Botanical survey of two Norwegian forest fields, dominated by European blueberry (*Vaccinium myrtillus* L.)

R. Nestby[1], T. Krogstad[2] and K.A. Hovstad[1]

[1]Norwegian Institute of Bioeconomy Research (NIBIO), Ås, Norway; [2]University of Life Sciences, Department of Environmental Sciences, Ås, Norway.

Abstract

In a project focusing on semi-cultivation of European blueberry (EB) from 2008 to 2011, a botanical survey was undertaken in two experimental fields in the municipalities of Snåsa and Lierne in the county of Nord-Trøndelag, Norway. The focus was mainly on growth of EB and *Vaccinium vitis-idaea*. We examined the effects of fertilization and cutting of EB to evaluate if established practices in the semi-cultivation of the wild American lowbush blueberry (*Vaccinium angustifolium*), also had potential for semi-cultivation of EB. We assigned four levels of fertilization randomly per block, with five replications. The Snåsa and the Lierne fields were clear-cut, 25 and 5 years prior to the survey, respectively. We pruned the remaining trees and shrubs to the ground when the experiment was established. Before application of fertilizer and cutting, we conducted a vegetation survey, recording the percentage cover of all plant species. Furthermore, we recorded maximum, minimum, and middle canopy height of EB and estimated percent cover and thickness of plant litter at the forest floor in 2008 and 2011. The survey consisted of three plots of one m². We placed each of them in the center of a fertilization plot, randomly distributed across the four fertilization treatments of each block at both sites. Twenty-six species were present in the fields, and the changes in botanical diversity were influenced by year, location, fertilization, and pruning of shrubs. Suggestions of how development of European blueberry in forest fields could be strengthened, and subsequently how the competitors could be weakened are presented. We showed that Pruning of EB decreased canopy cover, maximum- and middle- height, which was still lower three years after pruning than unpruned plants, and that *V. vitis-idaea* had a lower nutrient demand than EB.

Keywords: location, site, fertilization, climate, pruning, litter-layer

INTRODUCTION

The European blueberry [(EB, bilberry); *Vaccinium myrtillus* L.] is a calcifuge plant species with a circumboreal in distribution (Nestby et al., 2011). The estimate of average EB yield in Scandinavia is over 500 million kg year^{-1}, from which only 5-8% is used (Salo, 1995); Norwegian industrial demand is met with import from other European states like Sweden, Finland and states in Eastern Europe (Paassilta et al., 2009). From 1976 to 1991, Kardell and Eriksson (1995) examined the development of EB and *Vaccinium-vitis idaea* in Swedish forest fields. The area EB covered increased from 22.5 to 26.7% in the period and for *Vaccinium-vitis idaea* from 13.6 to 15.6%. This indicates that both species increased their biomass approximately 1% per decade in the period under the existing conditions. Our research period was shorter (2008 to 2011), but we introduced some large changes in growth conditions, and examined how these effected EB and other species present, and we examined the potential for semi-cultivation of EB (Nestby et al., 2014). The semi-cultivation approach for EB resembles the system used for lowbush blueberry (*Vaccinium angustifolium* Ait.). This article focuses in general on how fertilizer influenced the vegetation, and we present a survey that maps all species in the fields and their canopy cover percentage in August 2008 and September 2011.

Clear cutting of forest fields

In cultivation of lowbush blueberry, it takes approximately ten years from clear cutting of bushes and trees until a lowbush blueberry field is fully established (Kinsman, 1993). In comparison, studies from Finland and Sweden have shown that establishment of EB fields after clear cutting of the forest, can take even longer (Atlegrim and Sjõberg, 1996; Palviainen et al., 2005). They report that clear cutting of a *Picea abies* forest reduced EB shoot survival, production of annual shoots and therefore reduced EB ground cover. In addition, improved light conditions made leaves turn red. Moreover, EB remained in a marked nutrient sink in spite of the temporary decrease in rhizomes after clear cutting. The effect of clear cutting may be a size effect of the cutting, since results in Norway were opposite and plant growth was improved after clear cutting, probably because the Norwegian clear cuts were smaller than in the neighbour states (Nielsen et al., 2007).

Soil conditions, uptake and partitioning of nutrients

EB ground vegetation is the most widespread vegetation type in Norwegian coniferous forests (Flower-Ellis, 1971; Fremstad, 1997) and closely connected to podzol soils. EB has a shallow and weakly developed rooting system that develop from underground stalks, mostly found in the O-horizon. The humic properties therefore appear to be of great importance to EB vegetation. In our trials, the O-layer of the Snåsa field were nearly 8 cm thick, while the Lierne field had an O-layer of 4.5 cm. The E-layer, wash out layer below the O-layer, was nearly 6 cm thick in both fields (Nestby et al., 2014). The low pH of the natural growth medium suggests low plant availability for nutrients in general. However, deficiency symptoms for nitrogen (N) and phosphorous (P) have not been reported for blueberries of natural vegetation, even if they are high yielding. This is mainly due to symbiosis with ericoid mycorrhiza, (Read, 1980; Myers and Leake, 1996; Jeliazkova and Percival, 2003).

