ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume LVIII 51 Number 5, 2010

LIME-INDUCED CHLOROSIS AND DROUGHT TOLERANCE OF GRAPEVINE ROOTSTOCKS

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Received: February 15, 2010

Abstract

PAVLOUŠEK, P.: *Lime-induced chlorosis and drought tolerance of grapevine rootstocks.* Acta univ. agric. et silvic. Mendel. Brun., 2010, LVIII, No. 5, pp. 431–440

Due to the expansion of phylloxera into European vineyards rootstocks became an integral part of successful modern growing of grapevine. Breeding of rootstocks and their selection for resistance against both biotic and abiotic factors can be classified as a biotechnology. In this respect, the capability of grapevine plants to adapt themselves to pedological conditions, especially to drought and a high content of lime (or factors inducing their chlorosis) represents a very important breeding goal. In this survey possible causes of lime-induced chlorosis and drought damage and their consequences are analysed. Some important drought-and-lime induced chlorosis-related properties of some selected rootstocks are mentioned as well.

rootstock, drought, lime-induced chlorosis, resistance, lime

In the grapevine propagation, the use of rootstocks is not a new matter. The evidence of the use of rootstocks can be found out even in works written by the Roman author Columella who occupied himself with agriculture and viticulture.

However, the use of rootstocks obtained a new dimension after the phylloxera calamity, which destroyed European vineyards in the second half of the 19th century.

Rootstocks were introduced to Europe after the phylloxera invasion, a pest which rapidly spread through vineyards and destroyed large areas of sensitive cultivars. At present, grafting European varieties on pathogen-resistant rootstock is a normal procedure and many rootstock varieties have been developed by plant breeders and selectionists (ARRIGO and ARNOLD, 2007).

Although the resistance to phylloxera is the most important criterion when breeding and selecting rootstock, it is not the subject of this study.

The main ideas of breeding and selection of rootstocks were formulated by BUCHANAN and WHITTING (1991).

When choosing a suitable rootstock it is important to select one with a good tolerance to phylloxera and well as being to the specific climatic conditions and soil characteristics of individual vineyard sites.

The rootstock connects the grafted plants with soil and influences mutual relationships. The root system of the rootstock enables the uptake of water and nutrients from soil. The rootstock also shows a marked effect on the growth intensity of grafted plants. When selecting a suitable rootstock, it is important to consider characteristics and parameters of the site. The most important of them are the following: depth of the soil horizon, water-holding capacity of soil, slope and exposure of the site, and climatic conditions. The architecture of the root system of the plant is also very important for its resistance/tolerance to drought.

In the case of grapevine, selection and use of a suitable rootstock may help to solve problems of plant protection and of overcoming extreme soil conditions. Adaptability of plants to environmental conditions, e.g. their tolerance to lime, drought, low soil pH, soil humidity, salts etc., is very important.

This review tries to summarise data about the adaptation of rootstocks to soil (pedological) conditions, viz. their resistance to lime-induced chlorosis and drought. Regarding the global warming, these properties of rootstocks are very important also under conditions of the Central European viticulture.

Tolerance of grape rootstocks to lime-induced chlorosis

A high content of active and total lime in soil may result in the occurrence of grapevine chlorosis and show a negative effect on its growth, and fertility as well as on the quality of grapes. On the one hand, lime present in soil shows a very significant effect on sensory properties of wine. From geological point of view, this element represents an important component of the terroir and influences directly the character of wine. Wine growing regions situated on calcareous subsoil may be considered as very important from the viewpoint of making top quality wines. As a typical example is it possible to mention the Champagne wine growing region in France and/or Palava wine growing region in the Czech Republic. A considerate choice of suitable rootstocks represent one of the possibilities how to respond to an increased of lime in soil with regard to grape quality.

Lime-induced iron chlorosis, i.e. the condition of a reduced availability of soluble iron to the grapevine plants due high concentrations of bicarbonate ions in calcareous soils, can seriously impair the health condition of vines. The lime-induced chlorosis affects yield and quality of grapevines growing in lots of calcareous areas world-wide (BAVARESCO *et al*., 1994).

