Organic Apple Production in Sweden: Cultivation and Cultivars

Å.H. Jönsson
Faculty of Landscape Planning, Horticulture and Agricultural Science
Department of Crop Science
Balsgård

Doctoral thesis
Swedish University of Agricultural Sciences
Alnarp 2007

Acta Universitatis Agriculturae Sueciae
2007:14

ISSN 1652-6880
ISBN 91-576-7313-8

Tryck: SLU Service/Repro, Alnarp 2007

Abstract

Jönsson, Å. 2007. *Organic apple production in Sweden: cultivation and cultivars.* Doctor's dissertation.
ISSN 1652-6880, ISBN 978-91-576-7313-8

Consumer interest in organically grown fruit appears to have increased considerably in recent years but the organic apple growing in Sweden cannot match the demand. One objective of this thesis was to study conversion of an orchard with 'Aroma' and 'Karin Schneider' from IFP to organic production. The accumulated yield for both cultivars was slightly lower in the organic sections compared to the IFP-grown sections, due mainly to a lower number of fruits while fruit size remained the same. In organic sections, 10% of the fruit was damaged by scab but less than 1% in the IFP sections. Aphids and NTG (noctuids, tortricids and geometrids) inflicted the highest amount of insect damage and this damage was higher in the organic sections. No major treatment effects were found in fruit covering colour, ground colour, firmness, sugar content or malic acid content. Two observation trials with apple scab-resistant cultivars and one with cultivars suitable for organic production of fruit for industrial use were also carried out. In Trial I, the most productive cultivars were 'Bio Golden' and 'Topaz', and in Trial II 'Vanda' and 'Scarlet O'Hara'. The fall-ripening 'Rubinola' and the late-ripening 'Scarlet O'Hara', which keeps well in storage, seem to be suitable for organic growing in our climate. 'Rajka' is interesting since it appears to be resistant against the rosy apple aphid. In Trial III with industrial cultivars, 'Blenheim Orange', 'Bramley', 'Holsteiner Cox', 'Ingbo', 'Queen' and 'Vanda' appear to be promising due to high levels of tree and fruit resistance to pests and diseases, and production of fruits suitable for processing. A consumer evaluation of scab-resistant apple cultivars was also performed. The consumers evaluated five cultivars each. Each cultivar was scored for appearance, texture, juiciness, taste and overall impression. All quality attributes were positively correlated when calculations were performed across all consumer scores, with overall impression and taste having the strongest association. 'Rubinola' and the Baslgård selection 'K:1160' emerged as the best liked cultivars overall. Minimum number of consumers needed to obtain reliable results was determined by computer simulations indicating that the variation became stabilized already with 50 consumers.

Key words: consumer evaluation, cultivar trial, fungal damage, insect pests, integrated fruit production, *Malus*, organic growing, scab resistant

Author's address: Åsa Jönsson, Balsgård–Department of Plant Breeding and Biotechnology, SLU, Fjälkestadsvägen 459, S-291 94 Kristianstad, Sweden.

Contents

Introduction, 7
Background, 7
Yield and quality, 8
Diseases and insects, 9
Choice of cultivars, 11
Objectives, 12
Materials and Methods, 13
Conversion trial (Papers III and V), 13
Cultivar trials (Papers I and II), 14
Consumer evaluation (Paper IV), 15
Statistical analyses, 15
Results and Discussion, 16
Converting an orchard from IFP to organic growing (Papers III and V), 16
Soil and leaf analyses, 16
Growth and yield, 17
Yield damage, 17
Diseases, 19
Fruit quality, 19
Pests, 20
Predators and indifferent insects, 22
Cultivar trials (Papers I and II), 23
Growth and yield, 23
Pests and diseases, 23
Fruit quality and storability, 24
Conclusions about cultivars, 25
Consumer evaluation (Paper IV), 25
Quality attributes, 26
Consumer profile data, 28
Number of consumers required for evaluation, 28
Concluding remarks, 29
Organic apple production, 29
Choice of cultivars, 30
Future research needed, 30
Acknowledgements, 31
References, 31

Appendix

Papers I – V

This thesis is based on the following papers, which will be referred to by their Roman numerals:

I. Jönsson, Å. & Tahir, I. 2004. Evaluation of scab resistant apple cultivars in Sweden. *Journal of Fruit and Ornamental Plant Research 12*, 223-232.

II. Tahir, I. & Jönsson, Å. 2005. Organic production of apple for industrial use. *Acta Horticulturae 682*, 723-730.

III. Jönsson, Å. 2006. Insects and insect damage in an apple orchard converted from integrated production to organic production. *Acta Agriculturae Scandinavica Section B, Soil and Plant Science 56*, 70-80.

IV. Jönsson, Å. & Nybom, H. 2007. Consumer evaluation of scab-resistant apple cultivars in Sweden. *Agricultural and Food Science 15*, 388-401.

V. Jönsson, Å., Nybom, H. & Rumpunen, K. Fungal disease and fruit quality in an apple orchard converted from integrated production to organic production. (Manuscript).

Introduction

Background

In Sweden, apples are produced in three different systems, conventional growing, integrated fruit production (IFP) and organic growing. Most of the Swedish apple growers have now abandoned the conventional growing and instead subscribe to the IFP concept whereas only a few have taken the big step to organic apple production. Commonly encountered problems with yield and quality of the fruit in organic orchards act as powerful deterrents!

In a conventional orchard, measures needed during the growing season can be planned already in the preceding winter. A schedule can be drafted for control of diseases and pests, and spraying performed accordingly. By contrast, IFP regulations state that plant protection measures can be taken only when there is a proven need. Application of pheromone traps, beating tray samples, warning systems for scab (*Venturia inaequalis),* soil samples and visual observations of pests and nutrient deficiency determine if, when, and how much spraying and fertilising is required.

For organic orchards, regulations are issued mainly by the largest organisation for organic production, i.e. KRAV in Sweden. KRAV is a member of the organisation IFOAM (International Federation of Organic Agriculture Movements), with members in 103 countries. For organic growing according to KRAV (2006), pheromone traps, beating tray samples, warning systems for scab, soil samples and visual observations of pests and nutrient deficiency can be used but a documented reason for the action taken is not demanded. If there is a proven deficiency of micro nutritives and no organic means to increase this nutritive, in-organic fertilisers are allowed. When an orchard is converted from IFP to organic production, three seasons of organic growing are required before the harvest is approved as organic (KRAV, 2006). Measures should be taken to increase the diversity of insects, for example by planting trees and flowers that are beneficial to predators (KRAV, 2006).

Despite an increasing consumer interest in organic food, organic apple production is still quite restricted in most countries, probably due mainly to the difficulties encountered by organic apple growers. Apple orchards are usually productive for at least twenty years. During this time, weeds, pests and fungi sometimes establish in large quantities. In a conventional or IFP-orchard, resulting problems can be solved with efficient herbicides, systemic pesticides and curative fungicides. Most of the commonly used pesticides and fungicides are, however, not permitted in organic growing, and weeds must be removed mechanically or manually, which is very labour intensive. Exceptions exist though, and for instance *Bacillus thuringiensis* against butterfly larvae, pheromones against codling moth and Kumulus against fungal diseases, are allowed and often used in all of the cultivation systems.

Yield and quality

In Sweden, apples were grown on 1440 ha in 2005, yielding a total of 17,683 metric tons (Persson, 2006) and thus averaging only 12 tons per hectare. The reported numbers however include all orchards from 0.25 ha. Many of the smaller orchards are either very old or very young, and are therefore quite unproductive. In modern, efficient orchards managed with conventional growing or as IFP, mean yields are approximately 35-40 tons per hectare whereas organic orchards may achieve around 20 tons (Per Juhlin, fruit grower consultant, pers. comm.). In Sweden, organic apple production presently amounts to c. 10% of the total apple production acreage (Emma Lundin, Swedish Board of Agriculture, pers. comm.) but probably a considerably smaller part of the total yield.