Several studies have examined the effect of adding fertilizers on lowbush blueberry, and it was shown that both foliar and soil application of fertilizers may be beneficial for growth and yield, alone or in combination. Positive effects of fertilization with N, P, Ca, B and Zn on plant growth of lowbush blueberry have been reported; it seems as if diammonium phosphate is an excellent source of N and P, and that application of potassium (K) may have a negative effect (Percival et al., 2003; Smagula et al., 2004). Adding organic material as mulch is also a standard procedure that may improve yield (Lafond, 2004). In our research it was shown that EB had longer long shoots (LS) with more nodes per shoot at Snåsa than at Lierne in 2010 and 2011, but no difference in number of branches (SS) was observed (Nestby et al., 2014). However, SS length was longer at Lierne than at Snåsa in 2011, and therefore number of nodes per SS was higher. Browsing of EB was probably the reason of the strong branching growth observed at Lierne, in spring 2011 (Nestby et al., 2014).

Nitrogen remobilisation and growth response caused by extra N have a close connection to bud activation patterns (Grelet et al., 2003). In areas with high N deposition, EB was less frequent, less abundant and more susceptible to leaf damage due to the pathogen fungus *Valdensia heterodoxa* than in areas with lower levels of N deposition (Strengbom et al., 2003). However, in our 2011 research fertilization increased the SS/LS ratio at Snåsa for all fertilization levels and for the two medium levels at Lierne. A logical result considering the lower concentration of mineral nutrients at Snåsa compared with Lierne (Nestby et al., 2014).

Climatic conditions and soil moisture

It is important to choose the right site for semi-cultivation of EB in order to avoid frost during flowering, extreme wind conditions and drought. In *V. angustifolium*, plants allocate resources into vegetative growth at low soil moisture conditions and into reproductive growth when moisture levels are sufficient (Seymour et al., 2004; Glass et al., 2005). Similar drought-dependent patterns of growth and berry production are probably present in EB, indicating the importance of selecting sites for semi-cultivation that have drought resistance soil and are sheltered from the wind. The level of N in the soil O-horizon in a Norwegian spruce forest was not affected by drying or wetting of the layers, and the level of N mineralized was at a low level of 1.6 to 11.1 mg N kg^{-1} soil day^{-1} (Chen et al., 2011). In Snåsa and Lierne total N-values were 1.86 and 2.08 % N in the O-layer, respectively (Nestby et al., 2014). However, the O-layer in Snåsa was nearly twice as thick as in Lierne, and therefore contained more nitrogen.

In this research, we focused on effects of semi-cultivation and environmental variation on canopy development of EB and other species present in the research fields. The factors included in the study were climate, soil conditions and prehistory of clear cutting, and their interaction with mineral nutrition, pruning of tillers, soil type (site) and weeding or by using herbicides.

MATERIALS AND METHODS

Field descriptions

The experiments were conducted at two locations with boreal coniferous and mixed forest on silty sand in a geology dominated by sandstone, clay shale and granite (Table 1). The field located in Snåsa was on two parallel moraine ridges (referred to as site in this article) differing in growth and EB yield performance. The forest was clear-cut 25 years earlier and newly established small trees, mainly of birch, was cut in June 2008, and kept pruned during the project period. In Lierne the field was situated on a southern slope with uniform growth conditions, where Norwegian spruce (*Picea abies* L.) were clear cut using heavy machines five years earlier.

Table 1. Forest field location, coordinates, meters above sea level (MASL), experiments with block and plot size, number of replicates (R), and forest type.

Location	Coordinates	MASL	Experiment	Block size (m^2)	Plot size (m^2)	R	Forest type
Snåsa	64°18.011'N 12°28.42'E	297	Mineral fertilization pruning, site	15×15	3.75×15	5	*Picea abies*, *B. pubescens*
Lierne	64°29.99'N 13°29.99'E	427	Mineral fertilization	15×15	3.75×15	5	*Picea abies*

Mineral fertilization

Fertilizer treatments combined ammonium sulfate (NH_4SO_4) and YaraMila Opti-Start 12-23-0, containing 12% N and 23% P (Yara™, Norway) at four different levels in four plots (15.0×3.75 m^2) per block. The experimental design was a completely randomized block with five replications. Fertilizer combinations were; 1) control, 0 kg N and P ha^{-1} (N0P0); 2) 30 kg N and 20 kg P ha^{-1} (N30P20); 3) 30 kg N and 40 kg P ha^{-1} (N30P40); and 4) 60 kg N and 40 kg P ha^{-1} (N60P40). In 2008, half the amount of fertilizer was broadcast by hand the first week of August. In each of the years 2009, 2010 and 2011, the total amount of fertilizer was hand broadcast using half the amount of fertilizer the first week of June and the remainder first week of August.

