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Effects of Mulching on Fruit Yield, Accumulated Plant Growth and Fungal Attack in Cultivated Lingonberry, cv. Sanna, Vaccinium vitis-idaea L.

Mulchwirkungen auf Fruchtertrag, Pflanzenwachstum und Pilzbefall in kultivierten Preiselbeeren der Sorte 'Sanna' (Vaccinium vitis-idaea L.)

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Summary

Lingonberry (*Vaccinium vitis-idaea* L), cv. 'Sanna', was grown on a sandy mineral soil with seven different soil cover treatments (mulches):

(A) black plastic foil, (B) peat moss, (C) pine needle litter, (D) sawdust, (E) chopped pine bark, (F) gravel, and (G) bare soil (control). Yield and fruit weight were measured during three years. Symptoms of an unidentified fungus as well as accumulated plant growth were determined in the last year of the trial. pH was measured prior to and after the trial and soil analyses were performed when the third crop had been harvested.

Plastic foil and peat mulch promoted fruit yield, whereas pine needle litter mulch had a negative influence. In a year with deep and delayed winter frost, the organic mulch materials resulted in decreased yield, whereas plants on plastic foil and gravel were unaffected. Accumulated plant growth was positively influenced in peat mulch. In addition, pine needle litter had a significant positive effect when compared to sawdust which gave the poorest growth of all treatments.

Gravel mulch and the control resulted in the most severe fungal symptoms, whereas the most healthy plants instead were obtained in pine needle litter. The pH did not decrease during the five year period in chopped pine bark, but was lowered in other treatments, especially in peat moss and pine needle litter, from the initial 5.6 to 4.6 and 4.7, respectively.

Zusammenfassung

Preiselbeeren der Sorte 'Sanna' wurden auf einem Sandboden mit sieben Mulchbehandlungen angebaut: A Folie, B Torfmull, C Kiefernadeln, D Sägespäne (Nadelbäume), E Rindenmulch (Kiefer), F Kies 1–5 mm, G unbedeckter Boden (Kontrolle). Erträge und Einzelfruchtgewicht wurden in den Jahren 1995, 96, 97 ermittelt. Im dritten Versuchsjahr wurden die Symptome einer noch nicht definierten Pilzinfektion und das gesamte Wachstum der Pflanzen bonitiert. Der pH-Wert wurde vor und nach dem Versuch ermittelt, und allgemeine Bodenanalysen wurden nach der dritten Ernte durchgeführt. Folie und Torfmull förderten die Ertragsbildung, während Kiefernadelstreu einen negativen Einfluß zeigte. Nach einem strengen Winter wirkten die organischen Mulchmaterialen negativ, während Folienparzellen und unbehandelte Teilstücke unbeeinflußt blieben. Torfstreu wirkte günstig auf das Wachstum, und Kiefernadelstreu war immer noch etwas besser als Sägespäne. Die Pilzinfektion trat besonders auf Kiesmulch- und unbehandelten Flächen auf, während in Kiefernadelstreu die gesundesten Pflanzen waren. Der pH-Wert blieb im Rindenmulch gleich (pH 5,6), sank aber auf allen anderen Flächen ab, besonders bei Torf (4,6) und Kiefernadeln (4,7).

Introduction

Lingonberry (*Vaccinium vitis-idaea* L.), a woody, evergreen, low growing shrub, produces upright stems which originate from subterranean horizontal stems (rhizomes). Lingonberry fruit is an important berry crop harvested from the wild in the boreal regions of the world. The first attempts to domesticate lingonberry took place in Sweden in the 1960s and early 1970s (Teär 1972, Fernqvist 1977). Commercial lingonberry cultivation was introduced in the 1980s in Germany, and is now becoming increasingly popular also in Sweden.