Major reasons to choose organically grown fruit include both a concern for environmental issues and the perceived but so far not unequivocally proved increase in fruit quality (Lester, 2006). Organically grown apples have been reported to be firmer and sweeter than IFP fruit in Hungarian and American trials (Gonda, Holb & Bitskey, 2000; Andrews *et al.*, 2001) whereas an increase in firmness as well as antioxidant activity was noted in organically grown apples but no differences for sugar and acid in another American trial (Peck *et al.*, 2006). By contrast, trials in Canada showed no differences in any of the evaluated fruit quality and sensory attributes (DeEll & Prange, 1992).

Differences between apple cultivars apparently influence quality parameters to a much larger effect than the different production systems (Woese *et al.*, 1997). Therefore, choice of cultivar should take quality parameters into consideration. In Sweden, almost all fruit is produced for fresh consumption, and traits of prime importance are thus size, shape, colour, juiciness, firmness, and taste.

Only 10% of the commercial harvest in Sweden is used by the processing industry. Instead, we import concentrated apple juice corresponding to 70,000 metric tons a year. Raising the quality of the Swedish apples, e.g. by organic production methods, should increase the price of the raw material for, e.g., baby food products and thus make a domestic production for industrial use feasible. Industrial fruit production must meet certain criteria. Ideally, the fruit flesh should be white and the skin colour bright and yellowish (Kaak & Grauslund, 1991). Flesh firmness must remain over 5 kg/cm^2 after 10 weeks of storage. The relationship between fruit height and diameter should be close to 1.0 since a symmetrical shape is more suited to mechanical peeling, coring and cutting.

Several physiological disorders can diminish fruit quality. One of these is scald, which is characterized by a browning of the hypodermal layers of the skin and occurs after long-term storage (Bauchot *et al.*, 1999). Severity of scald is influenced by harvest date, maturity, geographic location, cultivar, rootstock, storage period and storage condition (Ingle & D'Souza, 1989; Tahir, 2006). Fruit affected by scald can still be used for processing. Bitter pit is another common physiological disorder in apples. The fruit can develop bitter pit on the tree but this disorder more commonly appears during storage. The nutritives P, K and Ca are involved in the development and amount of bitter pit (Pavicic *et al.*, 2004; Tahir, 2006). In some countries, russeting is also common and can cause a substantial decrease in the amount of marketable fruit. Weather conditions, humidity, temperature and sunlight, as well as nutritives in the fruit affect the amount of russeting. Cracks especially around the eye cavity of the fruit are a problem in some cultivars like ‘Karin Schneider’ but the reason for their development is unknown.

Diseases and insects

Most of the commonly grown apple cultivars are susceptible to detrimental fungal diseases like apple scab and powdery mildew and to various insects, thereby requiring frequent use of fungicides and pesticides. These problems become especially serious in organic apple production. Apple scab caused by the fungus *Venturia inaequalis* is the major disease of apple (Biggs, 1990; Chevalier, Lespinasse & Renaudin, 1991; Sandskär, 2003). Scab control is also the major reason for spraying in Swedish orchards today. Scab infects leaves and fruit, and to a minor extent, also shoots. Ascospores are the main source of infection and these are produced within pseudothecia that develop in leaves during the winter months. At bud break, the ascospores mature and can cause infection. When fruit or leaves are infected, conidia form on the surface of scab lesions and become the source of secondary infection during the rest of the season (Schawlann, 1999).

Mildew, *Podosphaera leucotricha*, passes the winter in tree buds and, more seldom, on branches. When buds develop in the spring, the fungi grow on leaves and young shoots as a white, mealy layer.

Brown rot, *Monilia fructigena*, infects the fruit and in rare cases continues into the shoots. The fruit can dry on the tree and hang over the winter or lie on the ground and if not removed cause an infection the following year. A fruit injury is required for an infection of brown rot. The infection can then spread to neighbouring fruit in the same cluster. Infection can be minimized by fruit thinning, removal of infected fruit and avoidance of mechanical damage on the fruit (Schawlann, 1999).

Apple canker, *Nectria galligena*, spreads by spores distributed by raindrops, wind and insects, and enters the tree by wounds made by, e.g., pruning and frost. This is a serious disease, annually killing many apple trees in Sweden and other countries with a cold climate.

Bitter rot caused by *Colletotrichum gloeosporoides* and bull's-eye rot caused by *Neofabraea alba* and *N. malicorticis* (synonyms *Pezicula alba* and *P. malicorticis*) are common storage diseases in apple. These diseases are very difficult to distinguish without examination under microscope, and therefore all symptoms in my study are reported as 'bull's-eye rot' since this appears to be the most prevalent in Sweden where it is mostly caused by *N. alba*. These fungi can infest the fruit from flowering until harvest, and the symptoms develop both before storing and in the storage room (Schawlann, 1999). In organic orchards, there are presently no means to control these fungi (Bertelsen & Grauslund, 1995).

Aphids of the genus *Dysaphis* are the most serious pests among all aphids in the south of Sweden and can cause a total harvest loss in organic orchards (Sandskär, 2003). The eggs hatch in the spring on the apple trees and the aphids attack the buds, spur leaves and rosette leaves, and young shoots. Shoots and leaves infected by either the rosy apple aphid, *D. plantaginea*, or the foxglove aphid, *D. anthrisci*, become severely twisted, however only leaves with foxglove aphids develop red spots or red areas. No difference can be seen on infected apples, which become small and knobbly. Also the insects themselves are very similar and cannot be discriminated by appearance. Spraying with soap or vegetable oil in the spring can induce suffocation of the eggs before hatching (Schawlann, 1999). Ants feed on the honeydew produced by aphids and protect these from predators. Ants are often easier to spot than the aphids and can thus be a useful indicator of the presence of aphids in the tree. A glue barrier around the tree trunk can control ants and thereby apparently also decrease the problem with aphids.

The codling moth, *Cydia pomonella*, lays its eggs one by one on the fruitlets in June during evenings when the temperature is above 15°C. After two weeks, the eggs hatch and the larvae burrow into the fruit to the core and eat the pips (Schawlann, 1999). Codling moth was the key pest in organic apple trials in Canada (Madsen, 1979; Judd, Gardiner & Thomson, 1997) and a major pest also in Hungary (Balázs *et al.*, 1997). Similarly, Sandskär (2003) reported 25% damage from codling moth in 2000 and 2001 in an organic apple trial in Sweden, with the cultivars 'Aroma' and 'Discovery'. Pheromones can be used to stop the males from finding the females, thus interrupting mating and egg production (Schawlann, 1999).

Some of the species of noctuids, tortricids and geometrids (NTG) have larvae that feed on the fruit and cause damage that is very similar in appearance, and sometimes so severe that the fruitlets drop (Alford, 1984).

Nymphs of the apple sucker, *Psylla mali*, are considered to be a serious pest in unsprayed orchards in England. They feed on leaves as well as flowerbuds and flowers, and can destroy flowers completely in whole trusses (Alford, 1984). The apple sucker is, however, not regarded as an important pest in organic orchards in Norway (Edland *et al.*, 1999). Since the South Swedish climate is relatively similar to the South Norwegian, apple sucker-induced damage is likely to be minor also in Sweden. Possibly the apple sucker instead acts mainly as a prey for predators and therefore attract these to the orchard.

Fruit tree red spider mites, *Panonychus ulmi*, suck on the leaves and give these a dull green, brownish and then silvery bronze colour. Severe attacks may cause premature leaf drop (Alford, 1984). In a Hungarian organic apple trial, the population pressure of spider mites was very small compared to other pests (Balázs *et al.*, 1997). When spraying with insecticides in IFP or conventional orchards, the spider mite problem often increases since number of predators is reduced. This indicates that predators normally are able to keep the number of mites below damaging levels. Eggs ready to hatch suffocate if sprayed in the spring with soap or vegetable oil.

The apple fruit moth, *Argyresthia conjugella*, prefers to lay its eggs on the fruit of mountain ash but if this is not available, it settles for apples (Schawlann, 1999). Newly hatched larvae immediately burrow into the fruit flesh to feed. These insects can be very detrimental and the damaged fruit cannot be used even in processing since the larvae affect fruit taste negatively.

