on a fact that they decrease eutectic point of cellular fluid [3]. Despite of a certain positive results in a field of vine frost resistance studies, the topic isn't sufficiently disclosed and requires further investigations.

First of all, it concerns a determination of a character of a relationship between level of a mineral nutrition and a level of resistance of vine varieties to stress-factors of abiotic nature for a justified preservation and an increase of plants productivity.

Numerous studies and an available information about an effect of microelements on vine doesn't settle the problem, especially, in a case of an annual expansion of a choice of fertilizers which contain and have a different ratio of known and new elements and forms of accessibility to plants.

Nowadays, in contrast to a completely examined influence of negative temperatures in winter period on vine, there are very few studies about an influence of relief shapes and methods of covering of vine on a distribution of minimal air temperatures in main wine-growing zones of Kazakhstan. A search and an implementation of low-cost and effective agrochemical methods and their implementation in technical requirements of an industry branch will provide a stable production of grapes and, consequently, an improvement of economic condition of the industry. In this connection, the aim of the presented study is an establishment of mechanisms and a development of agricultural engineering methods of an increase of an ampelocenose adaptability and grapes quality basing on an assessment of thermal regime in wintering period and a stable optimization of a mineral nutrition of plants using new groups of complex fertilizers implemented as a schematic top-dressings.

Program and investigation methods

The research was conducted from 2011 to 2013 on plantations of "Caspian food" ltd. of Saryshagan district of South Kazakhstan region and "Diana" farming company of Uigur district of Almaty region. Soils of both places were typical serozem with a typical fertility level. In context of heat supply characteristics, in the south sum of active temperatures reaches roughly 4500^{0}C and in the south-east it is about 3500^{0}C. A technology of vineyards cultivation is conventional for a south and a south-eastern part of an industrial wine-growing of Republic of Kazakhstan, which implies vine covering in winter.

The object of study were varities of vine of various ecological and geographical groups of western Europe origin (Cabernet Franc), Black Sea cost (Saperavi) and eastern group (pink Taifi).

Temperature conditions at vineyards were tested using minimal alcohol thermometers, installed under coverings in banks of soil at the height of 1.5 m, also, temperature of air on the ground level with snow and without snow was tested. A snow mantle height was tested by a ruler. Main methods of a frost resistance testing which are used in practice are related with a visual registration of damaging factor consequences. On the tested plants a degree and a character of buds, one year old shoots and long-term parts damage were determined by conventional methods of wine-growing industry. A number of buds which were left after cutting was taken into account; a number of developed shoots, including fruitful and fruitless; a number of inflorescences and bunches on shoots and vines. A harvest value was calculated. Results of vine harvests calculations were mathematically processed by dispersion analysis method [4].

In our experiments a study of new fertilizers series, Rosasol (Belgium) and Green (Italy), was conducted. The experiment was conducted on each sort with three tries 10 vines each. Annually on an every experimental zone a fivefold fertilization of plants in a various phases of development was conducted.

The experimental setup for Rosasol fertilizer includes following options: 1) A rupture of a bud – 2-3 leaves – ROSASOL P (3kg/hectare); 2) 4-5 leaves – shoots growth to 30-40 cm – ROSASOL EVEN (3 kg/hectare) + Magnum (2 l/hectare) + Rosabor (3 l/hectare); 3) Beginning of blossoming – ROSASOL EVEN (3 kg/hectare); 4-5) Ripening of grapes (with 15-20 days interval) – ROSASOL-K (3 kg/hectare).

The experimental setup for Green fertilizers: 1) A rupture of a bud – 2-3 leaves – BOROGREEN L (3 l/hectare); 2) 4-5 leaves – shoots growth to 30-40 cm – CALCIO GREEN 34 (3 l/hectare); 3) Beginning of blossoming – DREEN (3 l/gectare) + CALCIO GREEN 34 (3 l/hectare); 4-5) Ripening of grapes (with 15-20 interval) – KING LIFE (3 l/hectare).

