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Cover Crop and Mulching Effects on Yield and Fruit Quality in Unsprayed Organic Apple Production

B.F. Kühn and H. Lindhard Pedersen
(Aarhus University, Faculty of Agricultural Sciences, Department of Horticulture, Aarslev, Denmark)

Summary

To determine the optimal growing system for organic apple production three different cover crop management practises were established for two scab resistant apple cultivars; cultivar A 'Prima' and cultivar B 'Vanda'. The management practices included: Treatment 1: A permanent grass mixture in the alley way, Treatment 2: A permanent clover grass mixture in the alley way and Treatment 3: An annual mixture of grass and clover was sown every year in early July and mulched down the following year in April. Mechanical weed control in the tree rows was carried out yearly from April to July. No additional fertilizer, irrigation or pest and disease control were carried out. A mulching sub trial was conducted in the cover crops: after mowing the cover crops in Treatment 1 and 2: clippings were mulched into the tree row (Treatment A) or clippings were left in the alley way (Treatment B).

The permanent grass alley way system (Treatment 1) resulted in the lowest shoot growth, the lowest level of nitrogen in leaf dry matter and fruit with the highest percentage of skin colour. The permanent clover grass mixture (Treatment 2) increased the nitrogen level in the leaves and decreased the percentage of skin colour, moreover the apple scab and fly speck infection on the fruit skin increased compared to fruits produced in Treatment 1. The annual cover crop growing system (Treatment 1) produced vigorous tree growth, a high level of nitrogen in the leaves, high soil water content in the alley way, the highest yield of large fruits and a low percentage of skin colour. The mulching trial showed that leaving clippings of grass in the alley way (Treatment B) resulted in a lower yield of coloured fruit compared with fruit harvested following mulching of the clippings into the tree row (Treatment B). This effect was not only obtained for grass (Treatment 1) but also for clover grass clippings (Treatment 2). The soil water content in the tree row was highest following mulching clover grass. For the permanent grass system the highest content of soil water in the tree row was obtained for bare soil.

Key words. organic apple production – growing system – apple scab resistant apple cultivars – N-supply – soil water – pest and diseases – fruit quality

Introduction

In organic apple production it is important to determine the best soil management system that optimizes fruit production and fruit quality. Apple trees have shallow root systems and are found to be poor competitors for water and nutrients from weeds or cover crop species (Marsh et al. 1996; Walsh et al. 1996b). Therefore it is important to reduce the competition for water and nutrients from other plants in the zone close to the tree trunk. Cover crops or mulches may utilise or supply the fruit trees with nitrogen (N). Nitrogen is the most mobile of the essential plant nutrients (Koehn et al. 2002) and is very important for plant growth. Uptake of N by roots of apple trees as well as by cover crops or weeds will decrease the concentration of N in the soil (Koehn et al. 2002). Cover crops may, by competition for moisture and N, affect tree growth and delay fruit production (Haynes and Goh 1980). It has been shown that organic mulches increase soil water content (Houge and Nielsen 1987; Walsh et al. 1996b) and mulching treatments result in stronger tree growth and a reduced need for irrigation and fertilization with N.

Choice of cultivar in organic apple production is also very important. It is essential to be acquainted with the characteristics of the different apple cultivars when choosing cultivars for organic growing. The use of apple scab resistant apple cultivars is essential to reduce infections of apple scab, which is the most significant disease on apples at many locations. However, it is well known that apple scab resistance, especially in the monogenic based apple scab resistant cultivars, is not persistent and may be broken (Durel et al. 2000; Guerin and Le Cam 2004).

The aim of the this research was to investigate the impact of soil management practises on soil moisture, nitrogen in soil, leaf nutrients levels, apple tree growth, fruit yield and quality by evaluating three different alley way cover crop management practises and two different mulching methods on the production and quality of two scab resistant apple cultivars under an organic production system.

Material and Methods

Trial design and orchard management

The experimental research orchard is located at the Department of Horticulture, Aarhus University, Aarslev Research Centre (10° 27' E, 55° 18'N), on a sandy loam soil, with a clay content of 11–15 %. In January 1995, three separate cover crop treatments of two scab resistant apple cultivars; cultivar A 'Prima' and cultivar B 'Vanda', grafted on rootstock M9 and trained as free spindle were established in an organic production system. Each of the three cover crop treatments consisted of 2 rows per cultivars, with 23 trees in each row. The planting distance was 3.3 x 1.6 m. The distance between cover crop treatments was 6 m. The cover crop management systems established in the alley ways were:

Treatment 1: Grass: A permanent weak grass mixture of red fescue (*Festuca rubtra*) and meadow grass (*Poa pratensis*).