Some insects instead have a beneficial effect in the orchard since they act as predators. The red apple capsid, *Psallus ambiguus*, feeds on all stages of spider mites but also attacks aphids and other small arthropods. These insects are common on apple, alder, hawthorn and sallow. Eggs are laid in trees early in the summer and hatch the following April and May (Alford, 1984). The seven-spotted ladybird, *Coccinella septempunctata*, is very common and is an important predator of aphids. The bright yellow eggs of seven-spotted ladybird are often deposited close to aphid colonies on apple leaves. One larva can eat and destroy several hundreds of aphids during its development (Alford, 1984). Also the adult ladybird is a predator and overwinters in the vegetation. Enough prey must exist in an orchard for the ladybird to stay and lay eggs after the winter (Schawlann, 1999). Lacewings prey on aphids, mites and several other insects. Common green lacewing, *Chrysoperla carnea*, is common in fruit trees. They mate in early spring and lay their eggs in groups on the underside of leaves and branches. Normally two broods develop during a year (Alford, 1984). Earwigs, *Forficula auricularia*, cause some damage on fruits hanging in clusters but they are also important predators of fruit pests, feeding mainly on aphids but also on mites and insect eggs, including those of codling moth (Alford, 1984). Spiders are most abundant in unsprayed orchards, and they feed mainly on aphids, mites, adults and larvae of codling moth, and other small insects (Alford, 1984).

Choice of cultivars

Apple is a very diverse fruit crop, with many thousands of cultivars around the world. Many of these cultivars derive from chance seedlings arising spontaneously and subsequently selected for their desirable properties. Modern apple breeding programmes were initiated about a hundred years ago, and the majority of new cultivars instead arise from controlled crosses between carefully selected parents. ‘Aroma’ and ‘Ingrid Marie’ together with their red sports are the two most commonly grown apple cultivars in Sweden. ‘Aroma’ is presently recommended for organic growing in Sweden but not ‘Ingrid Marie’ (Juhlin, 2004). A problem they both have in common is their sensitivity to bull’s-eye rot (Schawlann, 1999).

Recently, there has been an increasing interest in disease-resistant apples that can be grown with less use of chemicals (Janse, 1993; Kellerhals *et al.*, 1997; Sansavini *et al.*, 2004). All over the world, apple breeding programs now have disease resistance as one of the main goals, and more than 100 new disease-resistant apple cultivars have been released since 1970 (Brown & Maloney, 2003). Certainly only a few of these new cultivars will become commercially important. For Sweden and the rest of Scandinavia, climate is a major problem since the growing season is shorter than in most countries where the cultivar development is taking place.

Resistant apple cultivars usually have at least one gene coding for scab resistance (Gianfranceschi *et al.*, 1994). The great majority of released scab-resistant varieties carry the *Vf* gene originating from *Malus floribunda* 821 (Fischer, Büttner & Fischer, 1998; Kellerhals *et al.*, 2000). Several scab races have been identified, and some of them have unfortunately proved to overcome the *Vf* resistance in, e.g. Germany and Denmark (Fischer, Büttner & Fischer, 1998; Bengtsson, Lindhard & Grauslund, 1999). Efforts are therefore made now to pyramidize resistance by the use of several different resistance genes (Sansavini *et al.*, 2004).

Modern apple breeding programmes also make use of genes coding for resistance to mildew, bitter rot, phytophtora rot (*Phytophtora cactorum*), blotch (*Phyllosticta solitaria*) and also some aphids, woolly aphid (*Eriosoma lanigerum*), rosy leaf-curling aphid (*Dysaphis devecta*) and rosy apple aphid. Mildew can be a severe disease in some cultivars but most often causes no major problems in Sweden. Resistance towards scab, the rosy apple aphid and the woolly aphid are probably the most useful for Swedish orchards.

The success of a new cultivar is ultimately determined by consumer preferences, which are affected by many different parameters (review in Harker, Gunson & Jaeger, 2003). Although appearance was the most important factor when choosing fruit and vegetables in the shop (von Alvensleben & Meier, 1990), consumers rated both texture and taste as more important when given the possibility to taste the fruit prior to making a purchase (Daillant-Spinner *et al.*, 1996). Moreover, consumer preferences can vary considerably over geographical distances as well as between groups within the population (Hampson & Quamme, 2000; Richards, 2000). A visual consumer test performed in Canada and New Zealand thus showed that preferences for the appearance of apples differed both between the two countries as well as between different cities in the same country (Cliff *et al.*, 2002).

Objectives

The major apple district in Sweden is situated in the South, around the village Kivik. Some of these orchards are found on land that has recently been claimed as groundwater catchment areas, and therefore, the use of synthetic pesticides and herbicides that could pollute the groundwater has become severely restricted. A possibly feasible alternative for these growers would therefore be to convert their existing IFP orchards to organic growing. One objective of this thesis was to study a conversion trial, from IFP to organic production, in an orchard with the two most widely grown apple cultivars in Sweden, ‘Aroma’ and ‘Karin Schneider’ (red sport of ‘Ingrid Marie’). Specific questions asked were whether the commonly used organic insecticides were sufficient, and whether the amount of predators would increase and thus help to keep the insect pest damage at acceptable levels during the conversion. Parameters like tree growth and yield, and fruit quality with special emphasis on size, colour, fungal diseases, physiological disorders and chemical contents were also focused. When planting a new orchard, modern scab-resistant cultivars should, however, be considered. Two observation trials with apple scab-resistant cultivars were carried out with the purpose to evaluate yield, fruit size, quality, storability and resistance. As a supplement, a consumer evaluation of scab-resistant apple cultivars was performed since the success of a new cultivar is ultimately determined by consumer preferences. Another objective with this study was to investigate the feasibility of using relatively inexpensive and easily available mass testing by untrained consumers, and the number of scores needed. Finally a cultivar trial for organic production of apple for industrial use was included in the thesis work. The purpose of this trial was to investigate 16 scion cultivars concerning their suitability for organic production methods and industrial fruit processing.

Materials and Methods

All growth trials were performed at SLU/Kivik in the province Skåne in the south of Sweden, where the major district for apple growing is situated, and the consumer evaluation was performed at 'Äpplets Hus' in Kivik.

Conversion trial (Papers III and V)

One hundred trees from each of two popular cultivars 'Aroma' and 'Karin Schneider' were used in a conversion trial. The organic sections are denoted as Aroma O (A-O, planted in 1990 except for the last 'Aroma' row which was planted in 1994) and Karin Schneider O (K-O, planted in 1996). Two or three shelter trees divided the organic trees from the following trees that were treated according to integrated fruit production (IFP) and denoted as Aroma Ic (A-Ic) and Karin Schneider Ic (K-Ic). Each of these four sections contained 40 trees. To act as a second control treatment, trees from another field on the same farm were added to the trial. The distance between the fields was approximately 500 metres. Twenty trees of each variety were taken randomly from this second field to participate in the trial. These sections were treated according to integrated fruit production and were denoted as Aroma Id (A-Id, planted in 1990), and Karin Schneider Id (K-Id, planted in 1996). The IFP sections situated in the same rows as the organic sections were called IFP-close, and the IFP-sections in the separate field were called IFP-distant.

To investigate the presence of insects in the field, beating tray samples were collected. Thirty-three trees were taken randomly in each of the sections. One branch in each tree was hit three times with a padded stick and the dropping insects were gathered in a net bag. The different insect species or groups were noted and counted. The beating tray samples were collected 7 to 8 times each year. Amount of scab infection in the trees was estimated in all three years. All scab-infected leaves were counted on four randomly taken annual shoots on each tree in each section on August 15, July 2 and August 19 in 2000, 2001 and 2002, respectively. For assessment of mite infection, 50 leaves were taken randomly on July 6, 2000, and number of predatory mites was calculated in a stereo dissecting microscope, from each of the sections A-O, K-O, A-Ic and K-Ic. At least one leaf was picked from each tree in each section.