Weed control is one of the main problems in lingonberry production since the plants are poor competitors against most weeds (Gustavsson 1993). The roots are fine and shallow, and mechanical weed control close to the plants should therefore be avoided. Chemical weed control of lingonberry is well documented and is quite efficient (Andersson 1974, 1977), but unfortunately slight chlororis and necrosis of lingonberry foliage has been observed as a result of terbacil and oryzalin treatments (Stang et al. 1993). In ecological production, weed control is the main reason for mulch application. In a plantation of 'Sanna', peat was more efficient than either lenasil or plastic foil for control of annual weeds, e.g. *Matricaria matricarioides* (Less.) Porter, *Chenopodium album* L. and *Viola arvensis* Murr. (Saario and Voipio 1997).

Since domestication of lingonberry was initiated, several mulching trials have been carried out with a number of materials. Maximum yield was recorded in Poland when using pine bark compared to peat-moss, pine needle litter, sand, and bare soil (Scibisz and

Pliszka 1989). In the same trial, closely correlated effects on growth and yield were observed when using pine bark and pine needle litter. In a Finnish study Lehmushovi (1977) reports that sand resulted in the highest yield compared to milled peat, bark humus, leca (pellets of burned clay), straw, and sawdust. In a Swedish investigation over three years, mulching resulted overall in a higher yield than bare soil. However, there were no significant differences between milled peat, wood-chips, and sawdust (Gustavsson 1996).

Mulching is used frequently in highbush blueberry (*Vaccinium corymbosum* L.), since this crop requires an acid soil. In addition, mulching serves as a weed controller, maintains an appropriate soil moisture content, and prevents extreme soil temperatures. Experiments with highbush blueberry show that root growth is impaired by temperatures below 14° and above 18°C (Abbott and Gough 1987). Amendment of organic material prior to establishment of blueberry and lingonberry generally increase growth and fruit yield (Peterson 1987, Stang et al. 1993).

However, apart from any benefits of organic mulching, there are also some disadvantages. Mulching is expensive, and higher levels of fertilization are needed. Mulching also prevents the soil from emitting heat, which may lead to a lower temperature at the mulch surface and increased frost injury during the blossom time. In a trial at Balsgård, the minimum average temperature was 1.8°C lower on the surface of mulched soil (4–5 cm layer of sawdust) compared to bare soil during two weeks in May (Gustavsson 1993). However, mulching with plastic foil would probably not increase the risk of frost injury.

'Fallen leaf disease' (provisional name), caused by an unclassified fungus, occurs frequently in some years in commercial cultivations (Nilsson 1974). The primary symptoms consist of spotting on the upper side of the leaf. Initially these spots appear late in the season, in September-October. The brownish red to brownish black spots are scattered over the leaf surface, and range in size from a few to several millimetres across; they often merge and may cover large parts of the leaf area. Severe attacks cause leaf drop.

Lingonberry research has been carried out at Balsgård for more than ten years. The present investigation aims to ascertain the effect of different mulching materials on plant growth, fruit yield, and fungal attack on 'Sanna', which is the most widely grown cultivar in Sweden.

Material and methods

The experiment was conducted on a sandy moraine, pH 5.6, at Balsgård, 56°,7'N, 14°10'E. The research area was 13.6 m × 11.2 m including guard rows and guard plants surrounded by a lawn on three sides and another lingonberry plantation on the fourth side. The trial consisted of a randomized complete block design, with 4 blocks and 7 treatments. Well rooted, uniform, 5–10 cm tall plants, derived from cuttings of the cultivar 'Sanna', were planted in the autumn of 1992. The guard plants consisted of 'Sanna' and 'Sussi' (proportion 1/1). Within each block, the various treatments were carried out on eight plants in a row. The rows were 1.25 m apart, and the distance between plants within rows was 0.40 m. Just before or after planting, mulch was applied in 0.30 m broad strips in the rows.

The soil surface treatments were: (A) mulching with black plastic foil before planting, (B) mulching with 3–4 cm of milled Sphagnum peat moss after planting, (C) mulching with 3–4 cm pine needle litter after planting, (D) mulching with 3–4 cm sawdust (conifers) after planting, (E) mulching with 3–4 cm chopped pine bark after planting, (F) mulching with 3–4 cm gravel after planting (grain size: 1–5 mm), (G) bare soil (control).