Pruning of tillers, site treatment and weeding

The experimental treatments were: 1) control (unpruned) and 2) tillers pruned close to the ground (pruned). We did the pruning late in August 2008, after fruit harvest of EB, growth registrations and botanical survey. The pruning treatments were applied to all plots in two of five blocks. In Snåsa, one block on the south and one on the north ridge were randomly distributed within ridges. The site treatments, only at Snåsa, were 1) south ridge (three blocks) and 2) north ridge (two blocks). Both ridges were at same altitude and east/west orientated separated by 50 m.

Chamerion angustifolium and *Rubus idaeus* were hand weeded at Lierne, every year. In both fields *Betula pubescens* birch, *Sorbus aucuparia* and *Picea abies* were pruned whenever necessary, to prevent them from competing with EB. *Deschampsia flexuosa* became a large problem at Lierne and we sprayed with cycloxydim herbicide (BSAF, Germany) in mid-July 2009, with very good results, also controlling other grasses.

Recording of species

In late August 2008 three new vegetation plots were randomly distributed between the four fertilization plots of each of the five blocks at both locations. We recorded species present and their canopy and ground cover (Table 2). Each plot was the size of an aluminum frame (1×1 m^2) placed on the ground. Each vegetation plot was marked for later recordings, by hammering a metal tube in the ground at two diagonal corners of an aluminum frame used to delimit the plot. In August 2011, was a second recording taken from the same plots as in 2008. For EB we also recorded the maximum, minimum and middle height of the canopy (the middle height is not the average of maximum and minimum heights, but a height evaluated with the help of a ruler). Finally, we estimated the thickness and percentage ground covering of the litter layer.

Table 2. Species present in the European blueberry fields in Snåsa and Lierne, common names, abbreviations and Latin names.

Latin name	Abbreviation	Common name
Vaccinium myrtillus	Vacc_myrt	European blueberry
Vaccinium vitis-idaea	Vacc_viti	Lingonberry
Cornus suecica	Corn_suec	Bunchberry
Rubus idaeus	Rubu_idae	Raspberry
Betula pubescens	Betu_pube	Downy birch
Sorbus aucuparia	Sorb_aucu	Rowan
Picea abies	Pice_abie	Norwegian spruce
Chamerion angustifolium	Cham_angu	Fireweed
Sphagnum spp.	Spha_spp.	Peat moss
Polytrichum commune	Poly_comm	Common haircap
Lycopodium annotinum	Lyco_anno	Bristly club-moss
Deschampsia flexuosa	Desc_flex	Wavy hairgrass
Agrostis cappilaris	Agro_capp	Common bentgrass
Deschampsia caespitosa	Desc_caes	Tufted hairgrass
Trientalis europaea	Trie_euro	Arctic star flower
Maianthemum bifolium	Maia_bifo	May lily
Melampyrum silvaticum	Mela_silv	Small cow-wheat
Luzula pilosa	Luzu_pilo	Hairy wood-rush
Solidago virgaurea	Soli_virg	Woundwort
Linnaea borealis	Linn_bore	Linnea
Rumex acetosella	Rume_acet	Red sorrel
Oxalis acetosella	Oxal_acet	Wood sorrel
Equisetum silvaticum	Equi_silv	Wood horsetail
Dryopteris linnaeana	Dryo_linn	Oak fern
Athyrium filix-femina	Athy_fili	Lady fern

Statistics

The statistical analyses of data were performed using SAS and the procedures GLM and Tabulate (SAS, 2016). Ordination of the vegetation data were done using non-metric multidimensional scaling (NMDS) as implemented in the vegan package in R (Oksanen, 2016).

RESULTS AND DISCUSSION

Influence of year on development of EB, *Vaccinium vitis-idaea* and the litter layer

The canopy cover for EB tended to decline between the start and end of the experimental period, averaged by location (Table 3), maximum and minimum height decreased, and middle height increased. *Vaccinium vitis-idaea* showed a similar response, but the canopy was much lower than for EB. This is most likely a result of pruning since results published earlier showed that new long shoots and branches developed after pruning in 2008 and reestablished the tillers, but they did not fruit the first year after pruning. It took three years after pruning before the yield was again acceptable (Nestby et al., 2014). Before pruning, old branches dominated the EB-tillers. It is therefore not surprising that the canopy (average of pruned and unpruned) still had reduced maximum height in 2011 compared with 2008. The tillers would take more years with growth and branching to retain the original size.

There was also a larger cover percentage of the litter layer at the end of the experimental period, while litter depth was unchanged.

Table 3. Effect of year on canopy covering percentage of European blueberry (EB) and *Vaccinium vitis-idaea*, on canopy heights of EB and on percent cover and on thickness of litter layer, at start and end of project period, as mean of location and all treatments.

Year	Species					Litter layer	
	EB				Vacc_viti		
	Cover (%)	Canopy height (cm)			Cover (%)	Cover (%)	Depth (cm)
		Max	Min	Middle			
2008[1]	27.3	46.7	2.0	13.0	10.6	43.0	1.7
2011	21.3	37.7	1.4	15.8	7.1	56.0	1.6
Mean	24.3	43.0	1.7	13.4	8.9	49.5	1.7
Se	3.3^{ns}	1.6**	0.3**	1.3*	1.6*	6.2*	0.2^{ns}

[1]Before pruning.