All trees included in the trial were harvested separately in three consecutive years. In 2000 and 2001, the fruit from each tree was weighed as a bulk and then counted and scored for damage. In 2002, fruit from each tree was still weighed but the counting and scoring for damage was performed for only eight randomly taken trees in each section. Fruit not classified as I-class were scored for damage caused by specific insects, other animals, fungal damage and other damage. The specific insects were moths (NTG), codling moth, apple fruit moth, apple sawfly and *Dysaphis*-aphids. The other animals were BES (birds, earwigs and snails) all of which cause similar damage. Fungal damage scored for was scab, brown rot and bull's-eye rot. Other damage was fruit deformity, mechanical damage, russeting, small fruit (<65 mm in diameter for 'Aroma' and <55 mm for 'Karin Schneider'), cracks, frost, hail and rotten fruit.

Before the trial started, soil analyses were performed to estimate the nutritional requirements in the organic and IFP-close sections. Soil and leaf analyses were also performed during the trial. The soil samples were collected with a soil probe in the top layer of the soil, 0-25 cm. In 2001 and 2002, 50 leaves were collected from each section twice a year for leaf analysis. Fruit analysis was performed on pooled samples for each section and date (15 in total). All samples were sent to the chemical analysis company AnalyCen.

Fifty I-class apples, from each of the eight random trees in each section, were stored separately at +2 °C. The stored apples were evaluated at the time estimated as the start of eating maturity and at the end of eating maturity, i.e. 90 days later. At each evaluation event, apples with the storage diseases bull's-eye rot and scald, and fruit rotten due to unknown causes were counted and removed. Subsequently, five apples were taken randomly from each box for physical and chemical analysis. Amount of red skin colour and ground colour was estimated visually. After removal of the skin, firmness was investigated with a fruit pressure tester, Facchini, mod. FT 327. Each apple was penetrated twice, on opposite sides, to a depth of 8 mm with a probe of 11.3 mm in diameter. Sugar content was measured with an Atago digital refractometer PR-1 and expressed as % SS (soluble solids).

The 2002 apple harvest was analysed also for content of malic acid at harvest, start of eating maturity and at the end of eating maturity. Malic acid was analysed with a HPLC system.

Cultivar trials (Papers I and II)

Three cultivar trials were performed. Scab-resistant dessert apples were analysed in the first two trials and apples intended for industrial production were analysed in the third trial. In the first trial (Trial I), eight scab resistant cultivars from the Czech republic were planted in the spring of 1997 in a randomised block design, with five blocks containing one tree of each cultivar. The trees were propagated on the rootstock M9 or MM106. The second trial (Trial II) contained 13 cultivars, on the rootstocks M26 or MM111, from several countries and the Swedish cultivar ‘Amorosa’, on the rootstock MM106, as a control. This trial was planted in the spring of 1998, using a randomised block design with three blocks and one tree of each cultivar in each block. In the third trial (Trial III), 16 cultivars were investigated, comprising both traditional culinary cultivars as well as popular dessert fruit cultivars. The cultivars were grafted on the rootstocks MM106 and MM111. Six trees of each cultivar/rootstock combination were planted in 1998, randomised in three different blocks. No pesticides, herbicides or fungicides were used. Weeding was performed mainly with a rotary cultivator, but also by hand closest to the trunks. Drip irrigation was used in periods of drought.

In all three trials, optimum harvesting date was determined by measuring the Streif index [firmness / soluble solid concentration (SSC) x starch score]. Fruits of each tree were picked at optimum harvest date (Streif index = 0.25) and the fruit from each tree was weighed as a bulk, counted and scored for damage. A sample of fruits was stored at 2-3ºC and 90% RH, for about two months. Fruit quality (firmness, SSC and decay) was evaluated on 10 fruits/block, at harvest and post storage. In Trial I, fruit was harvested from 1998 to 2003 and damage was assessed in the same years. In Trial II, fruit was harvested from 1999 to 2003 and damage was scored from 2000 to 2003. In Trials I and II the scoring of damage, caused by insects, other animals, fungi and other causes, was performed in the same manner as described for the conversion trial above. In Trial III, all trees were harvested and scored in 2000-2003. Infected leaves and shoots were collected and used to estimate the susceptibility of the tree to pests and diseases. All the harvested fruit was scored for damage. Suitability for mechanical peeling, cutting and coring, was evaluated by measuring fruit height and the diameter of transverse and longitudinal cuts through the fruit. Fruit skin colouration was measured using a Minolta Chroma Meter CE-200 with 8 mm diameter window. Flesh colour was assessed by ocular inspection using a 5-point scale.

Consumer evaluation (Paper IV)

In connection with a popular apple fair, sensory evaluations of 11 (September 28-29, 2002) and 15 (September 27-28, 2003) scab-resistant apple cultivars was arranged at a small museum called Äpplets hus (translated as the Apple house) in Kivik. In addition, the much appreciated but not scab-resistant cultivar 'Aroma' was used as a reference.

The cultivars were divided into three groups with five cultivars in 2002 and four groups with five cultivars in 2003. In each group 'Aroma' was included. Each consumer tasted all five cultivars in one of these groups. The consumers were asked to score each cultivar for appearance, texture, juiciness, taste and overall impression on a 100-mm hedonic line scale on a form sheet. For appearance, taste and overall impression, the scales were labelled "very poor" and "very good" at the left and right anchor points. For texture, the scale was labelled "very soft" and "very firm". For juiciness, the scale was labelled "very dry" and "very juicy". The consumers were also asked to supply some personal data, e.g. if they prefer to buy organically grown apples and whether they would be prepared to do this also at a 0.55 Euro increase per kilo.

On the day before the evaluation weekend, five apples of each cultivar were taken randomly for physical and chemical analysis. Each cultivar was classified into one of 9 different shape categories. Background colour and amount of covering red colour was scored visually. After removal of the skin, firmness was investigated with a fruit pressure tester, Facchini, mod. FT 327. Each fruit was penetrated twice, on opposite sides, to a depth of 8 mm with a probe with the diameter 11.3 mm. Sugar content (soluble solids) was measured with an Atago digital refractometer PR-1 and expressed as % SS.

Statistical analyses

Conversion trial (Papers III and V): Most of the data was not normally distributed, and statistical analyses were therefore performed with non-parametric methods. The percentages of I-class fruit as well as fruit damaged for different reasons were compared in pairs with the Mann-Whitney U-test for the three treatments, the two cultivars and the three years. Possible associations between number of aphids found in the beating tray samples and number of fruits damaged by the aphids were investigated with the Spearman's rho correlation analysis. The effects of storage on quality parameters were also compared with the Mann-Whitney U-test. The data for growth and yield efficiency as well as amount of apples harvested, and malic acid content in the fruits were normally distributed and compared with one-way ANOVA together with Tukey HSD.

Cultivar trials (Papers I and II): For Trials I and II, data for yield and yield damage was not normally distributed and non-parametric statistics were therefore used. Mann-Whitney U-test was used to compare the cultivar yields in Trial I. Fruit quality and storability were analysed with one-way ANOVA together with Tukey HSD and the means were compared using Duncan's test. For Trial III, results were analysed with MS Excel, using ANOVA and Duncan's test.

Consumer evaluation (Paper IV): Consumer scores were analysed with one-way ANOVA together with Tukey HSD. Pairwise associations between consumer scores for the five attributes were analysed across the whole data set with Pearson correlation coefficients. Possible influence of the consumer profile variables on the evaluation scores was analysed using one-way ANOVA together with Tukey HSD (age and consumption) or Mann-Whitney U-test (gender, access to home-grown apples and interest in buying organic apples). The 352 consumer scores for overall impression of 'Aroma' in 2002 were used to determine the minimum amount of consumers required for a reliable consumer test. Means were calculated for 100 random subsets consisting of 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 evaluation scores, respectively. Standard deviation was calculated, in MS Excel, for each group of subsets and then plotted as a function of the number of consumer scores in the group.

The SPSS 10 Data Analysis Package (Norusis, 1990) was used for all calculations if not otherwise stated.