Additional mulch, except in the gravel (F) treatment, was applied in 1994 and 1996 to maintain a 3–4 cm soil coverage. Fertilization with 200 kg Complesal (Hoechst) NPK 12/5/14/ha was undertaken once in the spring each year. Additional nitrogen, 120 kg ammonium sulfate/ha (21%) (Merox), was applied each year in July. Irrigation was only undertaken in periods with prolonged lack of precipitation.

Total fruit yield and average fruit weight were recorded once a year during 1995–97. Each plant was measured for fruit yield, whereas all eight plants in a block were used to determine the average fruit weight. Symptoms of 'fallen leaf disease' were scored from 0 to 5 on each plant in October of 1997 (0 = no symptom, 1 = a few black dots on the upper leaf surface, 2 = several black dots on the upper leaf surface, 3 = several black dots together with entirely black leaves, 4 = entirely black leaves and some fallen leaves, 5 = many fallen leaves, bare plants).

Accumulated growth was measured by weighing the entire plant (except roots) which was cut off at the soil surface after harvesting in 1997. The pH was measured prior to planting and after the trial. Samples for soil analyses were taken just after cutting off the plants.

Weather data have been collected from Kristianstad-Everöd airport, approximately 10 km from the field trial. For statistical analyses, Super Anova computer package v. 1.11 was used.

Results

Fruit yield

The average fruit yield for all treatments together increased from 35 g/plant in 1995 to 60 g/plant in 1996 and to 81 g/plant in 1997 (Fig. 1). There was a highly significant variation ($p<0.001$) between the treatments for fruit yield in each of the three years, as well as in average yield for all three years taken together ($p<0.001$). In 1995 the highest yield was obtained in peat moss (B), in 1996 in the plastic foil (A) and in 1997 again in the B treatment (Table 1). Highest average fruit yield, over three years, was obtained in the A and B treatments (89 g/plant and 81 g/plant respectively), which differed significantly from all other treatments. The lowest average yield, 37 g/plant, was obtained in pine needle litter (C), which was significant lower than all other treatments except sawdust (D) and chopped pine bark (E). Variation (standard error) among plants was largest in the B treatment and smallest in the C treatment.

Large differences in yield were found among years (Fig. 1), with significant interaction ($p<0.001$) between treatments and years. The yield in the A treat-

Table 1. Fruit yield and fruit weight (g) during 1995 to 1997 and accumulated growth (g) by the end of 1997. The letters express a pair-wise Tukey comparison (p=0.05).
Fruchtertrag und -gewicht (g) 1995–1997 und akkumuliertes Wachstum Ende 1997.

Treatment	1995 yield	1995 fruit weight	1996 yield	1996 fruit weight	1997 yield	1997 fruit weight	1995–97 yield	1995–97 fruit weight	Accum. Growth
A. plastic foil	42 b	0.38	126 a	0.40	95 b	0.31	89 a	0.36 a	71 abc
B. peat moss	66 a	0.29	47 c	0.44	130 a	0.30	81 a	0.35 a	95 a
C. pine needle litter	14 c	0.22	48 c	0.34	51 c	0.26	37 d	0.27 b	78 ab
D. sawdust	26 bc	0.29	30 c	0.46	67 bc	0.26	41 cd	0.33 a	48 c
E. chopped pine bark	24 bc	0.31	28 c	0.40	83 bc	0.36	45 cd	0.36 a	74 abc
F. gravel	33 bc	0.34	80 b	0.38	77 bc	0.26	64 b	0.32 ab	64 bc
G. control	41 b	0.32	56 c	0.38	68 bc	0.24	55 bc	0.31 ab	54 bc