During the experiments sampling of vegetative organs was conducted with a consequent determination of physiological and biochemical properties:

- Chlorophyll content was evaluated by a spectral method on SF-46 [5];
- Sugars and starch content was evaluated by calorimetric method on FEK-M [6];
- In addition to generally accepted values, shoots thickness, a length of interstices and an anatomical structure of shoots were measured. For an anatomical structure of shoots measurements samples were taken in September. Transverse slices at basis, middle and top were cut using razor. The most successful of them were placed on an eyepiece micrometer equipped microscope MBP-1 object plate where a thickness of a bark part and a core part was measured [7].

Results and discussion

Metrological conditions in the years of study were almost the same as of many years. Plants preparation and wintering in the years of study was in conditions close to an average yearly standard temperature. Autumn was mild, long-lasting, dry in a first half of period and, in general, favorable for vine ripening. Vine was well-prepared for winter, embryonic inflorescences were formed and it was noted that shoots were ripened to a full value.

In November – December 2011 an average monthly air temperature in studied regions was lower than an average yearly standard temperature. The maximum difference in a case of "Diana" farming company was in December and reached -5.6^{0}C with an average yearly standard temperature of -4.9^{0}C. The similar factor of an average yearly standard temperature in a case of "Caspian food" ltd. in January of 2012 was -3.3^{0}C with an average yearly standard temperature of 2.3^{0}C. It was related with a rapid decrease of air temperature in the end of January. Negative temperature in a short time decreased to – 24^{0}C in the end of January. In December of 2012 an average monthly temperature in a case of "Caspian food" ltd. was 2-2.5^{0}C higher than an average yearly standard temperature and was equal to 4.5^{0}C. In January of 2013 in a case of “Diana” farming company temperature was, in a whole, close to a standard and was equal to -7.2…-8,3^{0}C. Only in a period from 25 to 27 January a negative temperature stress was registered. Negative temperature in a short period of time decreased to -20^{0}C. Winter was short, but with frosts, mostly without thaw periods, with a stable snow mantle of 5 to 15 cm height, sometimes to 30 cm in a case of “Diana” farming company, in a case of “Caspian food” ltd. a height of snow mantle wasn’t so big and it was unstable. As it is known, the biggest difference of air temperatures is in fine and still weather, the smallest – in gloomy and windy weather.

According to conducted observations, the highest air temperature gradients values in fine weather where registered at the heights up to 150 cm, at the same time, the coldest layer of air is detected on the height of 2 cm. Lower you can see average difference in temperature in different zones (fig.1). Data analysis shows, that at 150 cm height from a soil it is warmer than on 2 cm height on 1.7^{0}C.

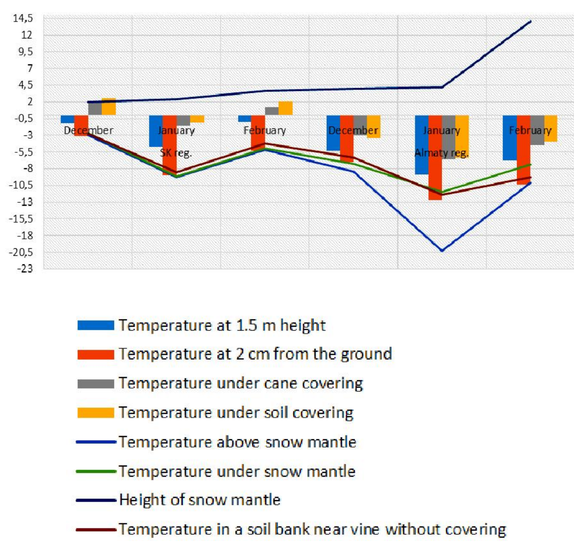

Fig.1. An average monthly air temperature at vineyards in wintering period of 2011-2013

It is worth mentioning, that in especially cold days big variations from average differences in minimal temperatures between heights occur. In that manner, in the period of the observations the biggest difference between minimal temperature on snow surface and und snow mantle was 3-4^{0}C, between snow surface and the height of 150 cm 6-7^{0}C. The lowest negative temperatures in a case of “Diana” farming company were registered in January (to -20^{0}C) which led to a significant damage of buds and vines which were spending winter without covering.