Results and Discussion

Converting an orchard from IFP to organic growing (Papers III and V)

Soil and leaf analyses

Soil nutrients were sufficient in all sections according to the soil analyses while content of leaf tissue minerals varied between the different treatments in our trial for calcium, potassium, nitrogen, phosphorus and magnesium. Content of potassium and phosphorus was higher in the organic sections compared to the IFP-sections while nitrogen was higher in the IFP-sections. Foliar spraying with calcium and magnesium probably caused the higher content of calcium and magnesium that was found in the IFP-sections. Soil potassium was higher in the organic sections compared to the IFP-sections, and probably caused the increased amount of this nutritive also in the leaves. Differences among treatments in content of nitrogen and phosphorus showed no association with the corresponding mineral contents in the soil. Both calcium nitrate and calcinit were used for foliar spraying in the IFP sections, and their nitrogen contents have probably affected the leaf content of nitrogen at the end of the season. This assumption is supported by an Egyptian study reporting an increase of both calcium and nitrogen in fruit and leaves after a foliar application with calcium nitrate (Aly, 2000). The calcium foliar spraying is supposed to provide a better storage ability and is frequently used in IFP orchards. There are, however, no organic products corresponding to the foliar calcium sprays.

Growth and yield

The older 'Aroma' trees were overall much bigger and grew faster than the 'Karin Schneider' trees in our trial. Some variation was also found between the studied sections for each cultivar in initial tree size and in growth during the three years. These differences were in all likelihood not caused primarily by the treatments per se, but instead by local differences like availability of water and nutrients, and in microclimatic conditions. For 'Aroma', yield per tree, number of fruits per tree and yield efficiency, calculated as the ratio between yield and TCA, was higher in the IFP-sections compared to the organic sections. For 'Karin Schneider', the pattern was less clear and varied between years.

Throughout our trial, percentage I-class fruit was below acceptable levels in all sections, but the problem was most pronounced in the organic sections. When calculated across both cultivars in 2000, values were significantly lower in organic sections, 42%, as compared to IFP-close, 53% or IFP-distant, 47%. In 2001, percentage I-class fruit was again lower in organic sections, 61%, compared to IFP-close, 74% but higher than in the IFP-distant sections, 54%. Finally, in 2002, percentage I-class fruit was lower in organic sections, 52%, compared to IFP-distant, 64%.

Insufficient fruit size was overall a major reason for the failure to reach I-class standard, and more efficient fruit thinning might have alleviated this problem. However, when the organic sections were compared to IFP-close, fruit size did not differ but instead number of fruits was somewhat lower. The sulphur-based fungicide Kumulus may have caused this reduction in fruit number. Sulphur is a major ingredient in products used for fruit thinning, and Kumulus may have damaged some flowers at the first spraying, which was performed in May in all three years. In a trial in New Zealand, treatment with lime sulphur and Kumulus reduced the yield in organic sections; fruit weight was not affected but number of fruits per tree was 12% lower in organic sections compared to IFP sections (Palmer *et al.*, 2003). Other treatment-related effects in number of flower buds and flowers would of course also be important. In our trial, flower buds were not counted, but a study in Switzerland reports more flower buds as well as better bud quality and larger fruitlets in IFP plots compared to organic plots (Bertschinger *et al.*, 2004). In the Swiss trial, sulphur was used for disease control in the organic plots and this could have caused the reduction in flower buds.

Yield damage

A high percentage of the fruit held insufficient quality at harvest, with fruit size being the most common problem; thus 29%, 29% and 19% of the 'Aroma' and 8%, 14% and 25% of the 'Karin Schneider' apples were too small in 2000, 2001 and 2002, respectively. Fungal infections caused 7% of the damaged fruit in 'Aroma', and 6% in 'Karin Schneider'. For 'Karin Schneider', cracked fruit amounted to 31.7%, 37.0% and 29.0% in the year 2000 for the organic, IFP-close and IFP-distant section, respectively, but was below 6% in all sections for both 2001 and 2002. More fruit was also damaged by frost in 2000 (4.0%) compared to

2001 (0.0%) and 2002 (2.7%) (Table 1). Cracks and hail were the main reasons for a significantly lower percentage I-class fruit in the year 2000 compared to the other years (Table 1). For 'Karin Schneider', the large amount of fruits with small cracks surrounding the eye cavity was a much larger problem than damage caused by fungi, even in the organic section (Table 1). Although cracked fruit commonly occurs in 'Karin Schneider', there are presently no known means to suppress these cracks and, accordingly, no treatment effects were found in our study.

Table 1. Newly harvested fruit of 'Aroma' (A) and 'Karin Schneider' (K) rated for damage due to too small fruit, fruit with cracks, scab, mechanical damage (MD), hail, brown rot (BR), rotten due to unknown causes, deformity (Def), russet, frost and bull's-eye rot (BER), for the treatments organic (O), IFP-close (Ic) and IFP-distant (Id). In 2000 and 2001, 40 trees were evaluated for each of the organic sections and IFP-close, and 20 for IFP-distant. In 2002, eight random trees were evaluated in each section.

Section	Year	Small	Cracks	Scab	MD	Hail	BR	Rotten	Def	Russet	Frost	BER
A-O	2000	27.87	0.11	16.09	4.45	0.57	0.00	1.71	0.09	0.04	0.17	0.09
A-O	2001	26.99	0.08	11.76	1.45	0.00	2.05	0.00	0.26	0.05	0.00	0.29
A-O	2002	13.50	0.00	22.85	2.68	0.00	4.60	0.00	0.10	0.00	0.00	0.00
A-O	**2000-2002**	**22.79**	**0.06**	**16.90**	**2.86**	**0.19**	**2.22**	**0.57**	**0.15**	**0.03**	**0.06**	**0.13**
A-Ic	2000	28.05	0.25	0.28	3.82	2.19	0.00	0.00	0.12	0.05	0.20	0.00
A-Ic	2001	24.45	0.03	0.00	1.48	0.00	0.20	0.00	0.19	0.01	0.00	0.00
A-Ic	2002	17.46	0.00	0.04	3.45	0.00	0.22	0.00	0.11	0.00	0.00	0.00
A-Ic	**2000-2002**	**23.32**	**0.09**	**0.10**	**2.92**	**0.73**	**0.14**	**0.0**	**0.14**	**0.02**	**0.07**	**0.0**
A-Id	2000	33.97	0.42	0.02	4.34	3.73	0.03	0.40	0.42	0.09	0.38	0.00
A-Id	2001	43.14	0.07	0.01	2.11	0.00	0.98	0.00	0.20	0.02	0.00	0.00
A-Id	2002	24.65	0.00	0.00	1.71	0.00	3.64	0.00	0.13	0.00	0.00	0.00
A-Id	**2000-2002**	**33.92**	**0.16**	**0.01**	**2.72**	**1.24**	**1.55**	**0.13**	**0.25**	**0.04**	**0.13**	**0.0**
K-O	2000	12.32	31.74	7.23	2.78	6.46	0.00	0.07	0.23	0.87	0.42	0.00
K-O	2001	10.50	5.69	2.93	2.44	0.00	4.90	0.00	0.41	0.00	0.00	0.21
K-O	2002	9.32	5.11	7.11	1.64	15.93	1.02	0.00	0.63	0.00	0.00	0.00
K-O	**2000-2002**	**10.72**	**14.18**	**5.76**	**2.29**	**9.62**	**1.97**	**0.02**	**0.42**	**0.29**	**0.14**	**0.07**
K-Ic	2000	2.04	37.01	1.95	1.99	3.85	0.16	0.00	0.28	0.45	0.98	0.00
K-Ic	2001	8.75	2.03	0.10	2.40	0.00	0.46	0.00	0.78	0.00	0.00	0.00
K-Ic	2002	46.93	0.95	0.00	1.61	0.00	0.00	0.08	0.25	0.00	0.10	0.00
K-Ic	**2000-2002**	**19.24**	**13.33**	**0.68**	**6.00**	**1.28**	**0.21**	**0.03**	**0.43**	**0.15**	**0.36**	**0.00**
K-Id	2000	13.56	29.02	0.00	0.82	9.68	0.04	0.00	0.23	0.49	0.60	0.00
K-Id	2001	33.14	5.89	0.00	1.67	0.00	0.60	0.00	0.44	0.15	0.00	0.00
K-Id	2002	18.40	4.13	0.18	1.72	0.20	0.00	0.33	0.22	0.00	0.22	0.00
K-Id	**2000-2002**	**21.70**	**13.01**	**0.06**	**1.41**	**3.29**	**0.21**	**0.11**	**0.30**	**0.22**	**0.27**	**0.00**

Treatment effects were especially pronounced and serious for scab, with a much higher percentage scab damaged fruit in the organic sections, 16.9% as a mean over all years for A-O and 5.8% for the organic K-O but below 1% scab damage for the IFP-sections. Also brown rot, bull's-eye rot and rotten due to unknown fungi occurred more often in organic sections, further described under the heading Diseases below. Other kinds of damage, e.g hail, frost and russet, were of minor importance and showed no clear differences between treatments. Hail and frost are not influenced by the growing system but russeting can be affected by diseases and pests and the means used to prevent infection. For instance mildew and mites have been reported to induce fruit russetting (Schawlann, 1999).