Deficiency symptoms of lime-induced chlorosis

An exact diagnosis of lime-induced chlorosis is a primary precognition of a successful fight against this physiological disease.

Iron deficiency chlorosis is one of the major problems affecting a variety of crop species grown in calcareous soils (GRUBEN and KOSEGARTEN, 2002).

Iron deficiency causes various morphological and physiological changes in plants (BERTAMINI and NEDUNCHEZHIAN, 2005).

Symptoms of lime-induced chlorosis may be observed on the whole vine but the most important ones occur on the leaf surface.

Iron-deficient plants are characterized by the development of a pronounced intervenial chlorosis similar to that caused by magnesium (Mg) deficiency but occurring first on the youngest leaves. Intervenial chlorosis is sometimes followed by chlorosis of the veins, causing the whole leaf to become yellow. In severe cases, the leaves become white with necrotic lesions (ABADIA, 1992).

Typical symptoms of lime-induced chlorosis are the inter-vein yellowing of leaves and a decrease in plant biomass because, under conditions of iron (Fe) deficiency, a decreased photosynthetic performance of plants is induced by a lower content of chlorophyll in leaves (BAVARESCO and PONI, 2003).

MENGEL, BÜBL, SCHERER (1984) characterises chlorosis as a disease manifesting itself by yellowing of young leaves, whereas more mature leaves are frequently green. Plant growth is often considerably depressed, independent of whether young leaves are chlorotic or green.

KOSEGARTEN *et al*. (1998) suggested that the impaired formation of new leaves and restricted leaf growth is a typical and more sensitive symptom of Fe-deficiency than is leaf chlorosis.

Chlorotic symptoms also vary from year to year as a result of environmental variables, like yields, temperature, rains. In soils where shallow layers are less rich in $CaCO_3$ than deeper layers, it is likely that vines develops chlorosis only when the age and roots explore layers with poor conditions for Fe uptake (TAGLIAVINI and ROMBOLA, 2001).

As lime-induced chlorosis results from relationships existing between soil conditions on the one hand and root system of on the other, it influences also growth properties of vines.

BAVARESCO, GIACHINO, PEZZUTTO (2003) mentioned that, lime-induced chlorosis of grapevine was characterized by a dramatic reduction of shoot growth, grape production and leaf Fe content, and a distribution of dry matter towards roots more than to the clusters.

Vines growing on high-bicarbonate soil significantly reduced the dry matter production of individual organs and the total plant weight. Lime stress conditions increased the percent distribution of dry matter in the stem and roots and decreased that one in the fruit (berries and cluster stems) (BAVARESCO and PONI, 2003).

A high content of lime mostly causes a low availability of iron, which is a result of its non-solubility occurring in soils showing higher values of pH. Under such conditions, iron cannot be uptaken by roots of plants (HELL and STEPHAN, 2003).

This lime-induced iron deficiency shows a strong effect not only on grapevine plants but also on some other economically important fruit species cultivated on calcareous soils. It is quite common also in peach, pear, quince-tree, kiwi, and citrus fruit plantations (TAGLIAVINI and ROMBOLA, 2001).

Lime-induced stress conditions show a strong effect on production of grapes and reduce the yield of grapes per vine. When growing grapevine on calcareous soils, a lower number of grapes per annual shoot depends on stress conditions existing in the preceding growing season (when the flower buds were differentiated) while a small size of grapes and berries is a consequence of iron deficiency in the current year (BAVARESCO, PRESUTTO, CIVARDI; 2005).

The occurrence of lime-induced chlorosis influences above all the growth of vines and the size of photosynthetising leaves as well as yield and quality of grapes, it can be concluded that the iron deficiency is caused mainly by increased levels of calcium carbonate and the resulting high contents of bicarbonates in soil. These high levels of bicarbonate ion are typical just for these calcareous soils (PESTANA, FARIA, DE VARENNES, 2004; MENGEL, BREININGET, BÜBL, 1984).

