



Recultivation of opencast peat pits with *Vaccinium* culture in Estonia

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Abstract

In Estonia there are 22,000 to 24,000 ha of opencast peat pits which are damaged by peat mining. One possibility to use these abandoned areas is to recultivate them with species whose natural growth habitat is similar to exhausted peat fields. To avoid carbon emission and to re-establish an exhausted peat area, the acidophilic ericaceous species as stress tolerant should be investigated as possible candidates. The experiment was carried out in opencast peat pits in the southern part of Estonia during three years. The species studied were cranberry (*Oxycoccus palustris*) and lowbush blueberry (*Vaccinium angustifolium*). The two main combined fertilizers used were Kemira (0:12:18) and Rekle (10:20:20)+ microelements. Top dressing fertilizers were applied in early spring 1999 at rates of 126 kg ha⁻¹, 200 kg ha⁻¹ and 252 kg ha⁻¹. The soil of the experimental area belongs to the soil subgroups of Fibri-Dystric Histosol according to FAO soil classification and soil pH ranged between 2.8-3.5. A randomized complete block design was used for experiments. Variance analysis was employed in data processing. The influence of fertilization on the study species was established by evaluation of 100 berry mass (g) for both species. Surface coverage (%) and the yield g 1m⁻² were studied for cranberry. For lowbush blueberry, bush width (cm), height (cm) and yield per bush (g) were studied. The results from this study indicate that fertilization had a positive influence on the yield and vegetative growth in most trials with lowbush blueberry, particularly when compared with control (without fertilization). The vegetative growth of cranberry was significantly influenced by fertilization. The effect of fertilization on the yield was moderate. The 100 berry mass (g) was significantly influenced by fertilization when the Kemira combined fertilizer was used at a rate of 200 kg ha⁻¹ for cranberry; for lowbush blueberry, all combined

fertilizers used revealed a significant influence except for the Rekle combined fertilizer when used at a rate of 126 kg ha^{-1} . In the first year, after the application of top dressings for cranberry, the fertilizers did not reveal a significant impact on the yield. In the following year a significant influence was observed in the case of both combined fertilizers used. All applied top dressings affected the yield per bush (g) for lowbush blueberry. In the conditions of Estonia, cranberry (*Oxycoccus palustris*) and lowbush blueberry (*Vaccinium angustifolium*) appear suitable species for recultivation of opencast peat pits.

1 Introduction

Altogether 23% of the total area of Estonian ($45,227 \text{ km}^2$) is covered by mires, which is the largest proportion in Northern Europe [8]. The total area of mires here is 1,009,101 ha, while 477,000 ha are of commercial importance [12]. The total area of exhausted peat fields will be doubled in the near future as a result of intensive peat production, and more abandoned areas will be added to the already existing 22,000-24,000 ha.

Ombotrophic bogs are known as a nutrient-poor environment. The capacity of their soils to ensure plants with nutrients depends on atmospheric inputs. Opencast peat fields are poor in forms of essential nutrients (N, P, K) available for plants. Moreover, in opencast peat fields where natural bog water system and the plant cover are destroyed, the process of revegetation with natural plant species is slow. At the same time, mineralization and surface deflation are fast compared with peat formation. Annual peat loss can reach 8 t ha^{-2} . All Estonian virgin state bogs are able to produce 0.7 million tons of peat, while losses form 5 million tons. Raised bogs are able to produce 1.2-2.0 mm of peat per year [8].

In the current economic situation, arable peatlands are not profitable to use either for agricultural activities or forestation. A number of experiments have been conducted to recultivate opencast peat pits with different plant species. However, neither agricultural activity nor forestation has gained major success owing to high water level, the poorly decomposed uppermost layer and the variable environment of the rhizosphere of peatlands. Despite the presence of a natural seed bank in the uppermost peat layer, germination and later growth of young seedlings are very low. One possibility to use such abandoned areas is to recultivate them with species with are stress tolerant and whose natural growth habitat is similar to peatland. Therefore, it is reasonable to investigate the possibility of recultivation of opencast peat pits with acidophilic ericaceous species. Former Soviet countries and the present Russia have used some *Vaccinium* species for recultivation of opencast peat pit areas [5, 10, 18].