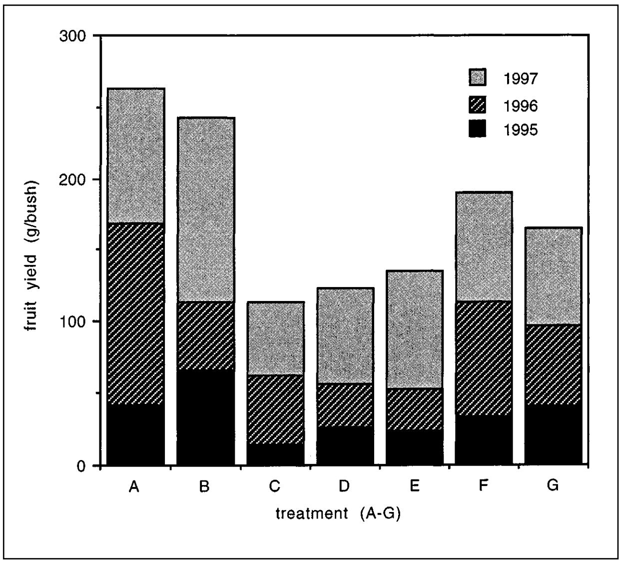

Fig. 1. Fruit yield (g) during 1995 to 1997 in seven different mulch treatments: A plastic foil, B peat moss, C pine needle litter, D sawdust, E chopped pine bark, F gravel, G control.
Fruchtertrag (g) 1995–1997 bei sieben verschiedenen Mulchbehandlungen: A Folie, B Torfmull, C Kiefernadeln, D Sägespäne, E Rindenmulch, F Kies, G Kontrolle.

ment was relatively low in 1995, but increased considerably with 126 g/plant in 1996 and then decreased again to 95 g/plant in 1997. The same pattern was noticed in gravel (F). By contrast, a relatively high yield was noticed in the first year in the B treatment, a decrease in the second year, and finally an increase in the third year to the overall highest yield (130 g/plant) in this trial. Chopped pine bark (E) resulted in a low yield in the first and second year, whereas the yield was increased three times to 83 g/plant in the third year.

Fruit weight

Significant variation in average fruit weight was obtained between years ($p<0.001$) and between treatments ($p=0.005$). The fruit weight was highest in 1996 (0.34–0.46 g) and lowest in 1997 (0.24–0.36 g) (Table 1). Fruit weight generally increased from the first block to the fourth in all treatments, but not significantly ($p=0.057$). No interactions were found between treatment and year, and there was no correlation between fruit yield and fruit weight ($r=0.044$, $p=0.689$). The pine needle litter (C) resulted in the smallest berries over the three years (0.27 g/plant), which differed significantly from the A, B, D and E treatments (0.36, 0.35, 0.33 and 0.36 g respectively)

Table 2. Estimation of symptoms from fungal attacks (fallen leaf disease) on the plants for seven different treatments. The letters express a pair-wise Tukey comparison (p=0.05).
Bonitur der Symptome durch Pilzbefall (Blattfallkrankheit) in den sieben Mulchbehandlungen.

Treatment	Fungal attack (score, 0–5, 5=severe attack)
A. plastic foil	2.77 bc
B. peat moss	2.83 bc
C. pine needle litter	2.27 a
D. sawdust	2.81 bc
E. chopped pine bark	2.47 ab
F. gravel	3.25 d
G. control	3.06 cd

Plant growth

Accumulated plant growth was significantly affected ($p<0.001$) by treatment. Also between blocks there were significant differences ($p=0.030$), and an interaction was obtained between block and treatment. Fruit yield and accumulated plant growth were positively correlated ($r=0.559$, $p=0.002$). The highest accumulated growth, 95 g, was obtained in peat moss (B) treatment which differed significantly from gravel (F), 64 g, and control (G), 54 g, and sawdust (D), which resulted in the poorest growth, 48 g. (Table 1). The accumulated growth in peat mulch was increased by 76% compared to the control. The pine needle litter (C) improved growth only compared to sawdust.