Influence of location on development of EB, *Vaccinium vitis-idaea* and litter layer

The canopy cover of EB tended (p=0.06) to be higher at Snåsa than at Lierne as average of 2008 and 2011 (Table 4). *V. vitis-idaea* was rare at Lierne, but covered a relatively high percentage of ground at Snåsa, especially at the poor site. The litter layer covered more of the forest floor and it was thicker at Lierne compared with Snåsa. The reason is probably the prehistory of fields. The Lierne field was clear-cut a few years before the examinations began, in summer 2008. Large branches, left in the field after timber cutting, forming thick compact heaps on the ground, were carried out of the field. However, relatively large amounts of small branches and needles dropping from the branch heaps stayed left in the field. This could help to improve the O-layer; however, it was not thick enough to make a big difference on EB growth.

Table 4. Effect of location on canopy cover of European blueberry (EB) and *Vaccinium vitis-idaea*, on canopy heights of EB and on percent cover and depth of litter layer. The figures are means of measurements at the beginning and end of the experiments.

Location	Species					Litter layer	
	EB				Vacc_viti		
	Cover (%)	Canopy height (cm)			Cover (%)	Cover (%)	Depth (cm)
		Max	Min	Middle			
Snåsa	28.0	42.5	1.8	16.8	17.4	36.8	1.5
Lierne	20.6	43.9	1.7	12.0	0.3	62.1	1.9
Mean	24.3	43.2	1.8	14.4	8.9	49.5	1.7
Se	3.4^{ns}	3.9^{ns}	0.2^{ns}	1.3**	1.6***	6.1***	0.2*

Influence of fertilization on development of EB, *Vaccinium vitis-idaea* and litter layer

EB canopy cover tended to increase when fertilizing plants with medium levels, and it decreased at the highest level compared to control (N0P0). The highest fertilizer level produced a higher maximum height compared to the other fertilization treatments, while middle height was higher after fertilization of plants compared to control (Table 5). This agrees with observations in the same fields, reported earlier, showing that fertilization increased EB long- and short- shoot growth (Nestby et al., 2014). For *V. vitis-idea*, canopy cover was highest at the fertilization with lowest NP level combined (N30P20). It seems like *V. vitis -idae*a responded less to nutrients than EB. Fertilization had no effect on cover of the litter layer. However, fertilization tended to increase the depth of the litter layer (Table 5), probably because of more and larger leaves dropping from the fertilized plants.

Table 5. Effect of fertilization on canopy covering percentage of European blueberry (EB) and *Vaccinium vitis-idaea*, and on canopy heights of EB and on percent cover and thickness of litter layer, in average of beginning and end of project period and location.

Fertilization	Species					Litter layer	
	EB				Vacc_viti		
	Cover (%)	Canopy height (cm)			Cover (%)	Cover (%)	Depth (cm)
		Max	Min	Middle			
N0P0	18.8	35.6	1.5	11.7	4.3	40.6	1.1
N30P20	29.3	43.5	1.7	15.1	14.3	57.5	1.6
N30P40	27.8	39.8	1.7	15.0	9.1	46.1	1.6
N60P40	21.8	50.1	1.9	15.1	8.1	52.7	2.1
Mean	24.4	42.3	1.7	14.4	8.8	49.5	1.7
Se	5.1^{ns}	4.9^{ns}	0.3^{ns}	2.0**	2.3^{ns}	9.5^{ns}	0.3^{ns}

Site effect in Snåsa on development of EB, *Vaccinium vitis idaea* and the stray layer

The Snåsa field consisted of two ridges of different growth conditions (referred to as sites). The total N content and plant available P, K and Ca level in soil were higher in the O-layer on the south than on the north ridge (Nestby et al., 2014). Canopy cover and maximum and middle height of EB on the more fertile site tended to be larger and higher respectively, than on the less fertile site (Table 6). In contrast, the canopy cover of *V. vitis-idaea* was higher on the site with low soil fertility, strengthening the suggestion from the fertilization experiment that *V. vitis-idaea* has lower nutrient requirements, and are less competitive in fertile soils as compared to EB. The litter cover tended to be more extensive on the site with low soil fertility. However, the depth of the litter layer was higher on the site with a more fertile soil most likely caused by larger above ground biomass production.

Table 6. Effect in Snåsa of site on canopy covering percentage of European blueberry (EB) and *Vaccinium-vitis idaea*, and on canopy heights of EB and on percent cover and thickness of litter layer, in average of beginning and end of project period.