Diseases

The organic sections were noted for significantly more scab than the IFP-sections, both on leaves and fruit (Table 1). Lack of sufficiently efficient fungicide treatments in the organic sections was especially pronounced in 'Aroma' with larger trees that do not dry up as fast after rainfall or morning dew as the smaller 'Karin Schneider' trees. In 'Aroma', leaf infection with scab was almost four times as high as in 'Karin Schneider'. Strong pruning has previously been shown to decrease scab considerably in scab-susceptible cultivars, apparently due mainly to the improved spray disposition (Holb, 2005). In our trial, leaf infection with scab was almost four times higher in 'Aroma' compared to 'Karin Schneider'. Presently it is, however, impossible to distinguish between effects due to tree size or to cultivar properties.

The most common problem during storage was bull's-eye rot, and treatment proved to have a strong impact on this disease: the amount of fruit with bull's-eye rot was significantly higher in the organic section than in the IFP-sections. Low temperatures and ULO storage generally suppresses the development of bull's-eye rot (Bertelsen & Grauslund, 1995) and could be helpful, but storage duration must probably be shortened for organically grown fruit compared to IFP fruit. Choice of cultivars that are less prone to bull's-eye rot, as well as distribution of the fruit as soon as it has reached eating maturity is also important, but this requires well-developed marketing channels.

Scald occurred only infrequently, and with significant variation among years. In the year 2000, the organic 'Aroma' section had a lower amount of scald, 2.4%, than IFP-distant, 28.0%, whereas 'Karin Schneider' had a smaller amount in IFP-distant, 0.4%, compared to both organic, 9.0%, and IFP-close, 6.4%. Generally, scald is not very common in Sweden, possibly due to the relatively cool weather during fruit ripening. In our trial, all sections however suffered from scald in the year 2000, whereas only four apples with scald, all 'Aroma', were harvested in 2002 and none in 2001.

Fruit quality

In our trial, treatment had no apparent influence on fruit colour, firmness or contents of sugar and malic acid, despite previous reports that organic fruit is firmer and sweeter than IFP fruit (Gonda, Holb & Bitskey, 2000; Andrews *et al.*, 2001), and contains more malic acid than conventionally produced apples (Velimirov, 2004). Peck *et al.* (2006), noted an increase in firmness as well as antioxidant activity in organically grown apples but no differences for sugar and acid.

By contrast, significant differences were found between cultivars in most of the fruit quality variables. Calculated over treatments and evaluation dates, ground colour was more yellow and amount of covering colour higher for 'Karin Schneider' compared to 'Aroma' in all three years. Sugar content was higher in 2000 and 2002 for 'Karin Schneider' compared to 'Aroma', and also firmness was higher in 2002.

Nitrogen content was lower in the organic apples compared to the IFP fruit in our trial, probably due to foliar spraying in the IFP sections with calcium nitrate and calcinit containing nitrogen. In trials performed in the U.S., organic fruit similarly had lower nitrogen content compared to fruit grown in IFP and conventional systems (Andrews, Glover & Reganold, 2001; Peck *et al.*, 2006). The lower amount of nitrogen was then suggested to be the reason for a higher firmness in the organic fruit. In our trial there was, however, no significant difference in firmness between the different treatments. Excessive nitrogen fertilization enhances susceptibility to scab (Leser & Treutter, 2006) and should therefore be avoided, especially in organic orchards where the disease pressure is already high.

No effects of the calcium spraying were seen in the fruit minerals analysis, suggesting that the spraying, which is undertaken to improve storability, may have been superfluous or not sufficiently efficient. Since calcium does not move from leaves to fruit, young fruitlets must be hit directly by the liquid.

Pests

Percentage fruit damaged by aphids was significantly higher in the organic (10.2%) and IFP-close sections (8.1%) compared to IFP-distant (2.1%) (Table 2). No major difference was found among treatments considering rosy apple aphid-damaged shoots. On August 23 in 2000, the numbers were on average 3.6, 2.7 and 4.5 damaged shoots per tree in A-O, A-Ic and A-Id. Corresponding numbers for the foxglove aphid were 1.3, 1.3 and 0.5 shoots. In 'Karin Schneider' average number of damaged shoots caused by the rosy apple aphid was 0.6, 0.1 and 0.3 in K-O, K-Ic and K-Id respectively, whereas damage by the foxglove aphid was 0.1, 0.3 and 0.4. In the year 2002, no visual damage of branches was observed. In accordance with this result, significantly fewer apples were damaged by aphids in 2002 compared with the years 2000 and 2001. Number of aphids found in the beating tray samples was overall higher in the organic sections across all three years, 737 in 'Aroma' and 681 in 'Karin Schneider' and in IFP-close, 526 in 'Aroma' and 419 in 'Karin Schneider', compared to IFP-distant, 60 in 'Aroma' and 128 in 'Karin Schneider'. A correlation was found between number of aphids in the beating tray samples and number of fruits damaged by aphids for 'Aroma' and for 'Karin Schneider' suggesting that beating tray samples can be used for determination of pest management actions against aphids.

Table 2. Percentage of the yield damaged by the rosy apple aphid (*Dysaphis plantaginea)* or the foxglove aphid *(Dysaphis anthrisci),* divided by year, treatment and variety combined with treatment. The treatments were organic, integrated fruit production (IFP) close to the organic (Ic) sections and at a distance (Id). The apple cultivars were 'Aroma' (A) and 'Karin Schneider' (K)

			Mann-Whitney				
	Dysaphis%		p-value			n-value	U-value
year	average	stdev	2000	2001	2002		
2000	7.3	14.0		0.263		399	18 646
2001	9.8	14.1			0.000	247	2 104
2002	0.1	0.6	0.000			248	1 808
treatment			O	Ic	Id	n-value	U-value
O	10.2	17.4		0.821		351	15 190
Ic	8.1	11.4			0.000	272	5 292
Id	2.1	5.1	0.000			271	5 283
cultivar			A-O	A-Ic	A-Id	n-value	U-value
A-O	8.7	10.9					
A-Ic	9.7	10.4					
A-Id	1.5	4.3					
K-O	11.8	22.2	0.012			175	3 011
K-Ic	6.5	12.0		0.000		176	2 673
K-Id	2.6	5.8			0.976	96	1 148

Very few moths were captured in the beating tray samples. In the pheromone traps total number of male codling moths was 17, 74 and 25 in 2000, 2001 and 2002, respectively. Numbers were very similar in the organic sections (8, 22 and 2 in 2000, 2001 and 2002) and in the IFP-close sections (9, 10 and 0). Much higher numbers were obtained in the IFP-distant sections, 42 and 23 in 2001 and 2002. Not a single apple with injuries from codling moth was found in any of the years. Sandskär (2003) found less damage in trees treated with sulphur and fatty acids compared to untreated trees; although above 20% in the treated trees, damage was significantly less than in the untreated plots. Thus treatment with sulphur and fatty acids may have helped to restrict codling moths to below damaging levels in the organic sections in my trial, while conventional pesticides did the same in the IFP sections.