The genus *Vaccinium* is highly polymorphic and comprises circumboreal species. Cranberry (*Oxycoccus palustris* Pers.) is an evergreen acidophilic subshrub; it forms trailing and woody vines and roots at the nodes. The leaves are covered by a thick wax layer which frequently obscures the stomata [16]. White and deep pink to red flowers are situated on the top of a fertile shoot singly or occur in clusters. The leaves do not develop on fertile shoots (especially north of 50° latitude). In the corolla, four lobes are strongly reflexed at the

anthesis. Differences in flowering depend on the latitude and on the variety or the natural plant form; a second flowering has been recorded as well. The colour of fleshy berries ranges from light to dark red. They are round, oblong or oblate in shape and are covered with waxy bloom varying in intensity [17]. Berry size varies depending on meteorological conditions, while the source of the variety and the amount of the yield are also important [14]. The main natural growth habitats are bog edges and transitional bogs. The species is widespread in areas with low pH (2.9-3.9) and in nutrient poor environments.

Lowbush blueberry (*Vaccinium angustifolium* Ait.) is a tetraploid, woody perennial plant that forms ramets, its root mass is high accounting for 80-85% of the total dry mass of the plant. The bulk of the root system is located in the upper 10 cm topsoil layer. The organs of sexual reproduction are situated in the top of aerial shoots which produce numerous pendulous, racemose inflorescences of variable length [17]. Individual pendulous flowers are complete and pentacyclic with an urceolate perianth configuration [11]. When fertilization occurs the plant produces true, fleshy berries whose colour ranges from light blue to black. The intensity of the colour depends on the wax layer and the surface colour is related to the quality of the berry [4]. The growth habitats of the species are soils poor in mineral nutrients and with a soil pH of 4.5 to 5.5. The growth of both *O. palustris* and *V. angustifolium* is dependent on native mycorrhizae which secure plant nutrient uptake and help tolerate stress in acidic peat soils [2].

The aim of the present study was to evaluate the growth of *O. palustris* and *V. angustifolium* in the case of cultivation as well as yield formation in opencast peat pits in the southern part of Estonia.

2 Materials and methods

The experiment was carried out in opencast peat pits in the Southern part of Estonia during 1999-2001 until the formation of first proper yield of the study species. The experimental area was surrounded with natural ombrotrophic bog. The study species were cranberry (*Oxycoccus palustris* Pers.) and lowbush blueberry (*Vaccinium angustifolium* Ait.). The soil of the experimental area belongs to the soil subgroups of Fibri- Dystric Histosol according to the FAO soil classification, with a soil pH of 1.8-3.5. The 0-15 cm soil layer contained 85% of organic matter; N% was 0.99 (according to Kjeldal); P was 33 mg kg⁻¹ and K was 111 (according to A-L method); Ca was 3641 mg kg⁻¹, and Mg was 436 mg kg⁻¹ (measured from the AMA solution, pH 7.0). The percentage of ashes was 3.6 (determined by dry ashing to constant weight at 500 to 600°C). The soil analyses for soluble N%, P mg kg⁻¹, K mg kg⁻¹, Ca mg kg⁻¹, Mg mg kg⁻¹ and organic matter (%) were done at the laboratory of Plant Biochemistry of the Estonian Agricultural University and dry ashing was performed at the Institute of Soil Science and Agrochemistry.

The two main combined fertilizers used were Kemira (0:12:18) and Rekle (10:20:20) + microelements. Top dressing fertilizers were applied in early spring 1999 at rates of 126 kg ha⁻¹, 200 kg ha⁻¹ and 252 kg ha⁻¹. A randomized complete block design was used for experiments conducted in four replications each.



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The area of the cranberry experimental plot was 7.2 m² with 0.4 x 0.4 m² plant spacing in 1995. The area of the experimental plots of lowbush blueberry was 130 m² with 0.5 x 0.5 m² plants spacing. The plantation was established in 1998. The analysis of variance was employed for data analysis. Measurements were taken from 100 berry mass (g), for both species; surface coverage (%) and yield per 1m² were studied for cranberry. Also, bush width (cm), height (cm) and yield per bush (g) for lowbush blueberry were recorded.