Treatment 2: Clover grass: A permanent clover grass mixture consisting of white clover (*Trifolium repens*) and a perennial ryegrass (*Lollium perénne*).

Treatment 3: Annual: An annual cover crop consisting of Italian ryegrass (*Lollium multiflorum*) and persian clover (*Trifolium resupinatum*) sown every year in July and mulched down the next year in April and mechanical weed cleaning from April to July.

In tree rows (1 m width) weed control was carried out mechanically. The trees were kept unfertilized and unsprayed. Fruit thinning was carried out by hand when needed. Detailed studies of soil water, content of leaf nutrients, tree growth, fruit production, fruit quality and susceptibility to pest and diseases were carried out in 18 single trees per cover crop treatment of each cultivar.

A sub-trial was established in Treatment 1 and Treatment 2 where, after mowing the cover crops, the following treatments were conducted: Treatment A. Mulching; clippings were mulched into the tree row; and Treatment B. Bare soil; clippings were left in the alley way.

Three replicates per treatment were established and the plot size included three trees.

Soil and leaf analysis and tree growth

Inorganic nitrogen (Nmin) content in the soil was measured in the 0–50 cm soil layer in mid April, June and September in 1999, 2000, and 2001. Nitrate-N and ammonium-N were determined colorimetrically according to slightly modified method of Crooke and Simpson (1971) and Best (1976), respectively.

The soil moisture was measured in the 50 cm top soil in the centre of the tree row and in the centre of the alley way in June–September 1998–2001. Measurements were carried out 3–11 times per year. Soil moisture was determined using a 'Trace' system that measured soil moisture by time domain reflectometry (TDR), Model 6050XI.

Leaf samples were collected in August 1998, 2000, and 2001 and analysed for nitrogen (N), potassium (K) and calcium (Ca) content.

Annual shoot growth was measured during winter for each of the 18 trees of each cultivar per cover crop treatment during the period 1998–2001. For each tree the total shoot production per growing season was calculated.

Fruit production and fruit quality

Fruit production was assessed from 1996 to 2001. Fruits were colour graded with a MAF RODA grader. From 1999 to 2001 fruit were graded in to three classes: Class 1: Fruit covered with more than 75 % red skin colour, Class 2: Fruit covered with 25–75 % red skin colour and Class 3: Fruit covered with less than 25 % red skin colour. Furthermore the fruits were hand graded into marketable and unmarketable fruit according to commercial rules for fruit size and skin disorders using the UN/ECE Standards for Apples (December 2000). Classes 1 and 2 fruit are marketable as Class 1 organic apple production in Denmark.

Twenty-five random fruits per tree were examined for skin damage caused by apple scab (*Venturia inaqualis*), fly speck (*Leptothyrium pomi*), sooty blotch (*Gloedes pomigena*), tortrix (different species), codling moth (*Cydia pomonella*) and apple sawfly (*Hoplocampa testudinea*). The percentage of damaged fruit was calculated per year in 1996 to 2001.

Statistical method

Statistical analyses of data were performed using SAS (Version 8 www.sas.com). The effects of the cover crop treatments were analysed with the *General Linear Models (*GLM) procedure. Data for comparing the three cover crop treatments included trees receiving the sub treatment B. Bare soil, and data for comparing the mulching sub treatments included trees in cover crop treatment 1. Permanent grass and 2. Permanent clover grass. Data consisting of whole numbers (character values) were arcsine transformed to fit a normal distribution before conducting statistical analysis. Means were separated with an LSD test and statistical significance was defined at $P<0.05$. Whenever significant interactions were determined, the results for individual interactions are presented. Although the two cultivars were very different in their measured qualities, their response to the treatments was approximately similar. Therefore a cultivar average was used for the statistical calculations.

Results

Soil and leaf analysis and tree growth

The annual rainfall and evaporation at the research site varied 628–864 mm and 538–613 mm, respectively, in the period 1998 to 2001.

The highest content of available nitrogen (Nmin) in the soil was consistently found in the annual system (Treatment 3, Table 1). By September, and on average over the growing season, the nitrogen content of the soil was significantly higher in the annual system compared with the two perennial systems.

