INFLUENCE OF SOIL MODIFICATION ON CHANGE IN ITS PROPERTIES AND MINERAL NUTRITION OF HIGHBUSH BLUEBERRIES

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Abstract
Blueberry cultivation is becoming more and more popular in Latvia, and several commercial plantations have been established recently. Highbush blueberries (*Vaccinium corymbosum* L.) are perennial and can grow without replanting for 50 years, therefore a choice of soil and its preparation have a great role. This article summarizes results of research carried out in commercial blueberry plantation established in 2004 on loamy Haplic Cambisol. Soil properties, especially reaction and organic matter content, initially were not suitable for blueberry cultivation, therefore deep tillage and application of soil conditioner (acid sphagnum peat) were done before planting and similar peat mulch was applied every second year. Berry yield of 4 blueberry cultivars, soil properties and the nitrogen, phosphorous and potassium content in growing plant leaves were determined. The obtained results showed that sphagnum peat is an effective material for lowering of soil pH in plant root layer (0 – 40 cm). Data about plant nutrient content in topsoil and subsoil as well as in growing plant leaves will help to develop criteria for soil fertility assessment and diagnosis of plant nutrition.
Key words: blueberries; cultivation in Latvia; soil properties**.**

Introduction

Highbush blueberries (*Vaccinium corymbosum* L.) raised interest in Latvia's farmers around 1995 when first plantations were established. At the same time, research was started together with studies of experience as the countries where this crop has already been grown commercially. Interest about the use of berries, their processing and marketing increased. Will highbush blueberry cultivation become the success story for Latvia like it happened in Chile, it depends on many circumstances but it is very feasible that there is a chance for diversification of agricultural activities (Buģina and Reševskis, 2009).

The experience obtained from other countries as well as in Latvia shows that blueberries have specific soil requirements, therefore not always it is possible to find a place where soil properties naturally are appropriate. Potential growers shall consider that scrupulous investigation of soil properties as well as good knowledge about blueberries requirements are the basic factors for successful selection of place where plantation might be established. Modification of soil properties (if possible) and site preparation are activities which should be done before blueberries are planted. Importance of that is high because the highbush blueberries are perennial plants which will stay at the same place up to 50 years without replanting. Only the above-ground parts of the bush are renewed periodically. Therefore site preparation, soil amelioration, variety and plant density selection, methods of growing, etc., are items which should be considered very carefully for establishment of a high productive and long-lasting highbush blueberry plantation. The research hypothesis was that appropriate modification of soil properties gives possibility of expanding the possible highbush blueberry cultivation area and to help its expansion in Latvia.

In Latvia, there is not many research data about the influence of soil physical and chemical properties on the development of vegetative and reproductive parts of highbush blueberries as well as about the methods suitable for modification of soil properties. Therefore the aim of the study was to investigate the influence of soil modification methods on its main properties which have importance for highbush blueberry cultivation.

Materials and Methods

Research was carried out at „Bīsnes" farm Mazozoli parish Ogre district in 2011 on the basis of a high bush blueberry plantation established in 2004. The total acreage of the plantation is 3 hectares with planting density of 2000 plants per 1 ha. Predominant soil – Base-unsaturated brown soil (Latvijas augšņu …, 2009) or Haplic Cambisol (WRB – World Reference Base for soil Resources), sandy loam, developed on stony moraine (Augšņu diagnostika ..., 2008). Original topsoil's reaction pH H_2O – 6.14, pH KCl – 5.37, and organic matter content – 25 g kg^{-1}. Before planting of bushes, radical improvement (change) of soil properties was done. In 2007, fertigation system was constructed. Experimental plots were set up on a convex slope in different relief positions. In 2004, bushes were planted in 1.65 × 3 m rows, which were deep cultivated and mixed with acid (pH KCl 3.0 ± 0.3) sphagnum peat. The same kind of peat was used every second year as a mulch to cover a 5-cm layer on soil surface between bushes. A strip, 0.7 m wide, along the bushes was kept free of vegetation during summer, but grasses *Lolium perenne* L., *Phleum pratense* L., *Festuca pratenis* H. and *Festuca rubra* L. were sown and periodically mown in inter-row space.

