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Nutrient status of the American cranberry in Latvia (2005–2016)

A. Karlsons* and A. Osvalde

Institute of Biology, University of Latvia, Laboratory of Plant Mineral Nutrition, Miera street 3, Salaspils, Salaspils municipality, LV-2169, Latvia
*Correspondence: andis.karlsons@lu.lv

Abstract. The American cranberry (*Vaccinium macrocarpon* Aiton) is an evergreen groundcover plant native to North America. Nowadays cranberries are successfully cultivated in Latvia with total plantings of more than 125 ha. Being a native wetland plant, cranberries are considered as nutrients low requiring crop, however, balanced mineral nutrition is one of the key factors that determine plant growth and yield development. Surveys were carried out to determine the actual status and trends in mineral nutrition of American cranberries in Latvia during 2005–2016. Together 190 plant samples were collected from different cranberry producing sites in Latvia over 3 periods: 2005–2007, 2008–2011 and 2012–2016. Cranberry tissue analyses were used as diagnostics method to control plant nutrient (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Mo, B) status. The obtained results revealed notable nutrient imbalance in the years of the study. In general, our results suggest that only about 50% of plant tissue nutrient indices were in the sufficient range. Deficiency of N P, S, Fe, Cu, and Mo, and high levels of Mn was found in the majority of samples analyzed. In general, diverse tendencies were stated for the nutrient supply of cranberries from 2005 to 2016: positive trend in nutrient status of cranberry crop were found for N, K, Ca, while mean concentrations of S, Fe and Mo, as well as frequency of optimal indices decreased. The small count of nutrient indices in high till toxic range suggested on environmentally sound way of cranberry fertilization practices in Latvia.

Key words: *Vaccinium macrocarpon* A., plant analysis, mineral nutrition.

INTRODUCTION

American cranberry (*Vaccinium macrocarpon* Aiton) is evergreen, perennial groundcover plant native to eastern and central North America including the eastern territories of Canada (Trehane, 2004). Commercial production of cranberries in the United States of America has existed for close to two centuries (Eck, 1990).

American cranberry has significant commercial value and offers important health benefits. Cranberry fruits are rich sources of bioactive compounds, such as phenolics, organic acids, anthocyanins, proanthocyanidins, flavonol glycosides and sugars (Reed, 2002; Szajdak & Inisheva, 2016). Cranberry juice and fruits are widely reported to demonstrate a number of health advantages including: inhibition of development and progression of cancer and cardiovascular diseases, antimicrobial activities and prevention of urinary tract infections and stomach ulcers, cholesterol reduction and the reduction of biofilm formation (Vattem et al., 2005; Chi-Hua Wu et al., 2008; Blumberg et al., 2016; Maki et al., 2016; Das et al., 2017). Berries are also valued for their fresh taste as well as their potential for being processed. Today, an increasing demand for healthy ingredients by the food industry and changed consumer consciousness provide great opportunities for further progress of cranberry production.

In general, about 98% of global production comes from the United States of America and Canada alone. However, with more than 125 ha of commercial plantings, Latvia is the fifth major cranberry producing country (worldatlas.com). The cultivation of cranberries in Latvia is comparatively recent – the first experimental plantation was established in 1985, but commercial cultivation of American cranberries started in last 20 years (Osvalde & Karlsons, 2010). Latvia is a country with abundant peat resources and intensive peat production. The total area of peatlands covers 10.7% of the entire territory and raised bogs occupy more than 41% of the peatlands. At present, about 9% of Latvia's raised bogs (about 70,000 ha) are affected by peat extraction, 20,000 ha are nearly exhausted (Osvalde et al., 2010; Silamikele et al., 2011). Therefore, the need of recultivation of more than 17,000 ha abandoned and excavated high bogs, along with moderate climate, sufficient freshwater supply, and high market demand provide excellent cranberry growing conditions.

