Scientia Horticulturae 202 (2016) 99–106

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Vegetative, physiological and nutritional behavior of new grapevine rootstocks in response to different nitrogen supply

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ARTICLE INFO

Article history:
Received 19 December 2015
Received in revised form 17 February 2016
Accepted 19 February 2016
Available online 27 February 2016

Keywords:
Vitis vinifera L.
Mineral nutrition
Vigor
Gas-exchange
Leaf chlorophyll
Soil type

ABSTRACT

Viticulture is in great need of new rootstocks sharing features of scion growth control and tolerance to major biotic and abiotic stress factors. A two year study was carried out in pots to assess performances of the two new M1 and M3 rootstocks vs. those of the commercial rootstocks 1103P and 101-14. Potted vines of M1, M3, 1103P and 101-14 rootstocks were grown in a calcareous and non calcareous soil and for two consecutive seasons subjected to three N supply levels at 0, 2 and 4 g of N per pot. Vegetative growth, leaf gas exchange, leaf greenness index (GI) and leaf blade nutrition were assessed. M1 and 1103P were the least vigorous genotypes in terms of total pruning weight; M1 also manifested a stronger apical dominance. Both M rootstocks and 101-14 showed increased leaf WUE at both N supply levels which was due to ability to maintain, at increasing N supply, similar leaf assimilation rates while significantly reducing leaf transpiration. Common tendency of any rootstocks was that increasing N supply corresponded to lowered leaf concentration of K, P, Mg and B. M1 was able to combine a series of desirable features including lower vigor, strong apical dominance, higher WUE at increasing N supply and quite well balanced leaf nutritional pattern. In the present trial M3 did not have the expected devigorating effect.

1. Introduction

Grafting is a standard practice in grape growing to overcome damage to the root system of *Vitis vinifera* L. vines caused by phylloxera (*Daktulospheria vitifoilia* Fitch) and to induce tolerance to other biotic and abiotic limiting factors (e.g. drought, flooding, salinity, etc.) (Cosmo et al., 1958; Carbonneau, 1985; Howell, 1987; Hardie and Cirami, 1988; Serra et al., 2013). Among these, tolerance to high limestone leading, in turn, to severe iron chlorosis, has been successfully tackled in the past by selecting rootstocks which might thrive even at very high lime concentration in the soil (Pouget, 1980; Galet, 1988). Conversely, availability of rootstocks carrying tolerance to drought is still an open issue which is being exacerbated by the pressure of global warming. There are several grape growing districts worldwide which were traditionally non irrigated now facing the need of additional water supply (Palliotti et al., 2014). In such instances, availability of tolerant rootstocks could allow solving the problem without necessarily having to equip the vineyard with an irrigation system (Ezzahouani and Williams, 1995; Williams, 2010; Serra et al., 2013; Tramontini et al., 2013).

Rootstock and graft union also exert profound influences on the vigor of the scion, yield and grape composition (Pouget, 1987; Wolf and Pool, 1988; Ollat et al., 2003). There is shared consensus that true semi-dwarf or dwarf rootstocks allowing permanent control of the vigor of the scion are still not available in viticulture. Therefore, unlike it usually happens in apple, there is little chance that vine growth and canopy size can be primarily controlled through the rootstock choice. More recently, the rootstock has gained attention as a quite reliable regulator of vine mineral uptake and transport (Delas and Pouget, 1979; Tardaguila et al., 1995; Keller et al., 2001; Bavaresco et al., 2003; Ibacache and Sierra, 2009; Peuke, 2009; Lecourte et al., 2015) showing significant impact on leaf and cluster mineral composition especially in regard to potassium (K), magnesium (Mg) and iron (Fe). It is quite well known, for instance, that

Abbreviations: C, calcareous; NC, non calcareous; tPW, total pruning weight; mcPW, main cane pruning weight; lPW, laterals pruning weight; *A*, assimilation rate; *E*, transpiration rate; g_s, stomatal conductance; (WUE_{inst}), instantaneous water use efficiency; (WUE_i), intrinsic water use efficiency; (GI), greenness index.

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http://dx.doi.org/10.1016/j.scienta.2016.02.032
0304-4238/

grafting on SO4 increases the attitude of accumulating K in clusters (Fregoni, 2005), which beyond certain level is detrimental to grape quality and wine stability (Mpelasoka et al., 2003). Moreover, such selectivity can alter the K-to-Mg ratio inducing physiological disorders like bunch stem necrosis and berry shrivel with negative impact on yield and fruit composition (Bavaresco et al., 2010).

By contrast, rootstock effects on nitrogen vine nutrition are quite controversial varying from significant changes (Dowton, 1985; Fisarakis et al., 2004; Holzapfel and Treeby, 2007; Ibacache and Sierra, 2009) to no changes (Csikász and Diofási, 2008; Dalbò et al., 2011). Nitrogen is recognized to be the most powerful ion at modifying vegetative growth and yield (Champagnol, 1984; Spayd et al., 1993; Bell and Robson, 1999). Nevertheless, it is well known that excessive nitrogen availability, especially when occurring in combination with vigorous rootstocks, might lead to a concurrent decline in yield and grape quality (Keller et al., 2001). The former is usually due to two main processes: excessive shoot vigor at flowering might boost natural flower drop (i.e. coulure) beyond the physiological threshold of self-regulation and heavy internal canopy shading cause by the luxury vegetation might impair floral bud induction. At the same time, final quality might decrease due to competition exerted by a too prolonged shoot growth, too compact clusters leading to higher susceptibility to cluster rot and large berry size having, especially for red wines, an unfavorable skin-to-berry ratio (Wolf and Pool, 1988; Bell and Henschke, 2005). A still open challenge in nitrogen nutrition of the grapevine is being able to assure adequate availability of the element when vine requirements are high (i.e. around flowering and fruit-set) and to restrain availability in other periods (i.e. post-veraison). Regulating uptake and assimilation of N through the rootstock would allow either to better synchronize the supply-demand function and limit leakage to the underground water in case of excessive supply (Keller et al., 2001).