In a zone of a culture not requiring covering a minimal air temperature in a bank of soil at vine top is 1.1^{0}C lower than at 150 cm height from a soil and 1.8^{0}C warmer than at 2 cm from the ground.

Therefore, differences in minimal temperatures at levels of 2 cm to 150 cm vary from 1 to 4^0, considering average yearly data 2.5-3^{0}C. In CIS maximal levels if that difference reach 7-8^{0}C [8].

Results of a registration of buds damage degrees considering types of vine winter covering are presented in table 1.

Table 1. An influence of vine covering method on winter hardiness

Experiments setups	Varieties	Buds left after cutting	% of live buds		Number of shoots developed from buds in average per vine		% of fruitful shoots per vine	Coefficient	
			main	substitutional	pcs.	%		fructification	fruitfulness
Almaty region									
Soil covering (control)	Pink Taifi	53	49	63	25	47	36	1.1	1.2
	Saperavi	66	54	68	44	67	58	1.3	1.4
Cane covering	Pink Taifi	54	46	56	28	51	35	1.1	1.2
	Saperavi	67	53	66	45	68	59	1.4	1.6
Hilling of vines by a bank of soil	Pink Taifi	46	21	29	12	29	23	0.7	1.0
	Saperavi	67	43	46	24	36	34	1.25	1.4
South Kazakhstan region									
Soil covering (control)	Cabemet Franc	48	48	61	29	59	52	1.28	1.5
	Saperavi	50	53	62	31	61	53	1.5	1.56
Cane covering	Cabemet Franc	50	56	67	34	68	44	1.3	1.5
	Saperavi	49	53	63	31	64	57	1.5	1.6
Hilling of vines by a bank of soil	Cabemet Franc	49	48	54	24	50	43	1.3	1.4
	Saperavi	51	45	52	25	49	57	1.48	1.5

Analysis of the data presented in the table shows, that cane covered vines and fully covered vines in conditions of Almaty region comparatively well retained main and substitutional buds. In a case of vines, which were not covered in winter, damage to buds was significantly higher.

Uncovered vineyards lost from 57 (saperavi) to 79% (pink Taifi) of central buds and, correspondingly, from 54 to 71% of substitutional. In a case of coverings use, vine had received insignificant damage due to negative temperatures and therefore more fruitful shoots were formed in comparison with vines without covering. Table grape variety pink Taifi was especially damaged and in 2012 didn’t form any fruitful shoots and didn’t yield any harvest.

In a case of South Kazakhstan region the biggest damage of buds was in the setup with uncovered vines and 9-12% lower number of shoots was formed. Fructification coefficient in all experimental setups had higher values than in the control setup. The maximum values were in a case of cane covering (1.3 and 1.5) and minimal (1.21 and

1.48) – in control a control setup. The same pattern was observed in a case of fruitfulness coefficient.

In last 50-60 years in Kazakhstan, as well as abroad at vineyards foliar application fertilizers are becoming more and more widely used. The method is based in sprinkling of leaves in morning hours or in gloomy weather with water solutions of mineral fertilizers – salts of micro and macro elements. In other words, foliar application fertilizers is a nutrition of plants by means of a suction of nutritious substances of a fertilizer in an ion form through leaves and other over ground parts of a plant [9].

As it is known, green leaves of Metaphyta are the main organ where photosynthesis, the process of conversion of light in chemical bond energy, is occurring. The most important component of photosynthesis mechanism is chlorophyll. Because an intensity of photosynthesis depends on chlorophyll content, we estimated its amount in leaves depending on fertilizers implementation.

Conducted analysis showed that chlorophyll content *a* in studied varieties in the setup with Green fertilizer exceeded the control level by 22.6%. In the setup with Rosasol that value was insignificantly lower.