Fungal attack

Significant variation ($p<0.001$) in fungal disease symptoms were obtained between blocks. Gravel (F) and the control (G) resulted in most severe symptoms of the 'fallen leaf disease' (Table 2). Pine needle litter (C) and pine bark (E) resulted in the least disease-affected plants.

pH and nutrient contents

Initially, pH for the trial plot was measured to 5.6. After five years of lingonberry cultivation, pH had decreased in all treatments including the control, except in the chopped pine bark (E), where the pH remained at 5.6. The lowest pH-values, 4.6 and 4.7,

Table 3. Soil analysis extraction and determination for phosphorous (P), potassium (K), magnesium (Mg) and calcium (Ca) using ammonium lactate/acetic acid solution (AL-analysis) from the seven different treatments. The data are given in mg/100 g dry soil. Soil pH was also measured.
Bodenanalysen (pH-Wert) und Bestimmung von Phosphor (P), Kalium (K), Magnesium (Mg) und Calcium (Ca) mit Hilfe der Ammoniumlactat/Essigsäure-Lösung (AL-Analyse) bei den sieben Behandlungen. Angaben in mg/100 g Trockensubstanz.

Treatment	pH	P	K	Mg	Ca
A. plastic foil	5.0	15	3.6	0.5	7
B. peat moss	4.6	12	2.8	1.2	9
C. pine needle litter	4.7	15	3.4	0.6	10
D. sawdust	4.8	16	3.9	0.6	7
E. chopped pine bark	5.6	16	7.2	2.3	44
F. gravel	4.8	16	2.1	0.2	5
G. control	5.0	14	3.0	0.4	9

were obtained in peat moss (B) and pine needle litter (C), respectively (Table 3). The content of phosphorous remained at the same level in all treatments whereas the contents of potassium (K), magnesium (Mg) and calcium (Ca) was substantially higher in pine bark (E). The Mg content was very low in gravel (F) and in the control (G).

Discussion

Growth and yield

Accumulated plant growth differed considerably between treatments. Sufficient water and nitrogen is very important to achieve good growth. Peat contains high amounts of nitrogen and nitrification is exceedingly vigorous (BRADY 1984). Moreover, it also retains water relatively well. Consequenly, the largest plants were obtained in peat moss followed by the low fruit yielding pine needle litter. BUTKUS et al. (1989) reported maximum growth with 6 kg/m² peat mulch: after four years the phytomass increased by 29–61 % in mulched plots, and the number of rhizomes increased 2–3 times. According to previous trials in Sweden, a thick peat layer may initially decrease shoot development but, in the long run, promotes growth (FERNQVIST 1977).

The present trial has demonstrated that mulching affects the fruit yield substantially and that the type of mulching material plays an important role. Two completely different mulch materials, peat (organic) and plastic foil (fabric), resulted in the highest average fruit yield. By contrast, pine needle litter decreased the fruit yield compared to the control. There may be some phytochemical compounds in the needles that affect the yield negatively. Sawdust, chopped pine bark and gravel mulch did not affect the fruit yield in any direction. These findings are contradictory to the yield improvements reported with all of the above mentioned mulches compared to a control (LEHMUSHOVI 1977; BUTKUS et al. 1989). DIERKING (1984) reports, instead, a slight yield improvement with pine needle litter mulch. Peat mulch was beneficial also in a Polish study (SCIBISZ and PLISZKA 1985; 1989). The use of plastic foil in lingonberry results in satisfactory weed control and good yield (SAARIO and VOIPIO 1997), which is in line with the present study.

Effects of weather conditions

The data show an interaction between year and treatment, and in 1996 the non-organic mulches resulted in considerably higher yields in comparison to other mulches. One explanation for these large differences in yield in 1996 is that flowering may have been negatively affected by spring frost, especially in the organic mulch treatments. Weather conditions in the spring of 1996 were severe. Deep delayed ground frost and an early heat wave in April caused frost dehydration. Shoot apices turned brown and flower buds were injured. Plants in the non-organic mulches, black plastic foil, and gravel were less affected, since these mulches presumably served as a heat conductor and the ground therefore thawed earlier than in the other treatments. The organic mulches, peat and sawdust, instead acted as a screen against insolation, so that the roots remained frozen in spite of high temperatures above the soil surface. LEHMUSHOVI (1977) in a five year study obtained low yield when using organic mulch, and substantially higher yield in sand mulch. The same trend was reported in another Finnish investigation (SAARIO and VOIPIO 1997), where higher fruit yield was obtained with cv. 'Sanna' when applying sand and plastic foil compared to organic mulches such as peat. DIERKING (1984) found, in contrast, no differences in yield with cv. 'Koralle' over three years between sand, peat and bare soil.

