Scientia Horticulturae 227 (2018) 48–56

Contents lists available at ScienceDirect

Scientia Horticulturae

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

ResearchPaper

Cane properties, yield, berry quality attributes and leaf nutrient composition of blackberry as affected by different fertilization regimes

Tomo M. Milošević[a,*], Ivan P. Glišić[a], Ivana S. Glišić[b], Nebojša T. Milošević[b]

[a] Department of Fruit Growing and Viticulture, Faculty of Agronomy, University of Kragujevac, Cara Dusana 34, 32000 Cacak, Serbia
[b] Department of Pomology and Fruit Breeding, Fruit Research Institute Cacak, Kralja Petra I/9, 32000 Cacak, Serbia

ARTICLE INFO

Keywords:
Berry quality
Fertilizer
Natural zeolite
Productivity
Rubus spp.

ABSTRACT

Research was conducted during three consecutive years to evaluate the effects of compound NPK (15-15-15), cattle manure and natural zeolite, commercially named “Agrozel”, applied alone or in combination, on cane properties, yield, berry quality attributes and mid-summer leaf mineral status of ‘Thornfree’ blackberry grown on an acidic, shallow, heavy-textured soil in the region of Cacak, Western Serbia.Results revealed that all evaluated traits significantly differed among fertilizer treatments and across years in general. In most cases, all evaluated properties, except leaf nutrient content, were affected by the fertilizer treatment × year interaction. Generally, mixtures of NPK, cattle manure and Agrozel (T_3) and NPK and cattle manure (T_7), and NPK alone (T_1) in most cases had better and similar capacity to improve primocane growth, bearing shoot characteristics, productivity, berry physical properties and levels of some macro- and micronutrients compared to other treatments, whereas the combined applications of Agrozel and manure (T_4) and NPK and Agrozel (T_5) and especially Agrozel alone (T_6) induced the lowest values for most properties. The effect of fertilization treatments on berry soluble solids content (SSC), titratable acidity (TA), juice pH and leaf N, Mg and Zn levels was not significant. The highest values of cane traits, berry external attributes and RI were obtained in 2008, yield, berry acidity, most of leaf nutrients in 2010, and SSC and juice pH were found in 2009, respectively. DOP and ΣDOP indexes revealed that primocane leaf nutrient amounts were within recommended levels, except P, K and B, which were below recommended standards. Three-year fertilization induced a good leaf nutrient balance.

1. Introduction

Blackberry is a very popular and widely grown fruit crop worldwide, particularly in regions with mild winters and moderate summers, and can easily adapt to different ecological conditions. Blackberries are consumed fresh, frozen or commercially processed into a variety of foods and other products such as jams, jellies, sauces, purees, wines, tea, ink, dyes, fruit leather, and medicine (Türemis et al., 2003). Also, they can be canned or dried. Berries are highly nutritious, containing high amounts of soluble fiber, vitamins and minerals; they also have high levels of antioxidants and anti-carcinogenic i.e. cancer preventive natural substances (Moyer et al., 2002).

In the past few decades, blackberry production has rapidly increased (Strik et al., 2007; Meyers et al., 2014). Today, the largest world producer is USA, followed by Mexico and China. In the earlier period, Serbia accounted for 69% (5300 ha) of Europe’s blackberry area, and had the greatest blackberry area in the world. This country produced about 25,000 t, the fourth highest production in the world, with 90% of blackberry production processed and exported (Strik et al., 2007). However, due to low berry prices in 2008 and 2009 and extremely severe winter frost and summer drought in 2012, Serbian blackberry production and blackberry area drastically dropped, with 16,000 t produced from 2009 to 2013 i.e. 4000 t on average (Milošević, unpublished data). There is substantial production in a number of other countries, and future growth is expected.

Blackberry plants have a unique life cycle. They are perennial, but fruiting is biennial (Ali, 2012). Primocanes, vegetative shoots developed in the current growing season, emerge, grow, develop floral and vegetative buds, and over-winter (Meyers et al., 2014). Floricanes are reproductive shoots in the second year of growth, when they flower, produce berries, die, and are pruned out. For these reasons, primocane management in the first year ultimately influences the yield and berry quality in the following growing season (Cortell, 1996).