Site	Species					Litter layer	
	EB				*Vacc_viti*		
	Cover (%)	Canopy height (cm)			Cover (%)	Cover (%)	Depth (cm)
		Max	Min	Middle			
Rich	30.0	49.7	1.8	19.1	11.6	34.2	1.7
Poor	24.9	31.6	1.9	13.4	26.2	40.7	1.1
Mean	27.5	40.7	1.9	16.3	18.9	37.5	1.4
Se	7.0 ^{ns}	4.0^{ns}	0.2^{ns}	1.7^{ns}	2.6**	6.8^{ns}	0.2*

Effect of pruning European blueberry

For EB there were no significant differences by pruning between canopy parameters measured in late August 2008 and 2011 (Table 7). However, percent canopy cover and height had still not achieved the original height three years after pruning. Control also had lower canopy cover and maximum and minimum height in 2011 compared to 2008, but not to the same extent as pruned blocks. However, middle height was unaffected. The litter cover increased after pruning, while depth did not change.

Table 7. Effect in Snåsa of pruning (P) in late August 2008 on canopy cover percentage and canopy heights of EB, and on percent cover and thickness of litter layer, at begin and end of project period, compared to control (C).

P	Year	Cover (%)	Canopy height (cm)			Litter layer	
			Max	Min	Middle	Cover (%)	Depth (cm)
P[1]	2008	38.2	48.8	3.0	16.2	31.0	1.6
C		33.4	51.2	2.2	17.1	27.9	1.7
P	2011	18.7	30.8	0.8	15.0	60.3	1.0
C		21.9	37.2	1.2	18.1	33.9	1.4
Mean		28.0	42.5	1.8	16.8	36.8	1.5
Se_P		4.7^{ns}	5.6^{ns}	0.2^{ns}	2.0^{ns}	6.4*	0.2^{ns}
Se_{year}		4.7**	5.6*	0.2***	2.0^{ns}	6.4*	0.2^{ns}

[1]Situation before pruning.

The succession of species in two fields in three years

European blueberry was the dominant species in both Snåsa and Lierne. In Snåsa, the cover decreased from 2008 to 2011 with and without pruning (C) with, respectively, 19.5 and 11.5% units, while at Lierne there was no change in canopy cover (data not shown). The change at Snåsa was most likely an effect of year, but pruning likely had some influence (Table 7). However, the EB at Lierne was subject to extensive browsing by European elk, red deer and small rodents in the years between 2008 and 2011, and therefore the effect on cover percentage of the mechanical pruning was obscured. *Vaccinium-vitis idaea* was the third most dominant species in Snåsa, covering 20.7% in 2008 and 14.1% in 2011, while it was almost not present at Lierne. The cover difference in *Vaccinium-vitis idaea* between Lierne and Snåsa, is most likely related to the higher soil fertility at the field in Snåsa.

Figure 1 displays the results of the NMDS analysis and can be interpreted as a visualization of species and vegetation plots in ecological space (Minchin, 1987). The first thing to notice is that the vegetation plots in Snåsa and Lierne, are separated along the first axis in Figure 1 and therefore are interpreted to represent site specific environmental conditions. There is no direct ecological interpretation of this first axis; however, it could be related to soil type. Species typical to blueberry forest and soils with relatively low pH occur at the left side of the plot (e.g., *Cornus suecica*, *Deschampsia flexuosa*, *Melampyrum silvaticum*, *Vaccinium myrtillus* and *V. vitis-idaea*). However, the picture is not clear since there are species typical for blueberry forest and acidic soils on the right-hand side of the plot too, such as *Linnaea borealis*.

The second axis seems negatively related to soil productivity and nutrients. The position of the species along the second axis displayed a negative correlation to the species' Ellenberg values for soil nutrients (Pearson correlation coefficient =-0.49, p=0.04). Examples of species with relatively high nutrient requirements are found at the lower part of the plot (*Rubus idaeus*, *Athyrium filix-femina* and *Gymnocarpium dryopteris)*. This axis is negatively correlated to species typical for nutrient poor soils found at the bottom of the plot. However, there are no clear gradients in nutrient requirements in the plot.

In the experiments, saplings of *Betula pubescens*, *Sorbus aucuparia* and *Picea abies* were pruned to the ground every year. Observations in the field indicated that saplings of the two latter species could be quite strong competitors for EB. *Rubus idaeus* was abundant in Lierne, but did not dominate, mainly because it was hand-weeded every year. *Spaghnum* spp. were abundant on the forest floor of both fields, and increased at Lierne during the period from 3.2 to 20.6%. At Snåsa it was slightly above 40% in both years, probably because the field had been undisturbed for a much longer period than Lierne, which was severely injured by heavy machines during clear cutting, and disappeared totally under the branch heaps. At both locations, the species *Deschampsia caespitosa* was abundant, but decreased during the project period. In Lierne, this was mainly because of spraying with an herbicide in July 2009, which significantly reduced the grass cover. Several other species typical for a blueberry forest were present, but were not dominating, as they were weak competitors to both EB and *Vaccinium-vitis idaea*.