Under such conditions, the occurrence of chlorosis symptoms is quite common and for that reason this type of chlorosis may be defined as a lime-induced iron chlorosis or, abbreviated, lime-induced chlorosis (PESTANA *et al.*, 2004).

Identification of chlorosis symptoms directly in the vineyard is therefore very important because it enables to implement the protection of plants against mechanisms, which induce this disease.

Causes of the occurrence of lime-induced chlorosis

Although the reasons of the occurrence of this type of chlorosis seem to be quite, the inducing mechanism of this phenomenon is still not clearly defined.

Various forms of iron present in soil and thein acceptability for plants contribute significantly to to induction of this type of chlorosis. Iron represents one of those minerals, which are utilised by plants to assure their sound growth. Iron is used by plants in two forms, viz. as Fe^{2+} and Fe^{3+}.

Iron also plays an important role in activities of the enzymatic system of plants: it actively participates in photosynthetic reduction-oxidation reactions, respiration, biosynthesis of proteins and chlorophyll, biological binding of atmospheric oxygen, and in reduction of nitrates and nitrites (TAGLIAVINI and ROMBOLA, 2001).

Cultivated plants differ in their susceptibility to Fe deficiency in calcareous soil; some are not much affected while others show severe leaf symptoms of chlorosis (TAGLIAVINI and ROMBOLA, 2001).

The total content of lime in soil is not very useful for predicting the development of the occurrence of this type of chlorosis. Active carbonates (active lime) is more reactive and, therefore, able to build and maintain high levels of HCO^-_3; for that reason it is a more reliable indicator (TAGLIAVINI and ROMBOLA, 2001).

TAGLIAVINI and ROMBOLA (2001) mentioned that individual genotypes may tolerate higher levels of active lime if amounts of available iron in the soil increase to a certain level. This concept resulted in the so-called "chlorotic power index" (CPI) (JUSTE and POUGET, 1972. In: HUGLIN and SCHNEIDER, 1998). This means that the amount of active lime is related to the amount of Fe extracted by ammonium oxalate. Table I show degrees of chlorosis intensity in relation to different values of CPI (LUPASCU *et al.*, 2009).

I: *Degrees of chlorosis intensity in relation to different values of CPI (LUPASCU et al., 2009)*

CPI value	Intensity of chlorosis
0	None
≤ 5	Small
6–15	Medium
16–35	High
≥ 36	Very high

The content of active lime in soil is a parameter, which is frequently used when selecting rootstocks for cultivation of grapevine plants in calcareous soils (CHAMPAGNOL, 1984).

The susceptibility to chlorosis is the most important selection criterion for rootstocks in many European wine-growing regions where such a condition is prevalent due to occurrence of highly calcareous soils.

According to BAVARESCO (1990), there are two basic strategies how to classify grapevine plants according to their capability to adapt themselves to conditions, under which the lime-induced chlorosis can occur:

- Strategy I involves four types of response in the roots as follows: a) enhancement of H-ions release, b) formation of rhizodermal or hypodermal transfer cells, c) enhancement of ferric iron reduction to ferrous iron, d) enhancement of release of reducing/chelating compounds e.g. phenols.
- Strategy II is characterized by an enhancement of release of non-proteinogenic amino acids and by a high affinity uptake system.

BAVARESCO (1990) formulated the following hypothesis: the response mechanism of tolerant grapevine rootstocks corresponds probably with Strategy I (BAVARESCO *et al.*, 1989) however, the vines are normally grafted and the behaviour of the whole plant towards lime-induced chlorosis is governed by the following two properties: (i) by the ability of roots to satisfy iron requirement of leaves; (ii) by the iron requirement of leaves to secure a normal iron nutrition of the plant (POUGET and OTTENWALTER, 1973).

The reason that Fe deficiency results in a rapid inhibition of chlorophyll formation is not fully understood, even though this problem has been studied for many years (BERTAMINI and NEDUNCHEZHIAN, 2005).