Growers worldwide, including Serbia, want high yields, large sweet berries with a pleasant flavor and long shelf life. These aspirations can be accomplished using intensive orchard management practices, including fertilization due to the fact that fresh berries are highly perishable and that their production, quality and shelf-life can be greatly

* Corresponding author.
E-mail address: tomomilosevic@kg.ac.rs (T.M. Milošević).

http://dx.doi.org/10.1016/j.scienta.2017.09.013
Received 16 January 2017; Received in revised form 19 July 2017; Accepted 16 September 2017
0304-4238/

Table 1
Average monthly values of air temperature and sum of precipitation during vegetative cycle for the period 1965–2010 and three studied years.

Period	Air temperature (°C)								Precipitation (mm)							
	Apr	May	Jun	Jul	Aug	Sep	Oct	VC	Apr	May	Jun	Jul	Aug	Sep	Oct	VC
1965–2010	11.5	16.8	20.0	21.5	21.2	16.7	11.4	17.0	51.6	72.7	87.3	79.1	58.0	56.2	51.1	456.0
2008	13.7	19.4	23.3	23.5	25.3	15.9	14.0	19.3	35.5	36.0	79.0	95.6	36.0	73.0	30.5	385.6
2009	14.8	20.2	21.4	24.0	24.7	19.2	11.6	19.4	12.5	43.0	98.4	41.0	35.5	30.0	91.5	351.9
2010	13.3	17.9	21.3	23.5	23.7	17.3	10.0	18.2	52.0	98.8	81.0	90.0	78.5	25.0	63.0	488.3

VC: vegetative cycle.

affected by different factors. Nutrition and fertilization are pre- and postharvest practices that affect productivity and fruit quality, and must be performed very carefully (Pritts, 2008; Strik, 2013). In Serbia, blackberry and other fruit growers widely use compound NPK (15-15-15) and N mineral fertilizers, and farmyard manure (Milošević et al., 2013). Compound NPK fertilizer and manure are applied to soil in late autumn, and N fertilizer is used in early spring, whereas micronutrients are incorporated when they are deficient. In the past two decades, in some Serbian plantations, particularly pome and stone fruit ones, established on soils with poor physical and chemical traits, clinoptilolite (natural zeolite) as a soil conditioner and slow release carrier and enhancer of fertilizers, commercially named "Agrozel", alone or in combination with mineral (N, P and/or K) and organic (manure) fertilizers, was applied in late autumn. Reasons for the use of natural zeolites are numerous, the most important being their positive effect on soil and plant in increasing soil electrical conductivity, thereby increasing nutrient retention capacity and soil pH. Also, natural zeolites are an important source of many nutrients (N, K, Ca, Mg, micronutrients) (Polat et al., 2004), they improve water use efficiency by increasing soil water holding capacity and water availability to plants (Reháková et al., 2004; Pal et al., 2013), thus directly and indirectly improving yield and fruit quality (Milošević et al., 2013). Serbian blackberry growers tend to use excessive amounts of fertilizers, thereby increasing production costs and potentially causing numerous environmental problems and damage through soil and water contamination.

Given the little, in some cases poor experience with blackberry fertilization, the main goal of this study was to evaluate the vegetative growth, bearing potential, berry quality parameters and leaf nutrient composition of 'Thornfree' cultivar grown in the Cacak region (Western Serbia), as dependent on fertilization treatments, including soil applications of two fertilizers (compound NPK, cattle manure) and natural zeolite used alone and in combination. We believe that the results will help to improve yield and fruit quality of blackberries.