Research was performed in 5 plots located in different positions on slope and representing different (4) varieties of highbush blueberries. Each plot consisted of 7 fully developed bushes located in one row. Soil sampling was done in April 19 in each plot and in two depths – 0-20 and 20-40 cm. Two soil profiles in different locations were prepared and described. The following analytical methods were used for soil analysis: pH – potentiometrically in 1*M* KCl suspension; organic matter (OV) for mineral soils – using Tyurin's method, for organic soil – by dry combustion; total nitrogen – by Kjeldahl method; plant available phosphorous and potassium in mineral soil – by Egner–Riehm method, but in organic soil – total concentrationa after dry ashing of sample. Soil physical properties were measured in June and repeated in August. Undisturbed soil samples using 50 mL stainless steel cylinders were collected for bulk density, porosity and field capacity measurements.

Two times per season, plant leaf samples from each plot were collected: in July 8 from previous year shoots, and in August 5 from new shoots. Total nitrogen was tested using Kjeldahl method, but after ashing total phosphorus (calorimetrically) and potassium (flame photometry) as well as total manganese (atom absorption) concentrations were analyzed.

Results and Discussion

Soil conditions (more important for highbush blueberry growth and development), which should be considered and monitored, are those, located within the strip where plant's roots are located. According to publications (Pormale et al., 2009), the main root distribution (around 90% by mass) of blueberries is within the 1-m strip horizontally and up to the depth of 40 cm vertically. Therefore, the main focus related to the soil conditioning, tillage and fertiliser application should be performed there.

Soil investigation (morphological observations, sampling and profile descriptions) showed that soil cover despite of different topography was comparatively homogenous without contrasting inclusions. Soils could be regarded as typical mineral soils belonging to the automorphic genetic class. In the lower part of hillside, the occurrence of free carbonates starts from the depth of 100 cm. These soils correspond to the Base unsaturated brown soil group (Latvijas augšņu ..., 2009). The soils located on the upper part of the morainic hill had a slightly different parent material. Firstly, at a shallow depth (40 cm), clayey material (lens) as well as fragments of dolomite were located. Therefore occurrence of carbonates started already within the depth of 30 cm. These soils according to the Latvia Soil classification correspond to the Eroded sod-calcareous group. According to the WRB 2006 classification, both of them are Haplic Cambisols.

Soil investigations showed that the plantation of highbush blueberries was established and it operates on a typical mineral soil formed on low calcaric till. Numerous researchers suggest that such soils are not suitable for highbush blueberries due to the high pH, low organic matter content, high soil density etc. Therefore, if other soils, more suitable for blubbery cultivation, are not available on the place, some modifications in soils' initial properties might be necessary. These activities were performed using deep (40 cm) ploughing in strips where bushes were planted, acid sphagnum peat was incorporated as well as bush strips were periodically covered with peat and sawdust mulch. Using such technique, soil conditions around the blueberries were transformed and together with the irrigation and fertilizer use provided good conditions for plant growth and productivity of berries within the range of 4 to 5 tons per ha annually.

Influence on soil's physical characteristics. One of the parameters important for any crop growth is bulk density of substratum. They survey showed that soil properties in the strips had changed dramatically, growth media is not more the real soil but rather substratum. As bulk density is dependent on moisture conditions, sampling was done twice – on June 9 and August 19. Parameters of bulk density measured on June 9, when vegetation was fully renewed and moisture conditions were typical for this time of year, are shown in Figure 1. Measurements were done in both sites – in lower part of plantation (soil profile) and in the upper part (additional site). Two sampling points were chosen in every site – unchanged soil in inter-row and modified substratum in the strip of bushes. Stepwise sampling using 5 cm increments from the soil surface up to 40 cm depth was applied.