Leaf analyses showed that the lowest nitrogen (N) and calcium (Ca) content and the highest content of potassium (K) was present in leaves from trees grown in the permanent grass cover crop (Table 2). Almost all leaf samples were found to be within the optimum ranges; which in Denmark are considered to be N: 2.0–2.5 % dry matter and K: 1.2–1.7 % dry matter. Leaf Ca content was found to be higher than the optimum range: 0.7–1.2 % dry matter; no symptoms of the physiological Ca deficiency disor-

Table 1. Effect of cover crop management practises on soil nitrogen content (N-min), determined three times during the growing season, average over two apple cultivars; 'Prima' and 'Vanda' from 1999–2001.

Cover crop system	15 Apr	15 Jun	15 Sep	Average
		(kg N ha^{-1})		
Grass	16.4	12.7	13.5 b*	14.1 b
Clover grass	12.0	14.8	12.6 b	13.1 b
Annual	18.7	26.2	33.6 a	26.2 a
P > F	0.3782	0.1869		0.0024
$LSD_{0.05}$			15.5	7.9

* different letters within a column denotes significant difference (P < 0.05).

Table 2. Effects of cover crops on leaf Calcium (Ca), potassium (K) and nitrogen (N) levels in leaf dry matter, and soil water content in tree row and alley way and shoot growth of two apple cultivars 'Prima' and 'Vanda' from 1999–2001 (leaf nutrients not measured in 1999).

	Leaf nutrients (% dry weight)			Water content in soil (Vol. %)		Shoot growth
Cover crop system	N	K	Ca	in tree row	in alleyway	(m tree^{-1})
Grass	2.08 c	1.61 a	1.21 c*	23.0	24.9 b	10.69 c
Clover grass	2.60 a	1.33 b	1.44 a	22.8	21.6 c	18.92 b
Annual	2.48 b	1.24 c	1.30 b	23.1	27.1 a	22.78 a
P > F	< 0.0001	< 0.0001	< 0.0001	0.6328	< 0.0001	< 0.0001
$LSD_{0.05}$	0.05	0.07	0.08		0.92	1.88

* different letters within a column denotes significant difference (P < 0.05).

der, bitter pit, were observed in any fruit samples. The soil water content in the tree rows was not influenced by the cover crop system (Table 2). However, in the alley ways the soil water content was significantly highest in the annual system and lowest in the permanent clover grass system (Table 2). Total shoot growth was influenced by the cover crop system (Table 2). The most vigorously growing trees were found in the annual system, while the weakest shoot growth was observed in the permanent grass system.

Leaf samples from the two mulching methods showed that mulching clover grass had no effect on leaf nutrients. However, mulching grass increased the content of N and Ca and decreased the K content (Table 3). Mulching organic material from the grass alley way into the tree row resulted in lower soil water content in the tree row in comparison to bare soil. However, mulching the clover grass into the tree row had an opposite and positive effect on the soil water content (Table 3).

Mulching mowed grass material into the tree row resulted in a higher shoot growth than when leaving the clippings in the alley ways (Table 3). However, in the clover grass system no differences in shoot growth were found when mulching the clippings into the tree row or leaving clippings in the alley way (Table 3).

Fruit production and fruit quality

The highest total yield was obtained in the annual system (Table 4A), however; the highest percentage of fruits with more than 75 % red colour was obtained in the permanent grass system. Fruit produced in the annual system were slightly larger than fruit from the two other cover crop systems (Table 4A). In the permanent grass system the highest yield and the lowest percentage of coloured fruit >75 % colour were found when mulching clippings into the tree row (Table 4B). For the clover grass system no significant differences between mulching methods were found.

Harvested fruit were graded according to skin damage caused by the different pests and diseases (Table 5). Fruit grown on the permanent grass system had on average less fruit with apple scab and fly speck infections (Table 5).

Although the cultivars were scab resistant when planted, their resistance was broken during the experimental period. 'Prima' maintained scab resistance for only 2 years after planting, while 'Vanda' retained scab resistant for 4 years after planting. The loss of apple scab resistance was severe in 'Prima'. On average, 4.2 % of the harvested 'Prima' fruits were infected with apple scab in 1998 and this increased to 93.4 % in 2001 (Fig. 1). After loss of the apple scab resistance the most severe symptoms were found in the clover grass system. The management system significantly influenced the incidence of apple scab damages on the cultivar 'Prima'. The highest percentage apple scab damaged fruit occurred in the clover grass system (Fig. 1). 'Vanda' had on average very few (ca. 0.5 %) fruits with apple scab damage irrespective of management system.