At the end of the 90s, the DISAA Department from the Università degli Studi di Milano has released four new rootstocks named as "series M" having tolerance features against drought, active lime and salinity as well as ability to differentially control vigor (Porro et al., 2013; Scienza, 2013). The purpose of the present study was to assess, in a two year pot study, vegetative growth, gas exchange and leaf nutrition of two of these new rootstocks (M1 and M3) when grown in different media (i.e. calcareous vs. non calcareous soil) and supplied with different N amounts vs. two standard rootstocks (1103P and 101-14).

2. Materials and methods

2.1. Plant material and experimental conditions

In May 2011 one-year-old cuttings of two known commercial rootstocks: 101-14 (*V. riparia* × *V. rupestris*) and 1103 Paulsen (*V. berlandieri* × *V. rupestris*) and two new selections named M1 [106-8 (*V. riparia* × (*V. cordifolia* × *V. rupestris*)) × Resseguier n.4 (*V. berlandieri*)] and M3 [R 27 (*V. Berlandieri* × *V. riparia*) × Teleki 5C (*V. Berlandieri* × *V. riparia*)] were grown in 12 L pots, filled with a non calcareous sandy loamy soil (NC) and a calcareous silty clay loamy soil (C) whose main physical and chemical parameters are reported in Table 1.

Pots were located in an outside platform equipped with a drip irrigation system, white anti-hail net (about 10% attenuation of the incoming radiation) and a trellis structure to support growing shoots. Two weeks after potting, vines were fertilized twice, over a 15-day interval, with a liquid Greenplant fertilizer (Green Has Italia, Cuneo, Italy) having 15(N) + 5(P_2O_5) + 25(K_2O) + 2(MgO) + micro to deliver a total of 1 g/pot of nitrogen. During this first year, vines were shoot thinned to retain four shoots per plant so as to obtain uniform material with a good vegetative growth.

Table 1
Soil physical and chemical parameters.

Parameter	Non-calcareous soil (NC)	Calcareous soil (C)
pH in H_2O	7.9	7.9
Sand (%)	61	6
Silt (%)	30	65
Clay (%)	9	29
Texture	Sandy loamy	Silty clay loamy
Active lime (%)	2.0	10.5
Total N (‰)	0.6	0.7
CEC (meq/100 g)	7.8	11.4
Exchangeable Ca (ppm)	7	6
Exchangeable Mg (ppm)	164	81
Exchangeable Na (ppm)	11	7

In 2012, the experimental plan was set. A total of 216 two year old plants, cane pruned with 7–8 buds, was randomized in a strip-split plot design having soil as the strip, rootstock as the plot and amount of nitrogen supply as the split factor. The nitrogen levels were: N0- no nitrogen applied, N1–2 g/pot of nitrogen supply, N2–4 g/pot of nitrogen supply. The resulting 24 treatment combinations (2 × 4 × 3) were replicated three times within each block (72 vines per block). Nitrogen, as ammonium nitrate (NH_4NO_3), was given in two doses, 10 and 30 May. At the time of first supply, the number of shoots per cane was normalized to 6 shoots/plant. The trial was duplicated in 2013 under the same experimental layout.

2.2. Shoot growth and leaf chlorophyll assessment

In both years, the total length of the two central shoots along the cane of six plants per treatment combination (144 monitored shoots as a total) was recorded last week of July when shoot growth was completed. On the same vines, in February 2013 and 2014, the one-year old pruning weight was recorded and the weights of main canes and laterals annotated separately.

Leaf greenness index (GI) was non- destructively measured, at the beginning of July, by using the portable meter SPAD 502 (Konica Minolta, Osaka, Japan). Clamped leaves were those inserted at the 8th node of the same shoots used for the growth measurements. On each leaf, readings were taken at four different position and data then averaged to yield a single mean per leaf.

2.3. Leaf gas-exchange

On the same leaves used for the GI readings, the gas exchange as net CO_2 assimilation (A), transpiration (E) and stomatal conductance (g_s) was measured with an infra-red gas analyzer Ciras-2 (PP Systems, Amesbury, MA, USA) featuring a broad-leaf chamber having a window of 4.5 cm^2. All readings were taken in the morning hours (10:00–13:00) of July 11 under clear sky and saturating light condition set at 1600 $\mu mol\ m^{-2}\ s^{-1}$ through the use of a supplemental lamp mounted on top of the chamber. Air flow was adjusted to 300 mL/min and inlet CO_2 was set at 400 ppm by using a cartridge system. Assimilation rate data was expressed as $\mu mol\ CO_2\ m^{-2}\ s^{-1}$ while transpiration rate and stomatal conductance data were given as $mmol\ H_2O\ m^{-2}\ s^{-1}$. Instantaneous and intrinsic water use efficiency (WUE_{inst} and WUE_i, respectively) were then calculated as A/E and A/g_s ratios.

2.4. Mineral ions analysis

At the end of July 2012 and 2013, leaves inserted at node 7 and 8 of the three central shoots of the same vines used for the SPAD and gas exchange readings were sampled yielding a total of 432 collected leaves per year (18 leaves per replicate). Leaves were then washed in distilled water, dried in a forced air oven at 65 °C, ground, and digested with HNO_3, in a microwave, after which blades were