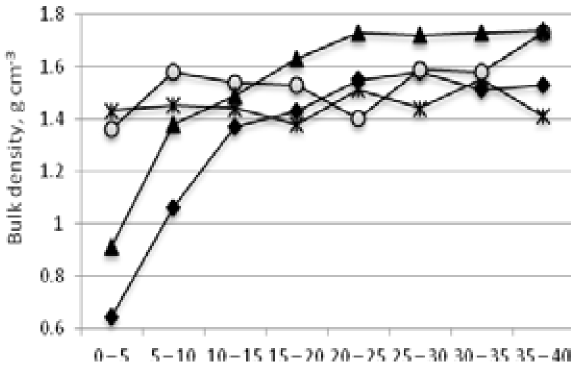

Figure 1. Soil bulk density in two experimental sites, cm:

soil profile	additional site
—×— unchanged soil	—○— unchanged soil
—♦— modified	—▲— modified

Bulk density in both locations for unchanged soil was very similar in all layers starting from the topsoil up to 40 cm depth. Density was rather high, about 1.50 g cm^{-3}, which points to the compaction effect – an usual occurrence in the places where soil tillage has not been used for several years. Modification effect was significant and affected the top layer up to 15 cm deep.

Field capacity is a parameter showing the volume of the water the soil is able to retain. This means that at higher field capacity soil or substratum can hold more plant available water in the periods when precipitations are absent. As highbush blueberry is a water consuming plant it is important to provide sufficient water supply all over the growing season including periods with high temperature and absence of precipitations. Influence of soil modification on field capacity of experimental sites is shown in Figure 2.

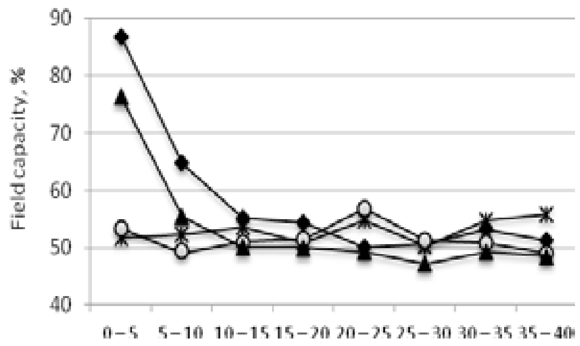

Figure 2. Field capacity depending on the depth of soil, cm:

soil profile — additional site

—×— unchanged soil —○— unchanged soil

—♦— modified —▲— modified

Field capacity has a close positive correlation with air porosity. Therefore upper layer of modified substratum has both higher field capacity (better water storage ability) and better aeration. The last one is important not only for providing good air exchange between soil and atmosphere but also for fast excess water infiltration during rainstorm or snow melting. In situation when drip irrigation system is operating and water supply can be adjusted according to the actual needs physical properties of substratum could be evaluated as adequate for good development of highbush blueberries.

Agrochemical properties of soil. Many researchers are discussing and pointing out the importance of soil (substratum) reaction for highbush blueberries cultivation. It is considered that this crop requires moderately acid growth media – pH KCl < 5.5. In many cases this is the limiting factor for establishment of plantations in mineral soils which are non-acid naturally or after liming. USA and Canada are countries where highbush blueberries are cultivated very widely, therefore advanced experience is accumulated here. Researchers from these countries suggest that for highbush blueberries the optimal soil reaction pH KCl is 4.5 – 4.8. In a very low pH KCl environment (lower than 3.4), plants are suffering, and if reaction becomes less acid (pH KCl 3.4 – 3.8), plants gradually recover but productivity (yield of berries) is very low. Therefore it is considered that pH KCl 3.8 is the lowest possible (reasonable) level for blueberry production (Haynes, Swift, 1985; Hancock, 2009). The similar research and findings were obtained in Latvia as well. A. Ripa reported that for highbush blueberry growth in Latvia, an optimal soil reaction is pH KCl 3.8 – 4.8 (excluding rabbiteye blueberries that require a higher pH KCl level – around 5.8) (Ripa, 1992). Similar recommendations are provided also by Polish researcher K. Smolarz (2009) who is also involved in the breeding of new varieties of blueberries. The high reaction of soil (pH KCl > 5.2) reduces mobility of plant available micronutrients Fe, Zn and Cu and relative deficient for blueberries could be a case (Haynes and Swift, 1985).