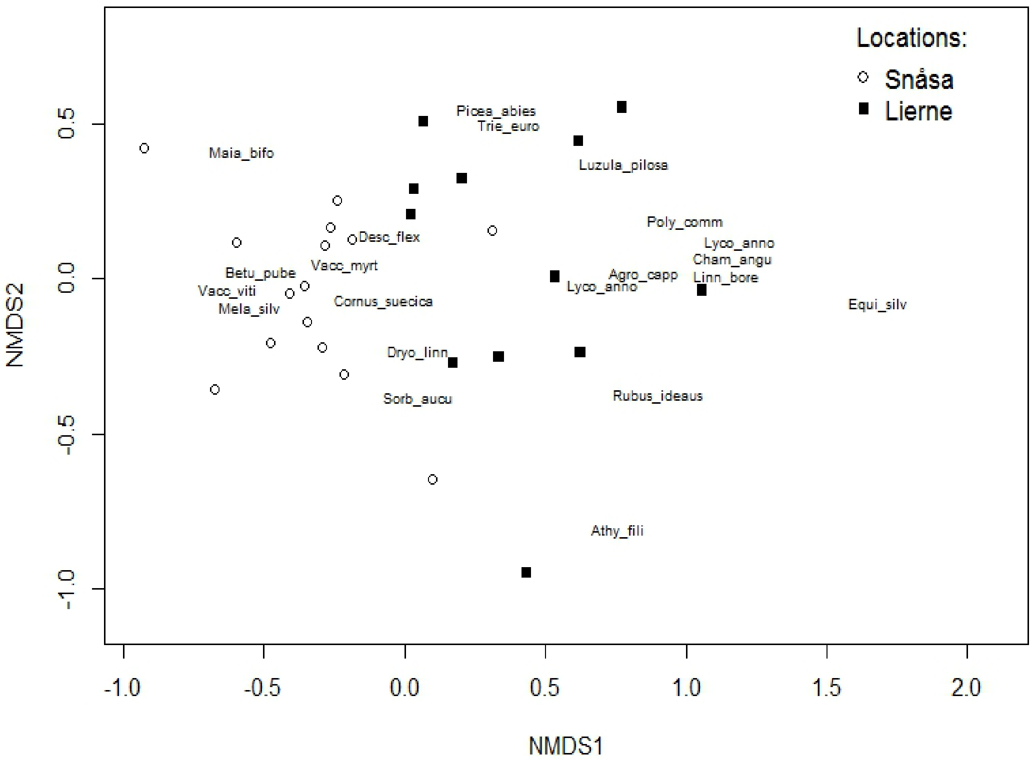

Figure 1. Ordination plot for 2008 showing species and plots present in an ecological space. Plots represent all species present, and their percent canopy cover.

Figure 2 illustrates the change in vegetation from the first year of the field trials (2008) to the final year (2011). Each vegetation plot is shown at the beginning of the trial in 2008 and at the end of the trial in 2011 (a dotted line connects the two positions of a single vegetation plot). Among plots there was a large variation in the distance they moved in the ordination plot, from the beginning to the end of the trials. The movement and hence the change in the plant communities were larger in the plots from Lierne on the right-hand side of Figure 2 compared to the plots at Snåsa on the left. Most of the movements are along the second axis (NMDS2), which we interpreted as related to soil nutrients. However, the plots both moved upwards and downwards and we cannot say there was an overall directional change in the vegetation. The large variation among plots may indicate that the response to fertilization by plant community and soil type depend on small scale variation in vegetation and soil.

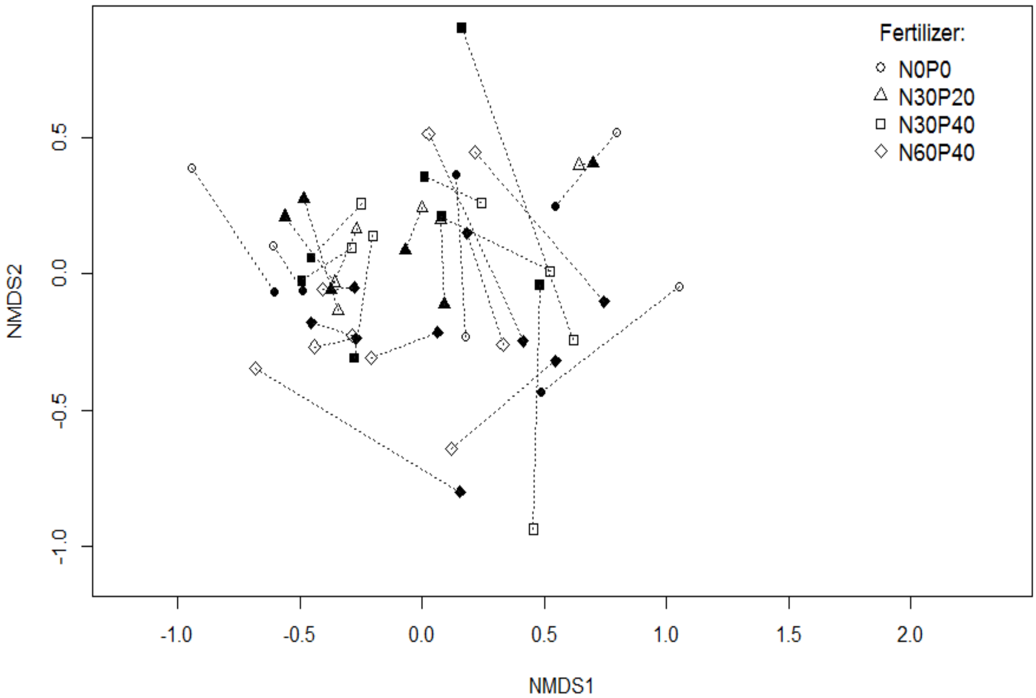

Figure 2. Ordination plot to illustrate the arrangement of plots in an ecological space and the movement of plots from the first survey in 2008 (open symbols) to the second survey in 2011 (black symbols). The figure includes vegetation plots from both the Lierne and Snåsa locations, and legends for fertilization level.