The reduction of plant biomass of susceptible plants is related to a reduced root growth due to soil bicarbonate and to a lower photosynthesis rate which also depends by a decrease of leaf chlorophyll, under Fe stress conditions (BAVARESCO, GIACHINO, PEZZUTTO; 2003).

According to MARSCHNER (1995), the growth rate of sink tissues and such organs as the roots, shoot apex, fruits and storage organs can be limited by supply of photosynthates from the source leaves or by a limited capacity of the sink to utilize the photosynthates.

In some cases, lime-induced chlorosis is related to a low Fe uptake and its translocation to leaves (BAVARESCO *et al.*, 1992), in others to a high content of Fe in leaves, which has to be somehow inactivated (MENGEL, BREININGET, BÜBL, 1984; BAVARESCO *et al.*, 1993).

Tolerance to lime-induced chlorosis in wild species and rootstocks varieties

Rootstocks represent a very important part of the concept of prevention of lime-induced chlorosis in vineyards. A perfect knowledge of soil conditions and of resistance of individual rootstocks to lime enables to optimize their selection of with regard to soil conditions.

Use of genotypes tolerant to chlorosis induced by iron blocking is a reliable tool how to solve problems of chlorosis occurrence (JIMENEZ *et al.*, 2008).

Breeding also contributes significantly to selection of lime-resistant rootstocks. Breeding efforts to get proper genotypes included successfully crossing between wild grape species, and some chlorosis-resistant rootstocks are now available for the grapevine growers of the many calcareous areas worldwide (FREGONI, 1980; POUGET, 1980; BAVARESO, FRASCHINI, PERINO, 1993).

Lime-tolerant grapevine rootstocks have some specific physiological mechanism to overcome chlorosis when grown on calcareous soils, including and improvement of root Fe uptake and reducing capacity (VARANINI and MAGIONI, 1982; BAVARESCO, FREGONI, FRASCHINI, 1991).

Vitis riparia and *Vitis rupestris* are very important species in the history of the rootstock breeding activities. These two species are not very tolerant to calcareous soils. *Vitis berlandieri* is recognized for adaptation to calcareous soils. *Vitis vinifera* is species tolerant to calcareous soils (COUSINS, 2005).

Knowing the characteristics of the important parental species and rootstock varieties used in rootstock development helps us to understand the viticultural attributes of individual rootstocks families.

Data about the tolerance of rootstocks to lime-induced chlorosis, as mentioned by COUSINS (2005) and CHAUVET and REYNIER (1979) are presented in Tab. II.

PAVLOUŠEK (2008) presented results of an evaluation of lime tolerance of rootstocks registered in the Czech Republic. From the viewpoint of the resistance to chlorosis, the rootstocks registered in the State Variety Book of the Czech Republic can be ranked from the most resistant to the most sensitive as follows: *Craciunel 2 – SO 4 – Kober 125 AA – Kober 5 BB – Teleki 5 C – Amos – LE-K-1*. These results are very important from the viewpoint of the use of rootstock varieties for propagation and growing of grapevine in the Czech Republic.

In Tab. III, the classification of rootstock variety, content of active lime and values of CPI are described (JUSTE and POUGET, 1972 In: HUGLIN and SCHNEIDER (1998).

III: *Classification of rootstocks on the base of the content of active lime and CPI (JUSTE and POUGET, 1972. In: HUGLIN and SCHNEIDER, 1998).*

Rootstock	Content of active lime (%)	CPI value
Vialla	-	2
Riparia Gloire	6	5
196-17	6	-
101-14	9	10
216-3	9	-
44-53	10	-
3309	11	10
1616	11	-
Rupestris du Lot	14	20
99R,110R,1103P,SO4	17	30
5BB,420A, 34 EM	20	40
161-49	25	50
140 Ru	25	90
41B	40	60
333 EM	40	70
Fercal	-	120

II: *Tolerance of rootstocks to chlorosis (after COUSINS, 2005, CHAUVET and REYINER, 1979, HOFÄCKER, 2004)*