Table 3. Effects of mulching on soil water content, shoot growth and leaf nutrients in two apple cultivars 'Prima' and 'Vanda', where nutrient analysis is given for calcium (Ca), potassium (K) and nitrogen (N) in 1998, 2000 and 2001.

	Permanent grass system					Clover grass system				
	Leaf nutrients (% dry weight)			Soil water	Shoot growth	Leaf nutrients (% dry weight)			Soil water	Shoot growth
Mulch treatment	Ca	K	N	(Vol. %)	(m tree^{-1})	Ca	K	N	(Vol. %)	(m tree^{-1})
Mulching	1.34 a	1.44 b	2.22 a	22.0 b*	14.6 a	1.36	1.28	2.54	24.2 a	18.9
Bare soil	1.21 b	1.61 a	2.08 b	23.0 a	10.7 b	1.44	1.33	2.60	22.8 b	17.3
P > F	0.0012	0.0026	0.0004	0.0021	< 0.0001	0.0900	0.1933	0.4568	< 0.0001	0.348
$LSD_{0.05}$	0.07	0.10	0.07	0.6	1.7				0.6	

* different letters within a column denotes significant difference (P < 0.05).

Table 4A. Effects of cover crop management system and mulch treatments on fruit yield and fruit colour, average of two apple cultivars 'Prima' and 'Vanda' from 1999 to 2001.

Cover crop system	Yield (kg tree^{-1})	Fruits < 25 % red colour (%)	Fruits > 75 % red colour (%)	Fruit size (g fruit^{-1})
Grass	13.3 b*	7.2 c	68.7 a	141.0 b
Clover grass	14.5 b	27.9 b	35.3 b	143.8 b
Annual	17.1 a	36.0 a	32.5 b	148.9 a
P > F	< 0.0001	< 0.0001	< 0.0001	< 0.0001
$LSD_{0.05}$	1.2	3.0	4.0	3.8

* different letters within a column denotes significant difference (P < 0.05).

Table 4B. Effects of mulch treatment in two cover crop treatments on fruit colour, average of two apple cultivars 'Prima' and 'Vanda' from 1999 to 2000.

	Permanent grass cover crop system			Clover grass cover crop system		
Mulch treatment	Yield (kg tree^{-1})	Fruits < 25 % red colour (%)	Fruits > 75 % red colour (%)	Yield (kg tree^{-1})	Fruits < 25 % red colour (%)	Fruits > 75 % red colour (%)
Mulching	15.7 a*	18.3 a	52.8 b	15.1	29.0	36.7
Bare soil	13.3 b	7.2 b	68.7 a	14.5	27.9	35.3
P > F	> 0.0001	> 0.0001	> 0.0001	0.3507	0.2231	0.9687
$LSD_{0.05}$	1.1	2.5	5.0	.	.	.

* different letters within a column denotes significant difference (P < 0.05).

In 2000, for the cultivar 'Vanda', 0.5 % apple scab infected fruits were recorded on harvested fruit, in 2001 the incidence of infected fruits increased to 2.5 % (data not shown).

Fruit grown in the annual system had the lowest incidence of sooty blotch. The most severe damages from fly speck and sooty blotch were observed in the cultivar 'Vanda' that has the most light-coloured apples. The apples were graded one to two months after harvest, inside that period no post harvest diseases occurred. Different tortrix species also caused severe damage to fruit, with the most damage being observed on fruit from the clover grass system (Table 5). Codling moth caused no serious damage in either cultivar or management system. Apple sawfly damage was generally limited to and most prevalent in the annual grass system.

Mulching clippings into the tree row did not influence the incidence of damage caused by pest and diseases (Table 5).

On average (1998–2001) marketable yield was significantly higher for 'Vanda' (8.9 kg tree^{-1}) than 'Prima' (7.7 kg tree^{-1}). The difference between the cultivars in the percentage of marketable fruit increased during the trial, mostly due to the loss of apple scab resistance of 'Prima' (Fig. 2). In 2001 'Prima' had on average only 23.0 % and 'Vanda' had 71.8 % marketable fruit.