The vegetation period of 1999 was warmer and drier than average for Estonia. On the contrary, the vegetation period of 2000 was characterized by occasional extremely high temperatures and a moderate amount of precipitation. The growth period of 2001 was moderately warm and with sufficient precipitation. In Estonia, average temperature in the summer months is 16-17 °C. Annual precipitation ranges from 550 to 750 mm.

3 Results

The results from this study showed that the vegetative growth of cranberry was significantly influenced by fertilization. The assessment of surface coverage showed that in control (without fertilization) it was only 10% in the first year (1999) and 25% in the second year (2000). In the variant where the top dressing Rekle (10:20:20) was applied, surface coverage was high, 60% in the first year, and 65% in the following year. The application of the Kemira (0:12:18) top dressing resulted in the 31% surface coverage in the first year and 55% in the second year. The influence of fertilization was significant in all variants in both years of the experiment.

The influence of fertilization on the yield was moderate. The 100 berry mass (g) was significantly influenced by fertilization, when the Kemira combined fertilizer was used at a rate of 200 kg ha⁻¹ and the average mass of 100 berries was 117 g. In the second year (2000) a significant impact of fertilizers was noted in all variants. The 100 berry mass ranged from 138 to 147 g.

In the first year, after the application of top dressings for cranberry, the fertilizers did not have a significant impact on the yield which was 245 to 547 g 1m⁻². A contrary situation was observed in the second year when the yield fluctuated from 472 g to 3403 g 1 m⁻² in different variants. The highest yield was obtained in the variant where the Kemira (0:12:18) combined fertilizer was applied and the lowest yield was recorded in the variant where the Rekle (10:20:20) fertilizer was used. The obtained yields per hectare would be the following: for control 4080 to 4660 kg ha⁻², with the application of the Kemira (0:12:18) combined fertilizer, 4726 to 5471kg ha; with the application of the combined Rekle (10:20:20) fertilizer 655 to 2448 kg ha⁻².

In the first year of the experiment (1999) the recorded height of lowbush blueberry plants was 9...16 cm, in the second year 8...23 cm and in the third year 9...27 cm. In the first year, after the application of top dressing the width of the lowbush blueberry plants were 22...38 cm. In the following year (2000) the width of the fertilized plants was larger, 48...56 cm, while the width growth of the unfertilized plants was 17 cm. In the third year (2001) the recorded

measurements were 44...51 cm for the fertilized plants and 20 cm for control. The mass of 100 berries was 36 g in control and 46...56 g in the experimental variants. The yield per bush was 11 g in control and 139...189 g in the other variants. Following the fertilization pattern and use of fertilizers of the present experiment, yields per hectare would range from 2190 to 2930 kg ha⁻². In case no any fertilization is applied, yields would be as low as 173 kg ha⁻².