In 2011, the soil reaction in experimental plots for the upper 0 – 40 cm soil layer was acid (pH KCl 2.95 – 5.35). Topsoil was comparatively more acid than subsoil due to the periodical application of mulch – acid (pH KCl 3.0 ± 0.3) sphagnum peat plus sawdust. Therefore for variety 'Bluecrop' at the depth of 0 – 20 cm, soil reaction reached even pH KCl 2.95, which actually can be considered inadequate or too acid. In such situation calcium uptake for plants is very limited. In very acid environment calcium is simply lacking (absolute deficit). If the blueberries are receiving water soluble calcium without the raising of reaction, e.g. by fertilisation, the negative effect of low reaction could be minimised.

Other parameters of soil agrochemical properties are shown in Table 1. Experimental plots were located at the different positions in the landscape. Therefore plots located on the upper part of landscape are marked with P, and with N – plots which were located on the lower part of hillsides. Soil sampling was done directly in the strips around bushes approximately in the zone where plant roots are located.

Organic matter (OM) content in topsoil varies significantly due to the application of mulch. Soil mulching was done periodically every second year. Therefore some experimental plots received fresh mulch, but some plots – from previous year. The difference between topsoil and subsoil in terms of organic matter and plant nutrient content was significant. Nutrient accumulation in the upper part of substratum are provided by from the applied fertilisers.

Table 1

Soil agrochemical properties

Position on landscape and variety	0 – 20 cm topsoil				20 – 40 cm subsoil			
	OM, g kg^{-1}	N, g kg^{-1}	P, mg kg^{-1}	K, mg kg^{-1}	OM, g kg^{-1}	N, g kg^{-1}	P, mg kg^{-1}	K, mg kg^{-1}
1. P ‘Bluecrop’	296.8	2.73	584	498	25.8	0.98	85	64
2. P ‘Bluecrop’	38.2	1.43	116	106	13.2	0.67	31	65
3. P ‘Northland’	43.9	7.96	124	80	22.6	0.88	74	75
4. N ‘Duke’	214.3	3.72	536	398	26.3	1.09	140	105
5. N ‘Patriot’	167.1	2.72	266	224	23.0	0.91	112	74

This layer could be regarded as a nutrient rich and probably stimulates development of blueberry roots close to the soil surface. But generally both the upper and lower part of substratum might be evaluated as containing an adequate amount of plant nutrients if the reference is made related to the other small berry bush trees grown in Latvia.

Evaluation of plant nutrient concentrations in soil (substratum) for highbush blueberries is rather complicated. Difficulties arise because of the small amount of research data which are obtained using one standardized analytical method and experiments performed in compatible conditions. Only then some correlation criteria could be developed. Currently, at least two kinds of analytical procedures for soil fertility evaluation are used by highbush blueberry growers in Latvia. The State Plant Protection Service offers the same analytical methods as for field crops (also used in this research) but they lack any interpretation criteria relevant for highbush blueberries. Officially, all growers who are involved in the Integrated horticulture scheme in Latvia should test the soil in their plantations using these methods periodically. Another laboratory which offers the soil testing for horticultural crops uses completely different analytical methods (soil extraction with 1*M* HCl for determination of all nutrients) and data are not compatible with data, obtained by methods recommended by Integrated horticulture scheme. But, at the same time, research data for interpretation of analytical results are more advanced for 1*M* HCl procedure (Nollendorfs et al., 2007). Therefore it is an open question to decide about the common scheme for soil fertility evaluation and to accumulate a sufficient amount of research data to be able to develop criteria for their assessment. Therefore any data and their interpretation are important.

One of essential plant nutrients having importance for highbush blueberry growth is nitrogen (Smolarz, 2009). Therefore, in this study, the attempt was made to evaluate which soil properties are influencing total nitrogen concentration in substratum. A method of multiple correlation was performed (Figure 3).

In the topsoil rich with organic matter mulch mineralization gradually occurs and mineral nitrogen in substratum releases. This is also reflected in the obtained coefficients of correlation. In general, it can be evaluated positively because according to other researchers (Ripa, 1992; Nolendorfs, 2004), for productive growth of highbush blueberries the content of organic matter in substratum should be more than 70 g kg^{-1}. The high content of nitrogen not only stimulates the blueberry growth but also promotes mineralisation of mulch. To keep the soil physical properties (bulk density, porosity etc.) on an adequate level, the fresh material should be applied periodically.