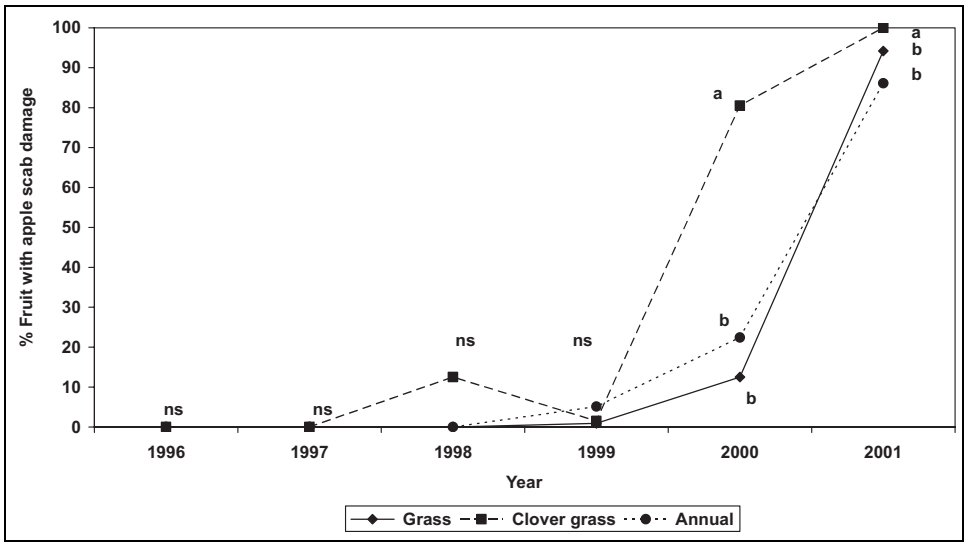


Fig. 1. Apple cultivar 'Prima' with apple scab damages grown in three different cover crop systems: grass, clover grass and annual. Treatments with different letters within year are significantly different at P<0.05. ns = not significantly different.

Discussion

Cover crop management system

The cover crop treatments had a significant influence on the level of Nmin in the soil. The different management treatments influenced the levels of available nitrogen in the soil. Bare soil normally releases around 45 kg plant available N ha^{-1} during the growing season in Denmark (Poulsen and Hansen 1962). In this trial the highest levels of inorganic N in the soil were obtained in the annual system at 26.2 kg plant available N ha^{-1} (Table 1), this resulted from the additional N released by the decomposing organic material and probably because there was no N uptake by the permanent cover crop in the alley way. The N content in the soil remains more or less unchanged during the growing season in the grass and the clover grass systems compared to the annual system, this is likely attributed to N uptake from the cover crop in the alley way. The rather low level of inorganic N in the grass cover crop management system was expected as grass is a stronger N competitor than apple trees, similar results have been obtained by Marsh et al. (1996). In both the clover grass and grass clover crop systems the inorganic soil N contents were stable at 13.1 and 14.1 kg plant available N ha^{-1} (Table 1). However, apple leaf samples showed a high content of nitrogen in trees grown with permanent clover grass cover (Table 2). This is probably attributable to a release of N from the decomposing organic material and a rather high N uptake of the apple tree roots. The high N fixation capacity and release in the clover grass system is likely to be linked to the high N in clover leaves as reported by Marsh et al. (1996) and Hornig and Bünemann (1996a). These apple trees had a high content of N in the leaves, higher than that recommended in Denmark. In the annual system the plant available N increased during the season due to the high N release, higher than the potential uptake by the apple tree roots (Table 1). It was observed that when N levels in apple leaf dry matter were low, K levels were high (Table 2). This is in agreement with Marsh et al. (1996). The high level of K in leaf dry matter in trees grown in grass cover

Table 5. Fruit with skin damage caused by apple scab, fly speck, sooty blotch, tortrix, codling moth and apple saw fly, average of two apple cultivars 'Prima' and 'Vanda' from 1996–2001 and marketable yield from 1998–2001.

Cover crop system	Apple scab	Fly speck	Sooty blotch	Tortrix	Codling moth	Apple saw fly	Marketable yield
	(% fruit with damage)						(kg tree^{-1})
Grass	10.0 c*	20.6 c	14.2 a	12.1 b	0.9 a	4.0 b	8.8 a
Clover grass	16.1 a	29.9 a	11.9 b	16.3 a	0.6 a	4.1 b	6.9 b
Annual	10.4 b	24.8 b	7.1 c	11.9 b	1.3 a	6.8 a	8.8 a
P > F	< 0.0001	< 0.0001	< 0.0001	0.0006	0.1227	< 0.0001	0.0003
$LSD_{0.05}$		2.5	2.0	2.5		1.3	1.1
Mulch treatment							
Mulching	12.0 a	26.3 a	13.0 a	10.6 a	0.8 a	4.6 a	8.2 a
Bare soil	13.0 a	25.2 a	13.0 a	11.7 a	0.9 a	5.7 a	7.8 a
P > F	0.5702	0.0695	0.4089	0.9851	0.5558	0.0707	0.4999

* different letters within a column denotes significant difference (P < 0.05).