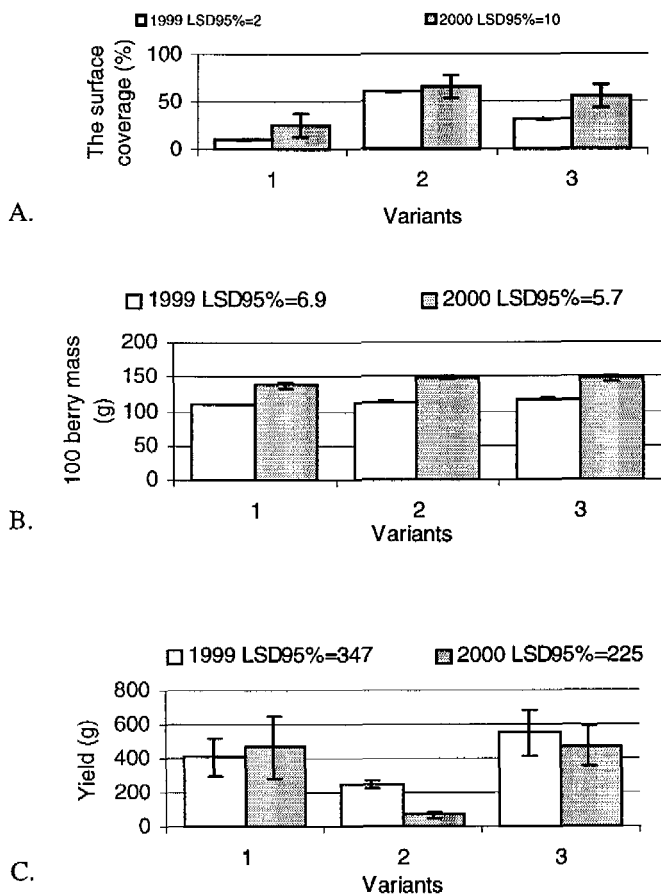


Figure 1: The influence of fertilization on the yield and vegetative growth of cranberry (*O. palustris*). A) the surface coverage (%), B) 100 berry mass (g), C) yield per 1 m². Variants 1- control, without fertilization, 2- complex fertilizer Rekle (10:20:20), rate 200 kg ha⁻¹, 3 - complex fertilizer Kemira (0:12:18), rate 200 kg ha⁻¹.

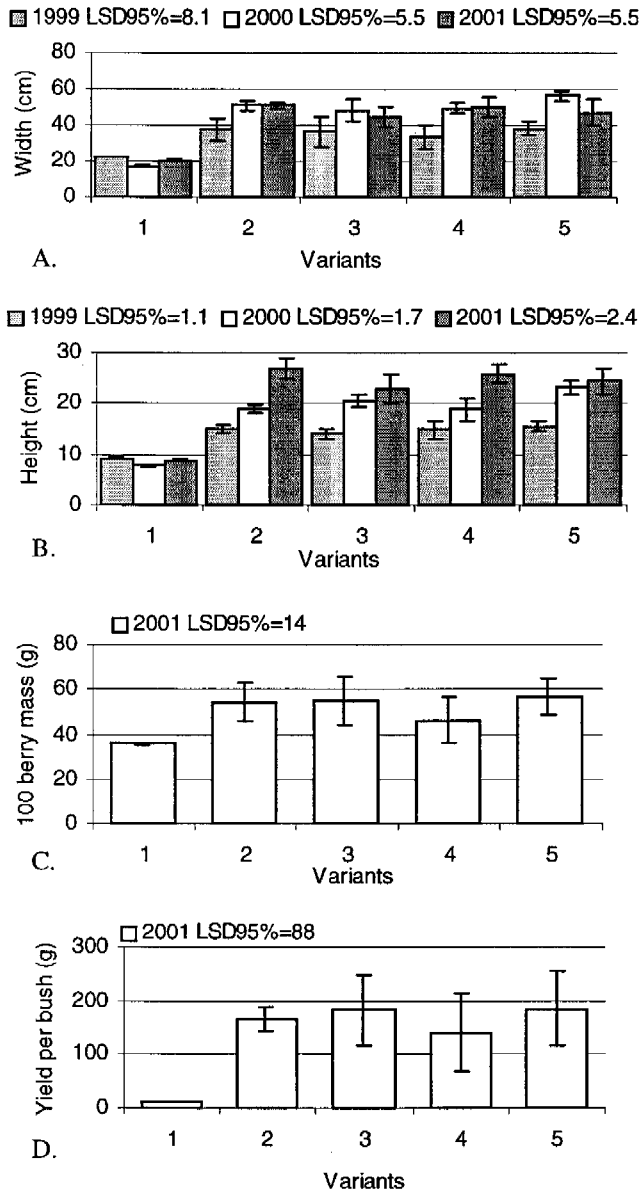
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Figure 2: The influence of fertilization on the yield and vegetative growth of lowbush blueberry (*V. angustifolium*). A) width (cm), B) height (cm), C) 100 berry mass (g), D) yield per bush (g). Variants 1- control, without fertilization, 2- complex fertilizer Rekle (10:20:20), rate 252 kg ha⁻¹, 3 - complex fertilizer Kemira (0:12:18), rate 252 kg ha⁻¹, 4- complex fertilizer Rekle, rate 126 kg ha⁻¹, 5 - complex fertilizer Kemira, rate 126 kg ha⁻¹.