Overall, cranberry growth and development are affected by many internal (plant physiology, genetics) and external factors such as light, temperature, water availability and quality. The cranberry plants are adapted to sandy (North America), nutrient-poor, low pH soils and its nutritional requirements are low compared with many other perennial fruit crops. However, proper mineral nutrition is one of key factor which can affect cranberry yield amount and quality (Roper, 2009; DeMoranville, 2015). While cranberry nutrient management and status in the North America has been studied in considerable detail, mineral nutrition problems of cranberry crop in Latvia and other European countries where production is recent have not been elucidated sufficiently (Osvalde & Karlsons, 2010; DeMoranville, 2015). In the United States and Canada cranberries are grown in beds layered with sand, peat, and gravel located in bogs which were originally formed as a result of glacial deposits. Applying 0.6 to 2.5 cm of surface sand to cranberry beds every 3 to 5 years is a common practice in commercial cranberry production for the majority of cranberry plantations in North America. As a result rooting zone typically contains about 95% sand (Davenport & Schiffhauer, 2000). Mostly sand is applied to cover old runners to stimulate new root development and upright production, as well as to control weeds and pests (Eck, 1990; Sandler et al., 2014). Also, roughly 90% of growers use a flood to protect the plants from desiccation in the winter and to harvest the fruit in the fall (DeMoranville, 2008). These cultivation conditions and technologies are considerably different from those in Latvia where cranberry plantings are mostly developed in raised bogs and flooding technique is not used. Therefore, direct application of nutrient recommendations from N. American production areas is limited. Considering that average yield in Latvia (2.3 t ha^{-1}) is significantly lower to compare with the United States of America (23.2 t ha^{-1}) and Canada (27.9 t ha^{-1}) research on mineral nutrition as one of potential limiting factors of reduced yield of American cranberries in Latvia are critically important (factfish.com). Over the last few years, several investigations into optimal cultivation technologies of cranberry crop grown in raised bogs were made. These studies are only in preliminary stage and reports concerning the mineral composition of cranberry plants grown in acid sphagnum peat as well as nutrient concentrations in this specific substrate are still scarce (Osvalde & Karlsons, 2005; Osvalde & Karlsons, 2010). A survey was carried out to determine the status and main trends in mineral nutrition of American cranberries in Latvia over 3 periods: 2005–2007, 2008–2011 and 2012–2016. Plant tissue analysis was used to evaluate the availability of nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Mo and B) in cranberry production in Latvia.

MATERIALS AND METHODS

Together 190 cranberry plant samples were collected from 10 different commercial cranberry producing sites in Latvia over three time periods 2005–2007 (44 samples), 2008–2011 (72 samples) and 2012–2016 (74 samples). All plantations were developed on extracted raised bogs and annually fertilized. For each plant sample 200 upright tips of current season were collected from locations representative of the planting. For analysis of nutrients, dry plant material was finely ground using a laboratory mill. Samples were dry-ashed in concentrated HNO_3 vapors and re-dissolved in 3% HCl for K P, Ca, Mg, Fe, Cu, Zn, Mn, B and Mo detection. Wet digestion was used for for N (in H_2SO_4) and S (in HNO_3) determination in plant samples. The levels of Ca, Mg, Fe, Cu, Zn, and Mn were measured by atomic absorption spectrophotometry (AAS) *AAnalyst 700* (PerkinElmer, Singapore), acetylene-air flame (Page et al., 1982; Anonymous, 2000). K was detected with the flame photometer *JENWAY PFPJ* (Jenway Ltd, Gransmore Green, Felsted Dunmow, Essex, UK). The contents of P, Mo, N, S, and B were determined by colorimetry: P – by ammonium molybdate in an acid reduced medium, Mo – by thiocyanate in reduced acid medium, N – by Nesler's reagent in an alkaline medium (modified Kjeldal method), B – by hinalizarine in sulphuric acid medium, S – by turbidimetric method by adding $BaCl_2$ with a spectrophotometer *JENWAY 6300* (Barloworld Scientific Ltd., Gransmore Green Felstad, Dunmow, Essex, UK) (Rinkis et al., 1987; Karlsons et al., 2008; Osvalde, 2011). The statistical analysis of the results was carried out using *MS excel 2016* software. Standard errors (SE) were calculated in order to reflect the mean results of chemical analysis. T-test 'Two-Sample Assuming Unequal Variances' at $P < 0.05$ was used for testing the differences between study periods. Evaluation of the mineral nutrition status of American cranberry was done on the basis of tissue standards developed by Nollendorfs (1998) for Latvia.

RESULTS AND DISCUSSION

To characterize the nutrient status of American cranberries in Latvia the levels of 12 essential nutrients were estimated in plant tissue samples. The acquired results – mean and range of macro and micronutrient concentrations in cranberry leaves, as well as tissue standards developed by Nollendorfs (1998) for American cranberries in Latvia are shown in Table 1. Our results suggest that from 2005–2016, only 50% of plant tissue nutrient indices were in sufficient range (Fig. 1). Percentage of plant samples with low, optimal and excessive amount of nutrients clearly revealed main cranberry mineral nutrition problems in Latvia (Table 2). Overall, mean macronutrient concentrations in plant tissue could be characterized as optimal, with the exception of low N (2005–2007; 32% optimal), slightly decreased P (2005–2016; 16–38% optimal) and S (2008–2016; 15–43% optimal). Different trends in macronutrient status of cranberries were found between analyzed time periods from 2005 to 2016, depending on the particular nutrient. Optimal mean values increased for nitrogen from 0.78 (2005–2007) to 0.91% (2012–

2016). Percentage of samples in the optimum range also increased from 32% to 38% accordingly (Table 2). Despite the fact that mean N concentrations for time periods 2008–2011 and 2012–2016 were similar, only 29% of indices were in optimal range for 2008–2011. It is explainable by high dispersion of the N concentration in cranberry tissue samples: from serious deficiency (0.45%) to abundance (2.85%).