Plant nutrient diagnosis. One of the methods to evaluate the crop nutrition status is to analyse parts of a growing plant. Compared with soil (substratum) analysis this method has some advantages. Plant nutrient concentration in growing plant tissues shows that the crop was (or was not) able to absorb the ions from the soil solution and they were already in the plant ready for all metabolic processes. Chemical procedure used to find this concentration is not important and compatibility problems are more evident. The only things which should be harmonised are selection of the plant part used for analysis and preparation of the sample. Therefore comparison of the obtained data with data from the literature is more possible and applicable. In Table 2, data obtained are presented. Two types of plant leaves were taken for analysis: leaves from the new shots produced in 2011, and leaves from shots which the plants produced a year before. The results were compared with data obtained by Nolendorfs et al. (2007). According to their research, the optimal concentration of plant nutrients in leaves varied within 17 – 20 g kg^{-1} of N, 2.0 – 3.0 g kg^{-1} of P, and 4.5 – 7.0 g kg^{-1} of K. If this criteria is considered as reference point then plant nutrient concentration in plants grown in experimental plots should be evaluated as inadequate.

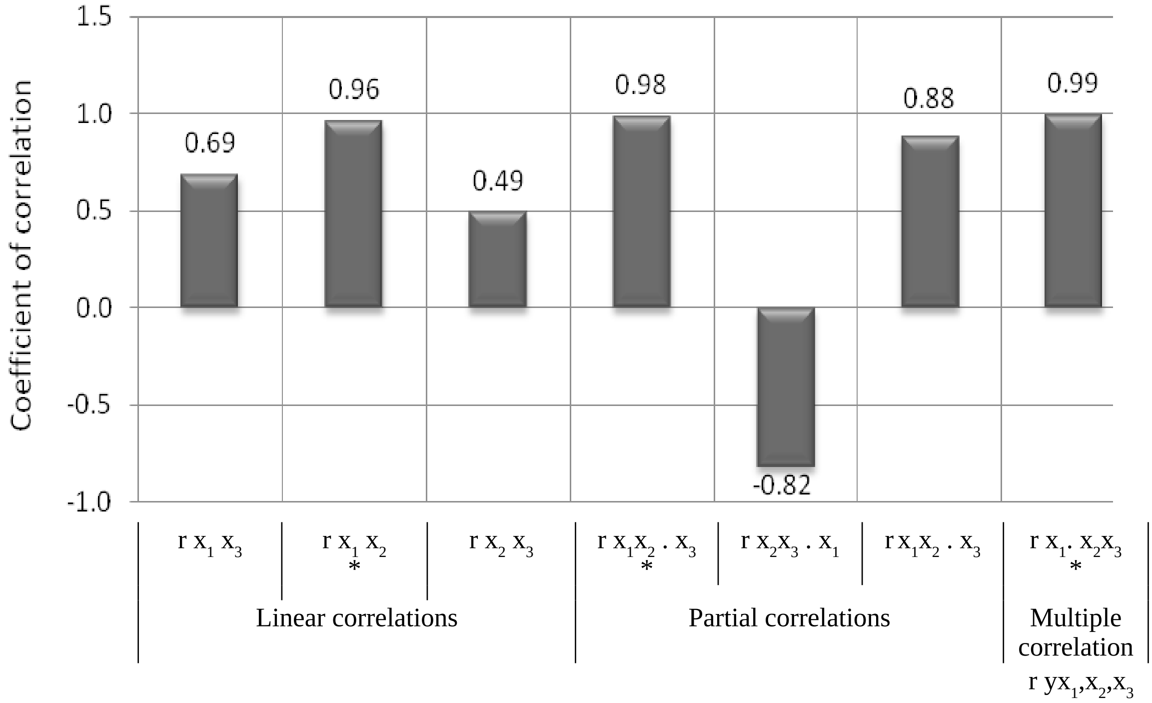

Figure 3. Evaluation of nitrogen concentration (y) and possible influencing factors (x_1, x_2, x_3) for subsoil, r yx_1,x_2,x_3.