Rootstocks	Tolerance to chlorosis	Reference
SO 4	Medium	COUSINS (2005)
Börner	Low	
420 A	Good	CHAUVET and REYNIER (1979)
Kober 5BB **SO4**	Medium	
140 Ruggeri	Very Good	
1103 Paulsen **110 Richter**	Medium	
Fercal	Very Good	
SO4, Binova, Teleki 8B, 140 Ruggeri, 1103 Paulsen, Richter 110, 26 G, Georgikon 28	Good	HOFÄCKER, 2004
Kober 5 BB, Kober 125AA, Richter 99, 41B	Medium	
Schwarzmann, Börner, Rici, Cina	Low	
3309 Couderc	Very Low	

Tolerance of grape rootstocks to drought

Drought stress is one of the most important abiotic stress factors which are generally accompanied by heat stress (ZULINI *et al*., 2007).

In recent decades it is possible to observe changes in the character of global climate. Warm years and longer period soil drought are more and more frequent. This means that modern viticulture must react effectively to this increasing frequency of the occurrence of drought periods.

Grapevine (*Vitis vinifera*) has developed various physiological and morphological mechanisms how to maintain its growth and fertility even under conditions of lack of water.

In Europe, varieties of *Vitis vinifera* are traditionally cultivated in non-irrigated regions. Yield of grapes as well as the quality of berries is therefore dependent on the adaptability of grapevine plants to drought. A good understanding and control of the water regime of plants as well as influencing their tolerance to drought stress on the base of application our knowledge of plant physiology and molecular biology may significantly increase not only productivity of plants but also quality of environmental conditions.

In grapevine, water supply of plants plays and important role in processes of plant growth and formation of berries. A limited supply of water reduces not only the growth of annual shoots but also the weight of berries and the final yield of grapes. A marked lack of water may result in reduced yields and an impaired quality of grapes. This means that in the course of the growing season the occurrence of stress induced by water deficit shows a significant effect on physiological functions of grapevine plants. Although the grapevine (*Vitis vinifera*) is a species showing a very good tolerance to drought, a severe stress may sometimes markedly influence qualitative properties and parameters of grapes. When using plant material adapted to drought conditions, it is possible to avoid losses caused by a severe water stress (VAN LEEUWEN *et al*., 2009).

Selection of rootstocks and varieties showing increased water-use efficiency is one of possibilities how to adapt modern viticulture to current climatic changes, especially to lower precipitations and longer periods of drought (VANDELEUR *et al*., 2009; FLEXAS *et al*., 2010).

Properties influencing the tolerance of grapevine plants to drought

In the course of phylogenesis the grapevine (*Vitis vinifera* L.) plants have developed various physiological and morphological mechanisms, which enable them to maintain their growth and fertility even under conditions of a limited availability of water.

Although grapevine (*Vitis vinifera* L.) is considered to be a species adapted to drought stress, the combined effect of high irradiation, high temperatures and low atmospheric water pressure tension would presumably act as major constraint for the leaf photosynthesis, particularly under conditions of severe soil water deficits usually encountered by this crop (FLEXAS *et al*., 1998).

The physiological mechanisms related to drought tolerance vary from genotype to genotype. It is necessary to screen genotypes for drought tolerance and take into consideration all important aspects, e.g. photosynthesis rate, transpiration rate, stomatal conductance and relative water content occurring at different level of water stress (SATISHA *et al*., 2006).

Grapevine varieties adapt themselves to water deficits by means of various mechanisms, e.g. by changes in the leaf area (GÓMEZ DEL CAMPO *et al*., 2003), xylem vessel size, and/or conductivity (LOVISOLO and SCHUBERT, 1998).

The architecture of grapevine root system represents an important factor of drought tolerance of plants. Geothropy of the root system is a genetic trait determined by rootstocks. On the other hand, the architecture of the root system is influenced also by spacing of plants and methods of tillage. The tolerance of grapevine to drought is also dependent on the quality of the root system, its architecture, the distribution of individual types of roots within the soil and the density of the root system in the place of water and nutrients uptake.