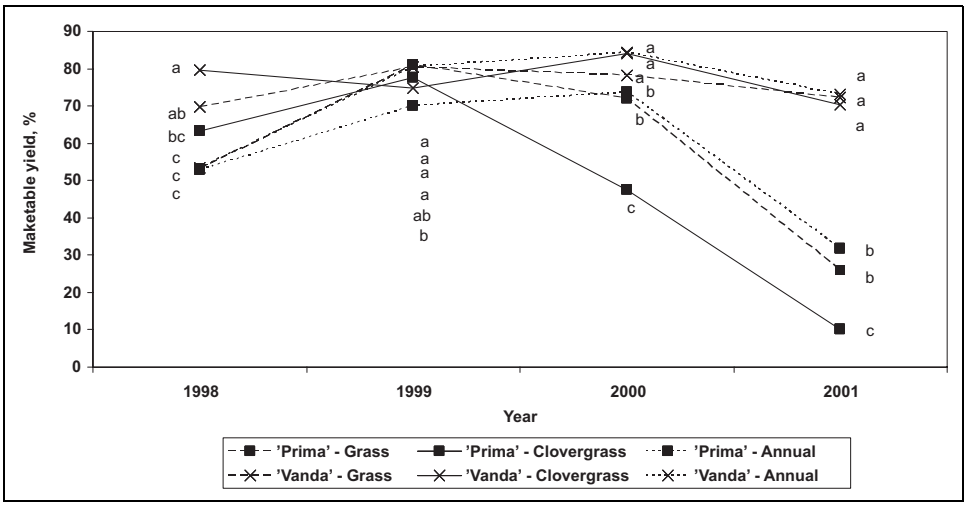


Fig. 2. Percent marketable fruit for 'Prima' and 'Vanda' apple cultivars for three different cover crop systems from 1998–2001. Treatments with different letters within year are significantly different at $P<0.05$.

crops may also be due to a high content of K in the grass, which is quickly available to the trees due to a fast decomposion. If the organic material is moved to the tree row (mulching) the K values are decreasing (Table 3). This may be due to a slower decomposion. The soil water content was significantly highest in the annual system. This was likely due to a higher content of organic matter caused by the annual mulched cover crop and due to a small uptake by the annual cover crop. Hornig and Bünemann (1996b) reported high soil moisture content in a clover system moreover the soil moisture in the grass mixture treatment was relatively low. In the present experiment this tendency could not be seen in the tree row (Table 2). The cover crop system affected tree growth significantly by influencing the soil water content and the soil N-content (Table 1 and 2). It was confirmed here as in related studies (Mervin and Stiles 1994; Hornig and Bünemann 1995; Marsh et al. 1996) that shoot growth vigour depends on the soil water content and the N availability, and a relationship exists between tree vigour and N content in leaf dry matter. The highest shoot growth was observed in the annual system. Additionally, high soil water content, high level of available soil N-min content and high level of N in leaf dry matter were found in the annual system (Table 1 and 2). It is obvious from this trial that grass is a very strong competitor to the apple trees for both nutrients and water, this agrees with reports by Walsh et al. (1996b) that grass cover crop has a tendency to reduce shoot growth. The cover crop system influenced the yield as well as the fruit size and quality (Table 4A). During 1999–2001, when fruit yield had stabilized, the highest yield and fruit size were obtained from the annual system; the highest shoot growth was also recorded in this treatment (Table 2). However, for this production system fruit quality results were poor. The annual system resulted in only 32.5 % of the fruit developing full colour, whereas for the N limited trees grown in the grass system, as much as 68.7 % of the fruit were well coloured (Table 4). According to these results, use of a grass system gave limited soil N availability (Table 1) resulting in a limited leaf dry matter N content, a high percentage K in leaf dry matter (Table 2) and a high percentage of well coloured fruits (Table 4A). In general systems that resulted in high leaf N also had a low percentage of well coloured fruits (Table 2 and 4). The relation between the fruit colour and N supplement has been discussed in other research (Oland 1960; Raese and Williams 1974; Vang-Petersen et al. 1977; Neilsen et al. 1984; Hornig and Bünemann 1995). Even though the yield in the permanent grass system was lower, the high percentage of coloured fruit at 9.1 kg tree^{-1} on average per year, compared to the annual system that produced only 5.6 kg tree^{-1} meant that a greater proportion of the crop was marketable. However it should be noted that fruit grown in the permanent grass system were slightly smaller than those from the annual system.