CONCLUSIONS

In EB, there was a change in canopy ground cover and growth from the start to the end of the project. There was a reduction in maximum EB tiller height, and canopy ground cover tended to decrease over the years. Location had a strong effect on canopy EB cover, and between the two sites of the Snåsa field both EB cover and stem height on the rich site tended to be higher than on the poor site. NP-fertilization tended to increase EB canopy cover, and the highest fertilizer rate increased height compared to other fertilization treatments. Pruning of EB decreased canopy cover, maximum- and middle-height, which was still lower three years after pruning than before pruning.

For *V. vitis-idaea*, ground cover decreased from the beginning to end of the project period, and the species was better adapted than EB to the poorer soil at Snåsa compared to the rich soil at Lierne. At the poorest site at Snåsa, *V. vitis-idaea* was relatively better adapted than EB, and fertilization generally reduced *V. vitis-idaea* growth, and canopy cover was highest at the lowest NP-level (N30P20). All this strengthens the suggestion that *V. vitis-idaea* has a lower nutrient demand than EB. It showed no effect of pruning, partly because some of the tillers were below pruning height.

The litter layer cover tended to increase by the end of the experimental period, but the litter depth was unchanged. Location had influence on litter layer, and litter layer covered a much higher percentage of the forest floor and was thicker at Lierne compared with Snåsa, probably because of the prehistory of fields. In Snåsa the litter layer tended to cover a larger percentage of the forest bottom on the poor site than on the rich site. However, thickness of the litter layer was less on the poor site, probably because the vegetation yielded less debris than the rich site.

European blueberry had to compete with other species that grew in the forest. However, in the research fields, EB was dominant. *V. vitis-idaea* was frequent in the poorest field (Snåsa) and especially on the poor site, but almost absent in the richest field (Lierne).

The trials indicated that growing conditions of EB have to improve on poor sites, if the intention is to increase fruit yield. Adding organic matter to increase thickness of O-layer at least to eight cm, and introducing medium NP fertilization in years with high fruit yield, would improve the growing conditions. *Cornus suecica* was relatively abundant in both fields, and it should be removed from the field since the red berries mix with blueberry at harvest making sorting of fruit more difficult. Peat moss was the second most abundant species, but seemed not to compete strongly with EB or *V. vitis-idaea*. *Rubus idaeus* and *Chamerion angustifolium* have potential to be competitors and has to be controlled. *Deschampsia flexuosa* can dominate, but herbicide application efficiently controlled it. Trees such as *Betula pubescens*, *Sorbus aucupari*a and *Picea abies* would in the long term, be competitors to EB unless controlled, and will be necessary to remove. Other species present seemed not to be a problem in the fields examined.

Literature cited

Atlegrim, O., and Sjõberg, K. (1996). Response of bilberry (*Vaccinium myrtillus*) to clear-cutting and single-tree selection harvest in uneven-aged boreal *Picea abies* forests. For. Ecol. Manage. *86* (*1-3*), 39–50 http://dx.doi.org/10.1016/S0378-1127(96)03794-2.

Chen, Y.T., Bogner, C., Borken, W., Stange, C.F., and Matzner, E. (2011). Minor resonance of gross N turnover and N leaching to drying, rewetting and irrigation in the topsoil of a Norway spruce forest. Eur. J. Soil Sci. *62* (*5*), 709–717 http://dx.doi.org/10.1111/j.1365-2389.2011.01388.x.

Flower-Ellis, J.G.K. (1971). Age structure and dynamics in stands of European blueberry (*Vaccinium myrtillus* L.). Ph.D. Dissertation. Res. Notes 9 (Royal College For. Stockholm), pp.108.

Fremstad, E. (1997). Vegetasjonstyper i Norge. NINA Temahefte 12. Trondheim. NO., pp.223 (in Norwegian).

Glass, V.M., Percival, D.C., and Proctor, J.T.A. (2005). Tolerance of lowbush blueberries (*Vaccinium angustifolium* Ait.) to drought stress. I. Soil water and yield component analysis. Can. J. Plant Sci. *85* (*4*), 911–917 http://dx.doi.org/10.4141/P03-027.

Grelet, G.A., Alexander, I.J., Millard, P., and Proe, M.F. (2003). Does morphology or the size of the internal nitrogen store determine how *Vaccinium* spp. respond to spring nitrogen supply? Funct. Ecol. *17* (*5*), 690–699 http://dx.doi.org/10.1046/j.1365-2435.2003.00776.x.