WILLIAMS and SCHMITH (1991) mentioned that the rootstock genotype shows the most important effect on the density of the root system. The growth of roots is also dependent on the relationship, which exists between the rootstock variety and soil conditions (MORLAT and JACQUET, 2003).

Roots are usually the first point where the stress is perceived by plants and where they respond to the existing stress conditions.

In grapevine plants, an inhibited growth of leaves and annual shoots represents a significant symptom of water deficit (STEVENS *et al*., 1995). The sensitivity of roots is usually lower than that of annual shoots (DRY *et al*., 2000).

The grapevine tolerance to drought is *de facto* the capability of plants to produce selectively new roots in those places where the groundwater is available. The water stress has a dominant effect on the growth of the grapevine and affects both the growth and the development of grapevines.

In summer, water available to the plant can often be insufficient because of a lack of precipitation or a low level of its reserves in soil. This can lead to a reduction in the vigour of the plant, its productivity, and quality of the crop.

Drought-induced decrease in photosynthesis is primarily due to a stomatal closure, which lowers CO_2 availability in the mesophyll, not due to a direct effect on the capacity of the photosynthetic apparatus (ESCALONA *et al*., 1999).

Stomatal closure is one of the first responses to soil drying, and a parallel decline in photosynthesis and stomatal conductance under progressive water stress has already been reported (MEDRANO *et al*., 1997).

SOAR *et al.* (2006) reported that rootstock effect on gas exchange of vineyard-grown grapevines is most likely due to differences in the relative capacity of rootstocks to extract and provide scions with water.

Rootstocks have been reported to affect the efficiency of water transport to the shoots via conductivity constrains imposed by the anatomy of xylem vessels (DE HERRALDE *et al.*, 2006).

Rootstock genotype has a major influence on root density (WILLIAMS and SMITH, 1991) even though the distribution of grapevine roots is significantly dependent on both edaphic conditions (SMART *et al.*, 2006) and vine (ARCHER and STRAUSS, 1985).

GREENSPAN (2006) differentiates between terms “drought-tolerance” and “drought-avoidance”. Drought-tolerance refers to the ability of the rootstock to support grapevine physiological functions during periods of low soil moisture availability. Rootstocks may exhibit drought-tolerance through several mechanisms:

- Maintaining a low hydraulic resistance to water flow, even under dry conditions.
- Maintaining photosynthetic activity in leaves, even under low water availability conditions.
- Preventing the abscission of leaves during periods of low water availability.

Drought-avoidance refers to the ability of the rootstock to prevent low vine water status by one or more of many mechanisms, including:

- Deep or extensive root exploration to fully exploit soil moisture reserves.
- Conservation of vine water use by inducing closure of the leaf stomatal pores to limit transpiration.
- Restricting vine vigour, thereby limiting the amount of transpiring leaf surface area.

Growth capacity and morphological adaptations occurring in the plant as drought tolerance mechanisms are relevant (PIRE *et al.*, 2007).

Some biochemical characteristics, e.g. the stability of chlorophyll, can be used for selection of cultivars resistant to drought conditions (SINBHA and PATIL, 1986).

Tolerance to drought in wild species and rootstocks varieties

The use of rootstocks makes it possible to give plants a certain capacity to adapt drought conditions. The knowledge of drought tolerance of rootstocks is important with regard to the utilisation of these gene resources in breeding work and selection.

The capability of plants to create a root system efficiently penetrating into the soil is an important factor, which enables them to survive during longer periods of drought and water-stress.

It is well-known that there are really remarkable differences in tolerance to drought. Some rootstocks (e.g. 101-14 and Schwarzmann) show a low tolerance while in others (e.g. Lider 116-60, Ramsey, 1103 Paulsen, 140 Ruggeri, and Kober 5 BB) this property is better (SOMMER, 2009). Also CIRAMI *et al.*, (1994) observed a good tolerance to drought in rootstocks Ramsey, 1103 Paulsen, and 140 Ruggeri.

Table IV. presented tolerance to drought in some rootstocks varieties after LAVRENČIČ *et al.* (2007) and POUGET and DELAS (1989).