As about chlorophyll *b* and its content in setups with Green and Rosasol, it exceeded the control setup values by 42.5 and 18.1%. Thus, foliar application fertilizers of vine led to an increase of chlorophyll content in leaves.

Sugars and other organic compounds formed during photosynthesis are used by cells of vine as nutrients. Moreover, frost resistance of plants depends on a content of carbohydrates in annual and perennial parts. The more carbohydrates the lower temperatures vine can sustain in winter period [10].

Basing on aforementioned, we determined carbohydrates content in annual ripen shoots. Analysis showed, that because rods were sampled in October (before the beginning of negative temperatures in autumn), hydrolysis of starch hadn't finished completely, as a results of which a polysaccharide content was minimal form 65.6 to 63.5%, in the case of Green fertilizer and technical varieties of Cabernet Franc and Saperavi in conditions of Saryshagan district to 54.4% - 51.2% in the control setup. In the case of Rosasol fertilizer a starch content was 0.86% higher than in the control setup, but the total sugars content was 1.15% lower.

In the case of Uigur district in comparison with Saryshagan district the total content of carbohydrates is 8.5% lower than Saperavi variety, i.e. insignificantly lower. In comparison with the control setup the total content of carbohydrates in that case was 12.4% higher. Thus, better accumulation of carbohydrates is provided by foliar application fertilizer Green.

Varieties of vine, which period of shoots growth due to biological features is shorter and processes of tissues formation proceed faster and are finished before autumn negative temperatures beginning, are the most adapted to continental climate conditions [11]. We had established, that a change of bark color intensity allows to draw conclusions only about periods of periderm formation by a shoot length. Varieties of different origin, according to observations, have a different speed of covering tissues color change by shoot length (Table 2). In that manner, the highest percentage of a ripen part of studied varieties of Cabernet Franc (97%) and Saperavi (95%) was observed in the setup with Green fertilizer implementation and the lowest in the same setup in a case of pink Taifi (61.5%).

Table 2. Ripening dynamics of various varieties of annual vines (by a change of bark color, % from total) 2011-2013

Varieties	Ripen part of shoot, %		
	Without treatment (control)	Rosasol (scheme)	Green (scheme)
Almaty region			
Pink Taifi	51.1	62.5	61.5
Saperavi	82.6	88.4	87.4
South Kazakhstan region			
Cabernet Franc	86	96	97
Saperavi	86	94	95

Certain differences in an anatomical structure of tissues of studied varieties in context of ripening degree were also established (Table 3).

Table 3. Anatomic and morphological structural features of annual shoots of vine in the end of vegetation ("Diana" farming company)

Property	Saperavi			Pink Taifi		
	control	Rosasol	Green	control	Rosasol	Green
Length (cm):						
shoot	157.0	167.0	174.0	249.0	265.0	298.0
interstice	7.6	8.3	7.6	11.0	11.2	11.7
Shoot diameter (mm)	7.6	7.9	7.9	8.7	9.5	9.8
Radius (mm):						
shoot	3.8	3.95	3.95	3.94	4.75	4.90
phloem	0.31	0.31	0.40	0.45	0.51	0.50
wood	1.78	1.89	1.91	1.71	1.79	1.76
core	1.20	1.10	1.15	1.81	1.84	1.88

In a case of varieties of Western European group and Black Sea basin, as a rule, most of diameter is allocated for wood and insignificant part for core. In a case of an eastern group, if shoots development is normal, core takes the major part of diameter.

As it can be seen from tables 4 and 5 data, the highest harvest was yield in a case of cane covering and slightly less in the control setup. The lowest harvest was yield in a case of not covered culture. Harvest increase in the case of "Diana" farming company was 14-8% for cane covering, reaching 7.80 ton/hectare for Saperavi variety and 7.51 ton/hectare for pink Taifi.