2. Material and methods

2.1. Study area and experimental layout

The study was conducted in 2008, 2009 and 2010 in an orchard located in the Gornja Gorevnica village (43°57′N, 20°19′E, 400 m a.s.l.) of the Cacak region (Western Serbia), a traditional fruit tree culture region. 'Thornfree', a trailing type of blackberry, as the most commonly grown cultivar in Serbian plantations, was used as a plant material. The plantation was established in 2005. Plants were spaced 1.2 m within rows and 3.0 m apart. I-trellis consisted of posts (spaced 7 m apart) and three horizontal wires at 0.7, 1.4 and 1.8 m above ground level with three cross arms. No primocane suppression was done in any treatment. In all three years, plants were pruned to establish treatments of 3–4 floricanes per plant. Floricane training was done in mid March. Floricanes were shortened to 2–3 buds above the top wire (total floricane height was about 2 m). Lateral branches were shortened to 2–3 buds. Before trial establishment, i.e. from 2005 to 2007, the plantation was fertilized in autumn with compound NPK (15-15-15) at a rate of 250 g per bush.

A randomized complete block design with ten plants (bushes) per treatment in four replicates ($n = 40$) was used. Fertilization treatments included: T_1 [compound NPK (15-15-15) mineral fertilizer (0.05 kg m^{-2})], T_2 [cattle manure (1 kg m^{-2})], T_3 [NPK (0.05 kg m^{-2}) + Agrozel (1 kg m^{-2}) + cattle manure (1 kg m^{-2})], T_4 [Agrozel (1 kg m^{-2}) + cattle manure (1 kg m^{-2})], T_5 [NPK (0.05 kg m^{-2}) + Agrozel (1 kg m^{-2})], T_6 [Agrozel (1 kg m^{-2})], and T_7 [NPK (0.05 kg m^{-2}) + cattle manure (1 kg m^{-2})]. Briefly, Agrozel (commercial name of natural zeolite) has a particle size of ≤1.0 mm, cavity volume of about 34%, a high thermal stability and a cation exchange capacity (CEC) of 216 mmol M^+ 100 g^{-1} (Daković et al., 2007). Well-rotted cattle manure, obtained from a local farm and about 7 months old, had the following average values of chemical characteristics: total N (N_{TOT})–0.54%, P_2O_5–0.31%, K_2O–0.63%, Ca–0.30%, Mg–0.11%, Fe–647 mg kg^{-1}, Mn–171 mg kg^{-1}, Cu–13.23 mg kg^{-1}, Zn–224 mg kg^{-1}, B–15 mg kg^{-1}, organic matter-15.6%, electrical conductivity-6.32, C:N ratio-18:1 and pH = 6.2 in 0.01 M KCl.

From 2007 to 2009, in late autumn, each fertilizer and natural zeolite, either alone or combined, were applied parallel to the row, 0.5 m from the row center. Fertilizers were applied to the soil with a field cultivator. The plantation was managed following the usual standard practice withot irrigation.

2.2. Weather conditions and soil traits

Some climate data for the research area are presented in Table 1. In the three experimental years, air temperature was higher than the long-term average, especially in 2008 and 2009. In the same period, precipitation was lower in 2008 and 2009, and higher in 2010 than the long-term average.

Soil chemical properties were examined prior to trial establishment. Soil samples were collected from 0 to 20 cm depth. The investigations were conducted on a shallow eroded vertisol or 'smonitza' soil consisting of 10% gravel and coarse sand (R > 1.00 mm), 54% sand (R = 0.05–1.00 mm), 29.88% silt (R = 0.002–0.05 mm) and 6.12% clay (R > 0.002 mm). The soil texture was clay-loam. The soil contained 1.70% organic matter, 0.14% N_{TOT}, 6.80 mg 100 g^{-1} available P_2O_5 and 26.8 mg 100 g^{-1} available K_2O. Soil pH in 0.01 mol L^{-1} KCl was 5.07 (slightly acidic).

2.3. Measurements

During the research period, primocane growth, bearing potential, yield, fruit quality attributes and leaf nutrient composition were monitored.

2.3.1. Cane, yield and berry quality characteristics

Mean lengths of primocanes and fruiting laterals were measured as recommended by Davidson (1993) and expressed as m and cm, respectively. Number of fruiting laterals per floricane and number of umbels per fruiting lateral were determined. Four primocanes and/or floricanes per 10 plants in four replicates ($n = 40$) per fertilizer treatment were used for the above evaluation.

In 'Thornfree', the minimum cane density required for maximum