CREGG (2004) stated that to compare the relative tolerance among different genotypes, the variables

IV: *Tolerance of rootstocks to drought (LAVRENČIČ et al., 2007, POUGET and DELAS, 1989)*

<table>
<tr><th>Rootstocks</th><th>Tolerance to drought</th><th>Reference</th></tr>
<tr><td>3309 Couderc</td><td>Low-very sensible</td><td rowspan="2">LAVRENČIČ et al. (2007)</td></tr>
<tr><td>1103 Paulsen</td><td>High</td></tr>
<tr><td>Riparia Gloire</td><td rowspan="4">Low</td><td rowspan="12">POUGET and DELAS (1989)</td></tr>
<tr><td>101-14</td></tr>
<tr><td>161-49</td></tr>
<tr><td>41 B</td></tr>
<tr><td>3309 Couderc</td><td rowspan="5">Moderate</td></tr>
<tr><td>Gravesac</td></tr>
<tr><td>SO 4</td></tr>
<tr><td>420 A</td></tr>
<tr><td>Fercal</td></tr>
<tr><td>110 Richter</td><td rowspan="3">High</td></tr>
<tr><td>140 Ruggeri</td></tr>
<tr><td>1103 Paulsen</td></tr>
<tr><td>140 Ruggeri, Georgikon 28, Richter 110, Richter 99, Börner, Rici, Cina, 41B</td><td>High</td><td rowspan="4">HOFÄCKER, 2004</td></tr>
<tr><td>Kober 5BB, SO4, Binova, Teleki 8B, 26G</td><td>Medium</td></tr>
<tr><td>Kober 125AA, Schwarzmann</td><td>Low</td></tr>
<tr><td>Teleki 5C</td><td>Very low</td></tr>
</table>

to evaluate are as follows: survival potential, growth capacity, and water use efficiency based of morphological and physiological adaptations that might occur in the plant.

The most drought-tolerant grapevine species are *V. arizonica, V. californica, V. champinii, V. doaniana, V. gidriana,* and *V. longii*. The lowest tolerance was observed in *V. berlandieri, V. cinerea, V. lincecumii, V. riparia*, and *V. solonis*. *V. rupestris* showed only a moderate tolerance to drought (PADGETT-JOHNSON, *et al*., 2003).

V. cinerea can assure not only a complete phylloxera resistance; it also shows a positive influence on scion performance especially in shallow, gravely, and consequently dry soils. Phylloxera-resistant *V. cinerea* hybrids are therefore recommended for vineyards established in sites with generally dry conditions. In dry locations *V. riparia x V. cinerea* hybrids represent a valuable expansion of the range of rootstocks currently available in Germany. Particularly on steep slopes and in seasons with rare rainfall the results obtained with these hybrids were superior (SCHMIDT *et al*., 2005).

The occurrence of drought is also very closely correlated with the overall soil conditions of the site. For that reason it is recommended to select individual rootstocks with regard to the type of soil and also to contents of loamy, clayey and sandy particles within the soil profile.

WHITE (2009) arranged rootstocks with regard to their drought tolerance and pedological conditions of the site in the following manner (Tab. V).

A good understanding of physiological mechanism that enable plants to adapt themselves to the water deficit and to maintain growth also during stress periods could help within the framework of individual breeding programs to screen and select stress-tolerant genotypes (WINTER *et al*., 1988).

CONCLUSIONS

Regarding climatic changes and a more and more frequent occurrence of periods of drought within the growing season, the problem of lime-induced chlorosis and drought damage of grapevine plants becomes to be more and more important.

Effects of lime-induced chlorosis and drought of grapevine rootstocks are therefore very important, especially in association with a better understanding of effects of these abiotic factors on grapevine on the one hand and the possibility of the use of such a knowledge when breeding and selecting rootstocks on the other.

The objective of this survey of literature was to provide a general overview of tolerance of individual rootstocks to important abiotic factors, i. e. to lime and drought.