Damages on fruit skin caused by pest and diseases were very variable. Results depended on the varied kinds of pests or diseases (Table 5). The lowest percent apple scab damages was seen in the permanent grass system and was related to a limited shoot growth and a low nitrogen release pattern (Table 1, 2 and 5). In the apple scab resistant cultivar 'Prima' no severe apple scab damage was reported on the fruits until fifth year (2000) after planting (Fig. 1). At this time damage was most severe in the clover grass system. The damage continued to be more severe on the apples grown in the clover grass system from 2000–2001 (Fig. 1). This treatment also resulted in the largest uptake of N in the trees (Table 2). Buchter-Weisbrodt (1996) found that high N supply reduces the phenol synthesis in the trees and this may be one of the mechanisms to the increased susceptibility to apple scab. Trees grown in high N releasing soil systems had a more vigorous shoot growth which favoured the development of diseases such as apple scab and fly speck. In these high N releasing systems the monogenic apple scab resistance was broken. The smallest marketable yield was observed in the clover grass system (Table 5). Furthermore the highest percentages of fruits with apple scab damages were found in this system.

Mulch treatment

Many reports have suggested that mulching clippings could preserve soil moisture levels, primarily due to a reduction in evaporation (Skroch and Shribbs 1986 and Hogue et al. 2002). However, this tendency was only just apparent in the clover grass system (Table 3). The expla-

nation of the overall low soil water content in the grass system may attribute to the fact that the amount of clippings was rather low or the fact that a higher shoot growth was obtained in the mulching treatment, which indicates that soil moisture was taken up by the trees and used for shoot growth (Table 3). Other reports have also demonstrated that mulching affects the rate of tree growth (WALSH et al. 1996a). A higher N content in leaf dry matter and a higher yield were observed following mulching of the permanent grass clippings into the rows however the resulting fruit were less coloured at harvest (Table 3 and 4B), likely a result of a higher N-uptake. Although MARSH et al. (1996) demonstrated a positive effect of mulching on soil and leaf nutrient levels, this research found no significant effects following the application of mulch as clippings (Table 3). In general the clover grass system resulted in a higher leaf N content than the grass with fewer well coloured fruits at harvest (Table 4B). In general the mulching treatment had no effect on the incidence of fruit skin damages caused by different pests and diseases (Table 5).

Cultivars

'Vanda' and 'Prima' were very different in growth habit, production and fruit quality. The scab resistance was broken in both cultivars during the experimental period; however 'Vanda' kept scab resistance longer than 'Prima'. The percentage marketable fruit was also different for the two cultivars; in 2001 'Vanda' had more marketable fruit than 'Prima' (Fig. 2), an explanation for this was that 'Prima' had a lower yield with more scab infected fruit.

Conclusion

To reduce the likelihood of apple scab development and increase the colour development of the fruit it is important to choose a cover crop system that supports the apple trees with adequate N, resulting in a leaf dry matter content around 2.1 %.

Limited N supply reduces tree growth and to some extent the yield, but increases fruit colour development, and decreases the incidence of diseases in unsprayed organic production systems. The level of marketable fruit was comparable to those grown under higher N supply.

None of the cover crop systems evaluated resulted in a deficiency of potassium or calcium.

The effect of mulching clippings from a cover crop depends on the cover crop material. Mulching clover increased the soil water content, but no other effects were observed. Mulching grass increased leaf N, shoot growth and yield, while the proportion of well coloured fruit decreased.

For sustainable organic apple production it is critical to consider apple scab resistant cultivars that have polygenic resistance to avoid loss of resistance.

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Addresses of authors: B. F. Kühn and H. Lindhard Pedersen (corresponding author), Aarhus University, Faculty of Agricultural Sciences, Department of Horticulture, Kirstinebjergvej 10, DK 5792 Aarslev, Denmark, email: Hanne.Lindhard@agrsci.dk.