The NTG group caused a mean damage of 6.4% on the fruit, which is almost half of the total insect damage, 14.5%. The organic sections, 7.3%, had a significantly higher damage percentage compared to the sections IFP-close, 6.2% and IFP-distant, 5.6%. A small but still significant difference was found for NTG damage between 'Aroma', 6.3% and 'Karin Schneider', 6.8% (Table 3).

On the 200 leaves examined for mite infection, only 15 mites in total were found. Since this amount was so small, and no signs of damage from spider mites appeared in the trees, this part of the study was abandoned after the first year.

The apple sucker was found in large amounts in the beating tray samples, especially in the year 2000 and in the cultivar 'Aroma'. In the year 2000, 2618 and

2488 apple suckers were captured in A-O and A-Ic, respectively. By contrast, in K-O and K-Ic only 91 and 56 apple suckers were captured. They appeared early in the season but disappeared around the middle of July. No damage was observed in the trees.

Very few moths were captured in the beating tray samples and no injuries caused by the apple fruit moth were found.

Table 3. Percentage of harvested apples damaged by NTG (noctuid, tortricid and geometrid moths). The production methods were organic, integrated fruit production (IFP) close (Ic) to the organic sections and at a distant (Id)

			Mann-Whitney				
	NTG %		p-value			n-value	U-value
year	average	stdev	2000	2001	2002		
2000	6.5	5.2			0.022	358	5 795
2001	7.0	7.5	0.724			510	30 372
2002	4.7	4.5		0.090		246	3 934
treatment			O	Ic	Id	n-value	U-value
O	7.3	5.9			0.021	342	11 062
Ic	6.2	6.8	0.012			442	21 041
Id	5.6	4.6		0.695		330	12 039
variety			Aroma			n-value	U-value
Aroma	6.3	6.7					
Karin Schneider	6.8	5.2	0.026			557	33 678

The effects of different cultivation methods on composition and abundance of the insect and mite fauna in apple orchards have received considerable attention but no clear patterns have yet emerged. Knight (1994) reported that the pest density was similar or lower in organic orchards compared to in conventional orchards, except for codling moth which was significantly more abundant in the organic orchards. Results pointing in the opposite direction were obtained in a trial in New Zealand (Suckling, Walker & Wearing, 1999). Lack of effective pest control limited the economic sustainability and restricted the productivity severely in this study. Just like in the New Zealand study, a higher amount of insects and insect damage was encountered in the organic sections in my trial.

Predators and indifferent insects

Number of predators found in the beating tray samples was higher in the IFP-close sections than in the organic sections during the first year of the trial. In the two following years, number of predators increased in the organic sections for ‘Aroma’ but remained relatively constant over the years for ‘Karin Schneider’. The ‘Aroma’ trees were larger and more compact which may have prevented some insects from falling directly into the net bag. By contrast, the larger trees of ‘Aroma’ may also have harboured a larger amount of some insects compared to the ‘Karin Schneider’ trees. There were more predators in the organic sections for both cultivars in 2002, compared to the IFP sections but the number of predators was not sufficiently high to keep pests under control.

Number of captured red apple capsids was 320, 189 and 322 in ‘Aroma’, and 28, 55 and 104 in ‘Karin Schneider’ in the years 2000, 2001 and 2002. The number of ladybirds was 25, 66 and 30 in ‘Aroma’ and 60, 52 and 27 in ‘Karin Schneider’ in 2000, 2001 and 2002. The number of lacewings was 38, 18 and 23 in ‘Aroma’, and 40, 22 and 50 in ‘Karin Schneider’ in the years 2000, 2001 and 2002, respectively. In spite of the difference in tree size, number of aphids did not differ very much between the two cultivars, suggesting that this prey was more accessible in the trees of ‘Karin Schneider’. The number of captured earwigs was 92, 33 and 55 in ‘Aroma’, and 8, 13 and 4 in ‘Karin Schneider’ in 2000, 2001 and 2002, respectively. Earwigs obviously showed a strong preference for ‘Aroma’, possibly because the larger trees of this cultivar provided a better shelter. The number of spiders was 81, 96 and 56 in ‘Aroma’, and 77, 72 and 50 in ‘Karin Schneider’ in 2000, 2001 and 2002, respectively. The total number of ants was 151, 115 and 57 in 2000, 2001 and 2002, respectively. The number of aphids was higher in 2001 compared to 2000 but much smaller in 2002 and is only partly consistent with the number of ants. The larger amount of apple suckers in 2000 may have caused the increase also in ants, since ants eat honey dew and this is produced by the apple suckers.

Cultivar trials (Papers I and II)

Growth and yield

Trial I: The most productive cultivars were ‘Bio Golden’ (55 kg cumulated yield), ‘Topaz’ (51 kg) and ‘UEB 2074/1’ (44 kg) while ‘UEB 2257/4’ (36 kg) and ‘Rajka’ (35 kg) produced the smallest five-year cumulative yields.

Trial II: The cultivars with the highest four-year cumulative yields were ‘Vanda’ (43 kg) and ‘Scarlet O’Hara’ (35 kg) while ‘BM 51596’ only yielded 1 kg. ‘Amorosa’ surprisingly produced the second lowest yield, 10 kg, and would definitely not be recommended for organic growing on basis of this trial. Yields were quite low for many other cultivars in this trial, suggesting that yield evaluations may not be sufficiently representative.

Trial III: Among the 16 cultivars, ‘Queen’ and ‘Wellington’ showed the smallest change, around 2%, in TCA whereas ‘Belle de Boskoop’, ‘Blenheim Orange’, ‘BM 40794’, ‘Holsteiner Cox’, ‘Ingbo’ and ‘Vanda’ showed the largest, around or above 5% for at least one rootstock. MM111 caused a larger increase in TCA than MM106. Cumulative yield per tree was highest for the cultivars ‘Belle de Boskoop’, ‘Bountiful’, ‘Bramley’, ‘Holsteiner Cox’, ‘Ingbo’ and ‘Vanda’. All of these cultivars had a yield that was at least four times larger compared to ‘Rubin’ and ‘Gravensteiner’, which had the lowest yield.

Pests and diseases

Trial I: Calculated over all cultivars and years, NTG had damaged 9% of the evaluated fruit at harvest. Other serious pests were *Dysaphis*-aphids which also caused a total mean damage of 9%.‘Rajka’ was the only cultivar that showed no damage from aphids. Bitter pit was a major problem in ‘Vanda’ (12%) and is the main reason why this cultivar must be deemed as unsuitable for organic growing in Sweden. Cracking was a problem for ‘UEB 2257/4’ (10%) and therefore this selection cannot be recommended.

Trial II: NTG produced the highest amount of damage, 11%, when calculated over all cultivars and years. There was very little aphid damage, and all cultivars except ‘Scarlet O’Hara’ (3%) were below 1%. Bull's-eye rot was a problem in ‘Amorosa’ (10%) and ‘BM 51596’ (5%). Bitter pit was again a serious problem in ‘Vanda’ (24%).

Trial III: In a visual observation of the trees the two cultivars ‘Belle de Boskoop’ and ‘Gravensteiner’ showed comparatively high susceptibility to pests and diseases whereas six cultivars, ‘Antonovka’, ‘Blenheim Orange’, ‘BM 40794’, ‘Bramley’, ‘Queen’ and ‘Vanda’, had good tolerance or resistance to some of the most important pathogens, namely apple scab, bull's-eye rot, aphids and tortricids. Seven cultivars produced comparatively sound fruits at harvesting: ‘Blenheim Orange’(13.6% and 8.3% damaged fruit on MM106 and MM111 respectively), ‘BM 40794’ (7.0% and 15.3%), ‘Holsteiner Cox’ (10.6% and 21.6%), ‘Ingbo’ (7.0% and 23.6%), ‘Queen’ (13.3% and 10.6%), ‘Rubin’ (7.0% and 15.3%) and ‘Vanda’ (13.6% and 13.3%).

In all likelihood, the cultivars in all three trials would produce a higher amount of I-class fruits in an orchard where organic methods were applied to protect the fruit from attacks from insects and fungi. Damage from NTG can be prevented by spraying with *Bacillus thuringiensis* while aphids can be checked by pyrethrum and fatty acids.