Terms: * correlation is significant ($p<0.05$)
r yx – correlation in absolute values
x_1 – N concentration in subsoil, g kg^{-1}
x_2 – OM concentration in subsoil, g kg^{-1}
x_3 – K concentration in subsoil, mg kg^{-1}

Table 2

Plant nutrient concentration in dry matter of leaves, g kg^{-1}

Position on landscape, and variety	New shoots			Previous year shoots		
	N	P	K	N	P	K
1. P ‘Bluecrop’	10.28	1.49	3.99	9.64	0.99	3.69
2. P ‘Bluecrop’	11.05	1.51	3.87	11.33	1.02	4.06
3. P ‘Northland’	9.78	1.20	2.83	8.59	0.80	2.21
4. N ‘Duke’	10.33	1.47	3.34	9.78	1.08	3.62
5. N ‘Patriot’	9.94	1.19	3.76	9.95	1.63	3.85

On the other hand, full scheme of blueberry fertilisation was done in 2011, including all necessary materials and applications. This scheme is already successfully maintained in the plantation for several years, therefore it is difficult to agree that plant nutrient inputs were too small. Probably some more literature should be read and field research should be done to find the correct criteria relevant for a similar soil and climate situation.

Manganese is one of chemical elements raising interest in highbush blueberry growers. Low concentration of manganese could be the limiting factor for high productivity of blueberries, but too high concentration can be harmful. Therefore concentration of manganese in plant leaves was performed (Table 3).

Table 3

Manganese (Mn) concentration in dry matter of leaves, mg kg^{-1}

Position on landscape, and variety	Previous year shoots	New shoots
1. P 'Bluecrop'	163	132
2. P 'Bluecrop'	240	154
3. P 'Northland'	203	229
4. N 'Duke'	271	190
5. N 'Patriot'	311	303

Generally, in both types of leaves samples, the concentration of manganese was high. It is reported that the optimal level of manganese in leaves for blueberry growth is 40 – 100 mg kg^{-1} (Nolendorfs et al., 2007). Also data are found that toxic influence of manganese for blueberries occurs when Mn concentration in leaves exceeds 450 mg kg^{-1}. It is not possible decrease the total Mn concentration in the soil. Better soil aeration can only stimulate oxidation of Mn compounds and make them less available for plants. Another way how to reduce Mn availability is to increase the concentration of plant available iron, copper, zinc and molybdenum in soil as well as to provide the plants sufficiently with water soluble calcium in both ways – through roots as well as through foliage by means of foliar application (Pormale et al., 2009). Additional aspect is an adequate nitrogen supply which stimulates growth and development of foliage part of bushes and 'dilutes' the manganese already absorbed by plants. The use of complex fertilisers containing more than 0.02% Mn in such a situation should be avoided (Nollendorfs, 2004).

Conclusions

The use of sphagnum peat significantly changed physical properties of soil. Soil bulk density was decreased but soil porosity and aeration increased. It positively affected growth of highbush blueberries because stimulation of air exchanges, increase in water infiltration and, as a result, facilitation of microbiological processes provide better environment for crop development. Rapid drainage of excess water was compensated by soil surface irrigation simultaneously with plant nutrient application. Irrigation installation is an important component for modified soil because the use of peat decreases soil capillary porosity and subsequently water supply from the deepest layers. The use of acid (pH KCl 3.0 ±0.3) sphagnum peat is an efficient way to decrease soil reaction in blueberry root zone as well as to raise the organic matter content in soil and partly to serve as a tool for depression of weeds growth between bushes. In many cases, soil is not a limiting factor for establishment of highbush blueberry plantations in Latvia. It is possible to select the methods for modification of its properties in the rows of plants, and plantations could be established also in typical mineral soils formed on low calcareous moraine. A few researches have been done in Latvia concerning optimal nutrient concentration in soil and in vegetative parts of highbush blueberries. The research in this direction is topical, because these data has high importance for fertilization planning.

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