During 1995–97 no late spring frost occurred at the present trial. Frost during blossom time in May-June may decrease yield on organic mulches since the air above the surface tends to be colder where organic mulch has been applied as compared to non organic mulch or unmulched soils (GUSTAVSSON 1993). Also, the same trend has been reported by FERNQVIST (1977), especially sawdust may cause an increased frost risk during late spring. In contrast, BUTKUS et al. (1989) report that flowers suffered less from frost in mulched plots compared to bare soil. Different mulch materials may also affect the soil temperature which can interfere with the cytokinin production and the flower induction during the growing season.

In this study, the mulch material also affected fruit weight, but to a rather low degree. Fruit size appears to be higher when the summer is rainy (Table 4): In 1995 and 1997 summers were dry and hot, whereas July was rainy in 1996.

Importance of compatibility

There was a small but not significant increase in fruit weight from block 1 to 4. Adjacent to the block 4, productive seedlings and advanced selections had been planted. Pollen from these plants may have been more compatible than pollen from 'Sussi' and 'Sanna', and thus generally increased fruit weight and, to a lesser extent, yield in all treatments. ERIKSSON (1975) reports an increased fruit set and higher number of seeds by cross pollination and another investigation shows that 'Sussi' has low compatibility with 'Sanna' as a pollen donor (GUSTAVSSON 1997). From these results we suggest that a lingonberry field should be planted with several cultivars to obtain maximum fruit set and fruit weight.

Table 4. Climatic data from Kristianstad-Everöd airport. Average monthly temperature and accumulated precipitation were measured from April-September 1995–97. The long term average is based on the period 1961–90.
Klimadaten des Flughafens von Kristianstad-Everöd. Die mittlere monatliche Temperatur und die akkumulierten Niederschläge wurden von April bis September 1995–1997 gemessen. Das langjährige Mittel ergibt sich aus den Jahren 1961–1990.

	TEMPERATURE (°C)				PRECIPITATION (mm)			
month	**average**	**1995**	**1996**	**1997**	**average**	**1995**	**1996**	**1997**
April	5.2	5.7	7.2	5.4	35	69	18	31
May	10.3	9.8	9.2	9.8	38	56	104	80
June	14.7	15.0	14.2	15.1	46	40	20	77
July	16.2	18.3	15.3	18.2	60	28	57	59
August	15.7	18.0	18.0	20.1	49	12	56	2
September	12.2	12.7	10.5	13.6	55	40	68	18

Disease symptoms

The effect of mulching on the fungal disease symtoms of lingonberry has not been previously reported. In the present study, different types of mulching material affect the intensity of disease symptoms on the leaves. Data were obtained only in 1997 when disease symptoms had accumulated over the years. Moreover, in this year attacks of fungi were promoted by rainy weather conditions in June and July, resulting in a very discriminatory data set. The most injured plants (grown on gravel mulch) had lost almost all their leaves which results in decreased winter hardiness. One reason for the severe attack on the plants growing on gravel and in the control treatments, may be that new mulch was not added every second year (as done with the other treatments) abscised dead leaves could therefore reinfect the plant every year.

Conclusion

According to this trial, peat moss is very beneficial for good growth and should be applied directly after planting. However, when the plants have become larger, peat mulch might suppress fruit yield due to frost damage during blossom time or by delayed ground frost. Peat mulch and other organic mulch materials should therefore be avoided in areas frequently exposed to late spring frost. Here, plastic foil mulch should be a good alternative.

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