V: *Dependence of tolerance drought and chlorosis of rootstocks on soil conditions (WHITE, 2009)*

Soil profile characteristics	Vineyard water status	Recommended rootstocks
Soil depth < 20 cm: sand, loam or clay including any root-impeding subsoil	Dry soil	110 Richter, 140 Ruggeri, 1103 Paulsen
	Irrigated soil	110 R, 140 Ru, 1103 P, Ramsey
Soil depth 20–75 cm, sands, loams or clays, with no root-impeding subsoil.	Dry soil	99R, 110R, 140 Ru, 1103P, Ramsey, Kober 5 BB
	Irrigated soil	99R, 110R, Ramsey, Kober 5BB, Teleki 5C, Schwarzmann, SO4, 420A, 101-14 (in loams and clays).
Soil depth > 75 cm, uniform or gradational profile of sand, loam or clay.	Dry soil	99R, 110R, 1103P, Ramsey (in sand), Kober 5BB.
	Irrigated soil	SO4, 101-14, Teleki 5C, Schwarzmann, 3306 a 3309 Couderc, 420A.

SUMMARY

The optimisation of relationships existing between plants on the one hand and site conditions on the other represents a basis for a successful growing of grapevine. The root system of plants is created by the rootstock and for that reason its adaptation to site conditions is very important. When choosing individual rootstocks, the most important factors are the content of lime in soil and resistance to drought. This survey of literature describes symptoms, reasons, and tolerance of rootstocks to lime-induced chlorosis. A high content of lime in soil participates in a blockade of iron uptake by the root system and causes the lime-induced chlorosis of plants. Chlorosis shows a significant effect on yield and quality of grapes. In association with global climatic changes, drought damages are more and more frequent in Czech vineyards. Tolerance of grapevine to drought can be influenced or controlled also by tillage and supplementary irrigation. However, rootstocks and the architecture of their root system are the most important factors. This survey of literature therefore presents and discusses factors influencing drought tolerance of individual rootstocks and of grapevine in general. The presented results may be used not only when establishing and treating new vineyards but also when choosing genetic resources suitable for breeding and selecting plants tolerance to these abiotic factors.

SOUHRN

Tolerance k chloróze vyvolané vápnem a k suchu u podnoží pro révu vinnou

Optimalizace vztahu mezi révou vinnou a podmínkami stanoviště je základem úspěšného pěstování révy vinné. Kořenový systém révy vinné vytváří podnož, a proto je důležitá adaptace podnože na podmínky stanoviště. Nejdůležitějšími faktory, které je třeba zohlednit při výběru podnože, je adaptace na obsah vápna v půdě a sucho. Tento literární přehled popisuje příznaky, důvody výskytu a toleranci podnoží k chloróze vyvolávané vápnem. Vysoký obsah vápna v půdě se podílí na blokování příjmu železa kořenovým systémem a dochází k výskytu chlorózy vyvolané vápnem na keři. Chloróza významně ovlivňuje výnos a kvalitu hroznů. V souvislosti s klimatickými změnami se stále častěji objevuje ve vinicích České republiky poškození suchem. Toleranci révy vinné k suchu je možné ovlivňovat ošetřováním půdy ve vinici nebo doplňkovou závlahou. Rozhodujícím faktorem je však opět podnož a architektura kořenového systému. Literární přehled proto uvádí vlastnosti, které ovlivňují toleranci révy vinné k suchu a toleranci jednotlivých podnoží k suchu. Shromážděné informace je možné využít při výsadbě nových vinic, ošetřování vinic a výběru genových zdrojů pro šlechtění na toleranci k těmto abiotickým faktorům.

podnož, sucho, chloróza vyvolaná vápnem, odolnost, vápno

Acknowledgements

My sincere thanks for support belong to the Ministry of Agriculture of the Czech Republic. This publication was written as a part of the research project QF 4141: Grape rootstock breeding with the use of grape genetic resources and modern testing methods.
This research project was solved within the framework of the Theme 3.1, Use of the Genetic Resources in Modern Applications; Priority 3.1.4. Improvement of the Biological Potential of Plants and Animals.

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