Jeliazkova, E.A., and Percival, D.C. (2003). N and P fertilizers, some growth variables, and mycorrhizae in wild blueberry (*Vaccinium angustifolium* Ait.). Acta Hortic. *626*, 97–304 https://doi.org/10.17660/ActaHortic.2003.626.41.

Kardell, L., and Eriksson, L. (1995). Bärprodukter och markvegetation. Effekter av kvävegödsling och slutavverkning under en 15-årsperiod, 1977-1991. SLU Rapport no. *60* (Swedish University of Agricultural Sciences, Department of Environmental Forestry) (in Swedish).

Kinsman, G.B. (1993). The History of the Lowbush Blueberry Industry in Nova Scotia 1950-1990 (Blueberry Producers' Association of Nova Scotia), pp.154.

Lafond, J. (2004). Application of paper mill biosolids, wood ash and ground bark on wild lowbush blueberry production. Paper presented at: Ninth North American Blueberry Research and Extension Workers Conference.

Minchin, P.R. (1987). An evaluation of the relative robustness of techniques for ecological ordination. Vegetation *69* (*1-3*), 89–107 http://dx.doi.org/10.1007/BF00038690.

Myers, M.D., and Leake, J.R. (1996). Phosphodiesters as mycorrhizal P sources: II. Ericoid mycorrhiza and the utilization of nuclei as a phosphorus and nitrogen source by *Vaccinium macrocarpon.* New Phytol. *132* (*3*), 445–451. PubMed http://dx.doi.org/10.1111/j.1469-8137.1996.tb01864.x

Nestby R., Percival, D., Martinussen, I., Opstad, N. and Rohloff, J. (2011). The European blueberry (*Vaccinium myrtillus* L.) and the potential for cultivation. A review. European J. Plant Sci. Biotech. *5* (*Special issue 1*), 5–16.

Nestby, R., Martinussen, I., Krogstad, T., and Uleberg, E. (2014). Effect of fertilization, tiller cutting and environment on plant growth and yield of European blueberry (*Vaccinium myrtillus* L.) in Norwegian forest fields. J. Berry Res. *4* (*2*), 79–95 http://dx.doi.org/10.3233/JBR-140070.

Nielsen, A., Totland, Ø., and Ohlson, M. (2007). The effect of forest management operations on population performance of *Vaccinium myrtillus* on a landscape scale. Basic Appl. Ecol. *8* (*3*), 231–241 http://dx.doi.org/10.1016/j.baae.2006.05.009.

Oksanen, J. (2016). Vegan: an introduction to ordination. https://cran.r-project.org/web/packages/vegan/vignettes/intro-vegan.pdf.

Paassilta, M., Moisio, S., Jaakola, L., and Häggman, H. (2009). Voice of the Nordic Wild Berry Industry. A Survey among the Companies (Oulu: Oulu University Press), pp.84.

Palviainen, M., Finer, L., Mannerkoski, H., Piirainen, S., and Starr, M. (2005). Responses of ground vegetation species to clear-cutting in a boreal forest, aboveground biomass and nutrient contents during the first 7 years. Ecol. Res. *20* (*6*), 652–660 http://dx.doi.org/10.1007/s11284-005-0078-1.

Percival, D.C., Stevens, D.E., and Janes, D.E. (2003). Impact of multiple fertilizer applicaions on the growth, development and yield of the wild blueberry (*Vaccinium angustifolium* Ait.). Acta Hortic. *626*, 423–429 https://doi.org/10.17660/ActaHortic.2003.626.57.

Read, D.J. (1980). The role of mycorrhizas in the nutrition of ericaceous plants with special reference to the genus *Vaccinium* L. Paper presented at: Productions spontanees Colloque Colmar.

Salo, K. (1995). Non-timber forest products and their utilization. In Multiple-Use Forestry in the Nordic Countries, M. Hytonen, ed. (Jyvaskyla: Gummerrus Press), p.117–155.

SAS. (2016). Version 9.4 (Cary, NC, USA: SAS Institute Inc.).

Seymour, R.M., Starr, G., and Yarborough, D.E. (2004). Lowbush blueberry (*Vaccinium angustifolium*) with irrigated and rain fed conditions. Small Fruits Rev. *3* (*1-2*), 45–56 http://dx.doi.org/10.1300/J301v03n01_06.

Smagula, J.M., Litten, W., and Loennecker, K. (2004). Diammonium phosphate application date affects *Vaccinium angustifolium* Ait. nutrient uptake and yield. Small Fruits Rev. *3* (*1-2*), 87–94 http://dx.doi.org/10.1300/J301v03n01_09.

Strengbom, J., Walheim, M., Näsholm, T., and Ericson, L. (2003). Regional differences in occurrence of understorey forest species reflect nitrogen deposition in Swedish forests. Ambio *32* (*2*), 91–97. PubMed http://dx.doi.org/10.1579/0044-7447-32.2.91