4 Discussion

In cultivation of cranberry, soil acidity has a major impact on plant growth [13]. The experiment conducted on opencast peat pits in the southern part of Estonia showed that present acidity pH_{KCl} , 2.8 to 3.5, was suitable for plant growth. The influence of fertilization on the growth of cranberry in Estonia has been studied earlier [9]. In nutrient poor soils, formation of roots is stimulated by fertilization. A more developed root system helps avoid the cold lifts on opencast peat pits. After planting, young seedlings are more affected by cold lifts than older plants. In the present experiment, when the plants covered the surface by the fourth growing year, it was reasonable to give fertilizers as top dressings.

The yield per hectare depends on the number of berries and on average berry mass. Cherkasov [1] reports positive results with the use of superphosphate (P 9%) 300 kg ha⁻². The same authors suggest to combined superphosphate with ammonium nitrate (N 34-35%), 60:60:0, or superphosphate with potassium chloride (K 50%), 60:60:60, as their combine application has the highest effect. In the present study modern combined fertilizers were applied to study the impact of combined fertilizers produced nowadays. It was shown that unless balanced nutrients and rates are used, formation of the yield is suppressed. The results of previous studies performed in natural ombrotrophic peat bog in Estonia are in accordance with those of the present study when the positive effect of fertilization was observed in the second year of fertilization, while in the first year berry mass was lower than in the following year.

The growth of young plants in opencast peat pits is influenced by different factors. The investigation confirms that growth of *Vaccinium* species is affected by micro-organisms which help plants obtain essential nutrients from the soil and enhance their tolerance of unfavourable environmental conditions [6]. In a nutrients-poor environment, too, fertilization plays an important role in the growth of plants [15], which was demonstrated by the present experiment. Comparison of different fertilization variants with control revealed significant differences in plant growth and development. The fertilization experiment conducted for the evaluation of the vegetative growth of lowbush blueberry seedlings showed that older plants were able to overcome stress by the third year of fertilization [7]. At the same time, the growth of young plants was negatively affected, which might be due to the development of a mycorrhizal association. In the case of annual fertilization of the blueberry plantation on sandy loam soils with the 17:17:17 combined fertilizer at a rate of 300 kg ha⁻² the recorded growth of ramets was 72 to 165 cm [3]. In the present study the fertilizers were applied once during the two-year period, which is a sustainable way to manage a peat bog environment, while still obtaining optimal yields. Considering the results of this study, even lower rates of fertilizers could be used in the future.

Cultivation of lowbush blueberry on abandoned peatlands is also useful in the economic aspect [19]. As it is profitable for farmers, they would be interested in putting recultivation process into practice. In the current situation, the number of lowbush blueberry and cranberry plantations is growing fast. Cranberry (*O. palustris*) is among the fastest growing plant species to cover damaged surfaces.

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The suggested method of recultivation is of evident importance, because in harsh conditions opencast peat fields remain without any natural plant cover for 7-10 years or even for a longer period. When cranberry and lowbush blueberry plantations are established, several bryophytes as *Polytrichum strictum* and *Funaria hygrometria* will appear among other cultivated plant species inhibiting peat mineralization. As observed during the present fertilization trials, the main part of opencast peat pits which was not recultivated is still devoid of any natural plant cover. Peat processing was terminated in this particular peat field at the end of the 1980s.

Cultivation of non-traditional berry crops in opencast peat fields has some very clear advantages; first, ericalean species are known as being stress tolerant; second, they do not need as intensive fertilization as other berry crops; third, there are lacking plant pathogens and pests damaging these species to such a degree that chemical plant protection will be needed. Moreover, as the present experiment showed, after application of fertilizers, natural plant species for bogs and fens as *Eriophorum vaginatum*, *Calluna vulgaris*, *Betula ssp.*, *Pinus sylvestris*, will invade opencast peat pits.

In conclusion, the results of this investigation demonstrated that cranberry (*O. palustris*) and lowbush blueberry (*V. angustifolium*) are suitable plant species for recultivation of opencast peat pits.

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