Table 4. Productivity values of vine as a function of covering methods ("Diana" farming company, average of 2011-2013)

Setups	Calculated productivity			
	Saperavi		Cabernet Franc	
	ton/hectare	% of control	ton/hectare	% of control
Control	6.82	100.00	6.93	100.00
Cane	7.80	114.40	7.51	108.40
Without covering	5.84	85.63	3.85	55.55
$HCP_{0.5}$	2.92		3.56	

In the case of "Caspian food" ltd. a harvest increase in the context of studied varieties was 19.57 and 21.64% reaching 16.31 ton/hectare in the case of Saperavi variety and 15.51 ton/hectar in the case of Cabernet Franc respectively.

Table 5. Productivity values of vine as a function of covering methods ("Caspian food" ltd., average of 2011-2013)

Setups	Calculated productivity			
	Saperavi		Cabernet Franc	
	ton/hectare	% of control	ton/hectare	% of control
Control	13.64	100.00	12.75	100.00
Cane	16.31	119.57	15.51	121.64
Without covering	11.21	82.18	10.57	82.90
$HCP_{0.5}$	3.2		2.2	

In the studied period an implementation of schematic dressings helped to increase an overall productivity of vine (table 6, 7). An average increase of harvest in the case of schematic treatments by Rosasol fertilizer in the case of "Diana" farming company was 40% reaching 9.62 ton/hectare and in the case of Green fertilizers implementation was 29.14% reaching 8.86 ton/hectare. In the case of "Caspian food" ltd. harvest increase 33.5% in the case of Rosasol reaching productivity of 17.63 ton/hectare. Somewhat lower values were obtained in the case of Green fertilizers - 28.45% with productivity of 16.94 ton/hectare.

Table 6. An influence of complex fertilizer treatment on vine productivity ("Diana" farming company, average of 2011-2013)

Setups	Calculated productivity			
	Saperavi		Pink Taifi	
	ton/hectare	% of control	ton/hectare	% of control
Control	6.82	100.00	6.93	100.00
Cane	9.22	135.19	10.02	145.00
Without covering	8.84	130.00	8.89	128.28
$HCP_{0,5}$	3.2		2.52	

Table 7. An influence of complex fertilizer treatment on vine productivity ("Caspian food" ltd., average of 2011-2013)

Setups	Calculated productivity			
	Saperavi		Cabernet Franc	
	ton/hectare	% of control	ton/hectare	% of control
Control	13.64	100.00	12.75	100.00
Cane	18.69	137.02	16.58	130.03
Without covering	17.38	127.41	16.51	129.49
$HCP_{0.5}$	4.3		3.2	

Conclusions

As a result of conducted research following conclusion can be made: the highest values of air temperature gradients in fine weather are observed until the height of 150 cm and the coldest layer of air is registered on 2 cm height; in the case of culture not requiring covering in a bank of soil it 3.1^{0}C warmer than at 2 cm height; the biggest difference between a minimal temperature on snow surface and the height of 150 cm is 6-7^{0}C; with a temperature decrease in the setup with uncovered vines sugars content is increasing in 1.19% in comparison with the control setup and reaching maximum in a minimal temperatures period; vine harvest in a case of vines which spend winter without covering was in the same level as the control setup and in the case of cane covering it was 11% higher; schematic foliar application dressings with complex fertilizers Rosasol and Green have a positive influence on photosynthesis and physiological activity of plants leading to an increase of chlorophyll content in leaves and main nutrients in leaves in a vegetation period and intensify starch conversion in sugars in a period of autumn decrease of temperatures. An increase of productivity of table and technical varieties was provided in the higher degree by Rosasol fertilizers (in average by 36.75%).

Therefore, it can be stated that it is practical to place more frost-resistant varieties on warmer slopes in a case they will not be covered in winter in a given farming company and less frost resistant, if they will be covered in winter anyway, is more practical to put in less favorable conditions for wintering and also that an implementation of schematic foliar application dressings provides an adaptability increase, a productivity increase and production quality increase.

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