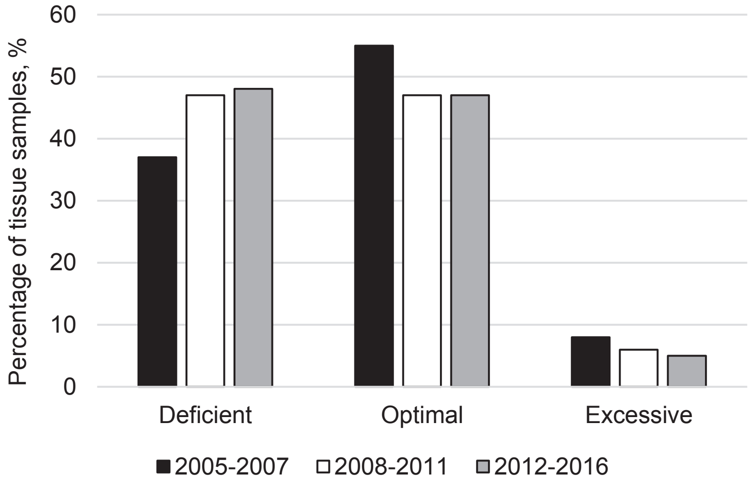

Figure 1. Distribution of total nutrient indices in different nutrient supply levels for cranberry tissue samples in Latvia, 2005–2016.

It should be noted that nitrogen is one of a key element in cranberry nutrition and adequate fertilization is necessary to maintain renewal growth, crop production, and flower bud development for next year's crop (Davenport, 1996; DeMoranville, 2015). The results obtained by Osvalde et al. (2011) on macronutrient concentrations in peat samples from different cranberry producing plantings in Latvia established on extracted raised bogs demonstrated serious N deficit in almost all of the peat samples, as well as insufficient mean concentrations of S.

Although a decrease of mean concentration of K was found in 2012–2016, in comparison to previous time periods, leaf K status for cranberries in Latvia could be characterized as optimal till high, as compared to sufficiency levels.

In general, a high range of macronutrient N, K and S concentrations was found: the ratio of the highest/lowest concentration for N-6, K-14 and S-9. Decreased S levels and a broad range of concentration are likely associated on the one hand with naturally low S concentrations in peat and increased leakage promoted by anionic properties, and on the other hand – with standard application of sulphate containing fertilizers.

Table 1. Nutrient concentrations in cranberry plant samples in Latvia, 2005–2016

Element	Concentrations in dried tissue						Optimal levels
	2005–2007		2008–2011		2012–2016		
	Range	Mean±SE	Range	Mean±SE	Range	Mean±SE	
Macronutrients, %							
N	0.40–1.35	0.78 ± 0.04a*	0.45–2.85	0.88 ± 0.04b	0.56–1.90	0.91 ± 0.03b	0.90–1.50
P	0.09–0.28	0.15 ± 0.01a	0.06–0.30	0.15 ± 0.01a	0.07–0.3	0.14 ± 0.01a	0.17–0.35
K	0.33–0.94	0.59 ± 0.02b	0.15–2.1	0.61 ± 0.03b	0.27–0.89	0.52 ± 0.02a	0.35–0.75
Ca	0.21–1.27	0.73 ± 0.04a	0.33–1.56	0.72 ± 0.03a	0.39–1.13	0.71 ± 0.02a	0.55–0.95
Mg	0.16–0.44	0.25 ± 0.01a	0.13–0.55	0.24 ± 0.01a	0.13–0.41	0.24 ± 0.01a	0.17–0.35
S	0.07–0.35	0.13 ± 0.01a	0.04–0.36	0.12 ± 0.01a	0.06–0.18	0.11 ± 0.01a	0.13–0.30
Micronutrients, mg kg^{-1}							
Fe	20–116	52.2 ± 3.2b	24–160	50.9 ± 2.8b	20–55	37.2 ± 1.2a	60–200
Mn	34–500	159.6 ± 15.1b	38–850	199.9 ± 20.5c	18.4–320	103.6 ± 8.5a	35–140
Zn	11–42	29.5 ± 1.0b	9–52	31.6 ± 1.1b	18.6–42	26.6 ± 0.6a	25–90
Cu	2.2–104	13.2 ± 3.2b	0.4–78	6.9 ± 1.2a	1.8–90	25.2 ± 3.9c	6.0–15.0
Mo	0.05–1.6	0.38 ± 0.05b	0.1–1.5	0.41 ± 0.03b	0.1–0.7	0.29 ± 0.01a	0.5–5.0
B	14–92	35.6 ± 2.1c	10–72	29.7 ± 1.5b	9–62	24.5 ± 1.2a	25–70

*Means with different letters in a row were significantly different (t-Test, $p < 0.05$, a< b < c).

Table 2. Distribution of cranberry plant tissue samples in different nutrient supply levels in Latvia, 2005–2016

Element	Percentage of samples (%) in different nutrient supply levels								
	2005–2007			2008–2011			2012–2016		
	Low	Optimum	Excessive	Low	Optimum	Excessive	Low	Optimum	Excessive
N	68	32	0	65	29	6	59	38	3
P	62	38	0	57	43	0	84	16	0
K	2	85	13	10	71	19	7	86	7
Ca	29	57	14	19	65	15	14	80	7
Mg	0	98	2	8	81	11	3	96	1
S	45	53	2	56	43	1	85	15	0
Fe	73	27	0	85	15	0	100	0	0
Mn	0	57	43	0	46	54	0	89	11
Zn	9	91	0	25	75	0	31	69	0
Cu	60	20	20	71	17	13	59	11	30
Mo	72	28	0	82	18	0	99	1	0
B	18	80	2	39	58	3	41	59	0

The levels of micronutrients in plant tissue were of particular interest as, with the exception of Zn and B, a serious imbalance in the microelement supply was found (Table 1). Insufficient levels of Fe and Mo, as well as increased concentrations of Mn, were found in in the vast majority of plant samples. In the years 2005–2011 only 15–27% of the samples had tissue Fe at concentrations ≥ 60 mg kg^{-1} which is optimal for cranberry growth, but in time period 2012–2016 already 100% of Fe indices were in insufficient range. The vast majority of samples tested (72–99%) were also insufficient in Mo (below 0.50 mg kg^{-1}). On contrary, there were no samples tested deficient in Mn. Moreover, about 43% (2005–2007), 54% (2008–2011) and 11% (2012–2016) of them were in the high range (above 150 mg kg^{-1}). Our study suggests that the increased Mn concentrations reflect high Mn availability in a low-pH cranberry soils (Osvalde & Karlsons, 2010) and possible application of Mn containing fertilizers.

At the moment the relationship between Mn and Fe in plants from acid soils has been little studied. In Nova Scotia, Canada, (Lockhart & Langille, 1962) measured Mn/Fe ratios in the leaves of lowbush blueberry (*Vaccinium angustifolium* Ait.), an acidophilic Ericaceous plant like cranberry, indicating possible interference of Mn with the uptake and utilization of iron at low pH values. The interaction between Mn and Fe, low Fe concentration in growing media, as well as insufficient fertilization are likely main reasons for dramatically low Fe supply in cranberry leaves. Low Fe supply in growing medium and accordingly in plant tissue are fundamental distinction compared Latvia and North America. In USA bog environments typically have abundant concentrations of soluble iron and other metals that may be even toxic to non-adapted plant species (Siebach et al., 2015).

According to recommendations based on first studies on cranberry nutrition in Latvia foliar supply of micronutrients (Fe, Cu, B, Mo) should be applied to correct specific deficiencies found in tissue tests (Osvalde & Karlsons, 2005). Our study demonstrates that only Cu status becomes more correspondent to tissue standards.

On, average 50% of the samples had tissue Cu levels below the optimal value of 6 mg kg^{-1}, while 20% to 30% were in high range (above 15 mg kg^{-1}). We suggest that considerable heterogeneity of Cu concentrations found in all study periods are linked with: a) excessive Cu levels were caused by contamination from foliar fertilizers and the use of fungicides with high Cu content, and b) insufficient Cu concentrations – by extremely low levels of Cu in the growing medium and lack of appropriate fertilization. In general, the results presented in our study differ from those of Roper & Combs (1992) for the nutrient status of Wisconsin cranberries where, with the exception of Zn, almost all cranberry producing beds had adequate conditions of mineral nutrition.

CONCLUSION

The main goal of cranberry fertilization is to remove limitation to yield and quality by supplying the plants with all nutrients in optimal concentrations. Plant tissue analysis revealed serious imbalance in American cranberry providing with essential mineral elements in Latvia during 2005–2016. Deficiency of N P, S, Fe, Cu and Mo was stated for vast majority of samples tested. Consequently, particular attention should be paid for decision making about fertilizer application rates and methods, as well as timing for these nutrients in cranberry nutrient management plan. Significant changes were found in the average nutrient concentrations during the past 12 years, showing a trend towards increase in nutrient status of N, K and Ca. Our research also reflects the decrease in concentration level and frequency of optimal indices for S, Fe and Mo. The present investigation suggests that environmentally wise cranberry fertilization in plantings mainly established on cutover peatlands is a site-specific decision and should be based on the precise analytical basis not only to obtain high and qualitative yield but also to prevent bog contamination.

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