Fruit quality and storability

Trial I: A high firmness at harvest was noted for ‘UEB 2345/1’ (7.3 kg/cm^2), ‘Topaz’ (6.7 kg/cm^2) and ‘UEB 2257/4’ (6.7 kg/cm^2) while especially ‘Rajka’ and ‘Vanda’ were softer and lost 20% of their firmness during storage. A high decay after storage was noted for ‘UEB 2345/1’ (7%) and ‘Vanda’ (6%). The three cultivars with best storability (least decay, SSC > 12%, firmness = 6-8 kg/cm^2) were ‘Rubinola’, ‘Rajka’ and ‘Topaz’. ‘Topaz’ had a high amount of small fruit and apparently requires a warmer climate to develop properly.

Trial II: Five cultivars were distinguished as the most firm at harvest, ‘Reglindis’ (10.5 kg/cm^2), ‘BM 51596’ (10.0 kg/cm^2), ‘Scarlet O’Hara’ (9.9 kg/cm^2), ‘Co-op 24’ (9.7 kg/cm^2) and ‘Co-op 26’ (9.0 kg/cm^2). During storage ‘Reglindis’ lost more of its firmness compared to the other four cultivars. The cultivars ‘Remo’, ‘Redfree’, ‘William’s Pride’, ‘BM 41497’ and ‘Co-op 12’ lost some of their SSC during storage and had less sweetness than at harvest. Highest percentage decay appeared in ‘BM 41497’ (35%) and ‘Co-op 12’ (24%). Best storability was noted for ‘Co-op 26’, ‘Reglindis’ and ‘Scarlet O’Hara’. Small fruits was a problem for several cultivars, thus ‘Katinka’, ‘Redfree’, ‘Reglindis’, and ‘William’s Pride’ had more than 10% fruits with a diameter below 60 mm.

Trial III: Two cultivars (‘BM 48087’ and ‘Rubin’) had a dull and reddish skin colour whereas five cultivars (‘Blenheim Orange’, ‘Bountiful’, ‘Bramley’, ‘Gravensteiner’ and ‘Wellington’) had the desirable bright and yellowish skin colour. Most of the cultivars had the white to very pale yellowish flesh that is most often preferred. Only ‘Belle de Boskoop’ and ‘Rubin’ had a more deeply yellowish flesh colour. All cultivars had acceptable flesh firmness (more than 5 kg/cm^2) after 10 weeks of storage. The highest SSC values were encountered in ‘Belle de Boskoop’, ‘Blenheim Orange’ and ‘Ingbo’. Six cultivars, ‘Blenheim Orange’, ‘BM 40794’, ‘Queen’, ‘Rubin’, ‘Vanda’ and ‘Wellington’, had a comparatively symmetrical shape and would therefore be more suitable to mechanical peeling, coring and cutting.

Conclusions about cultivars

None of the cultivars with more than 10% small fruit can be recommended for organic growing in Sweden. The total yield was below medium for ‘Rubinola’ but this cultivar had the highest percentage of I-class fruit in Trial I and appears to be suitable for organic growing in our climate. Another interesting cultivar is the late ripening ‘Scarlet O’Hara’ which keeps well in storage, and also looks promising for organic growing in Sweden (Fig. 1). ‘Rubinola’ has recently become recommended for organic growing in Sweden as well as ‘Rajka’ in spite of its low yields since it is considered healthy, attractive, tasty and easy to grow (Juhlin, 2004) (Fig. 1). In a Czech trial, ‘Rajka’ instead produced the highest yield in a trial with 17 apple cultivars (Blazek, Krelinova & Blazkova, 2003). In Poland, post harvest diseases were investigated for some scab resistant cultivars; ‘Rajka’ and ‘Rubinola’ were the least sensitive towards bull's-eye rot while the disease was a problem for organically produced ‘Topaz’ (Bryk & Kruczynska, 2005). In the same trial, ‘Rajka’ was susceptible to bitter pit but this was not a problem in our trial.

Among the 16 cultivars investigated for industrial use, the most promising were ‘Blenheim Orange’, ‘Bramley’, ‘Holsteiner Cox’, ‘Ingbo’, ‘Queen’ and ‘Vanda’. All of these cultivars had high levels of tree and fruit resistance to pests and diseases, and had fruits that were suitable for mechanical peeling, coring and cutting, were rich in SSC and had good firmness at harvest and after storage. The fruit flesh was white and the skin colour bright and yellowish as preferred in processing (Kaak & Grauslund, 1991).

Figure 1. From left to right the cultivars ‘Scarlet O’Hara’, ‘Rajka’ and the selection ‘K:1160’

Consumer evaluation (Paper IV)

Trained taste panels are often regarded as important and useful tools for evaluating new cultivars and promising selections. Using a trained panel is, however, generally more expensive compared to a volunteer consumer evaluation. As a complement, mass-testing by volunteers may therefore provide valuable data to a lower cost. Sometimes there is also need for a survey of a larger number of consumers, especially if there are any indications of heterogeneity in the future target population.

Quality attributes

In our study, all five quality attributes, appearance, texture, juiciness, taste and overall impression, were significantly correlated in both 2002 and 2003 when all the individual test scores were analysed together. This may partly have been caused by a tendency for consumers to either like or dislike a certain cultivar in all respects. Nevertheless, it is interesting to note that the highest correlation was obtained between taste and overall impression. Relatively high correlations with overall impression were noted also for appearance and juiciness.

Appearance: Cultivar means for appearance varied from 5.0 to 7.8 (a range of 2.8 units) in 2002 and from 6.3 to 8.7 (2.4 units) in 2003. For appearance, none of the cultivars had a mean score below 5.0 in 2002, or below 6.0 in 2003, which suggests that all of them were acceptable in this respect (Tables 4 & 5).

Table 4. The mean scores given by consumers for overall impresson (OI), taste, appearance, texture and juiciness of 12 apple cultivars in 2002. (n = 97-352)

	OI		Taste		Appearance		Texture		Juiciness	
Cultivar		Stdev		Stdev		Stdev		Stdev		Stdev
Aroma	6.8	2.1	6.3	2.5	7.8	1.8	5.8	1.6	6.1	1.7
Co-op12	5.4	2.2	5.1	2.7	6.8	1.9	3.5	1.8	4.9	2.0
Dayton	5.1	2.0	4.3	2.2	6.6	2.0	6.0	1.6	5.0	1.8
Fredrik	6.3	2.1	6.0	2.5	6.4	2.1	5.5	1.7	5.7	1.8
Frida	6.3	2.1	5.8	2.4	7.6	1.7	6.4	1.7	5.0	1.9
K:1016	4.8	2.3	4.3	2.7	5.9	2.4	6.1	1.7	5.0	2.1
K:1160	7.0	2.1	6.6	2.5	8.3	1.5	4.7	1.7	5.6	1.7
K:1210	5.0	2.0	4.6	2.3	5.0	2.1	6.1	1.7	4.8	1.9
Rubinola	7.5	1.7	7.4	2.0	7.5	1.8	5.7	1.5	5.7	1.5
Scarlet O'Hara	6.1	2.2	5.8	2.5	6.9	2.2	7.2	1.6	4.5	2.1
Vanda	5.8	2.0	5.3	2.5	5.2	2.2	6.0	1.7	6.0	1.5
William's Pride	5.5	2.0	5.6	2.3	5.4	2.6	5.2	1.8	4.9	1.9

Texture: For texture, cultivar means ranged widely, from 3.5 to 7.2 (3.7 units) in 2002 and from 2.6 to 6.9 (4.3 units) in 2003. ‘Scarlet O’Hara’ was scored as significantly harder than the other cultivars, and ‘Co-op 12’ as significantly softer in 2002. In 2003, ‘Frida’ instead had the highest score for texture and ‘Co-op 12’ again the lowest (Tables 4 & 5). The rating of texture had no importance for overall impression. The cultivar means for texture were positively correlated with the penetrometer-derived values for firmness both in 2002 and in 2003, demonstrating a close correspondence between physical measurements and consumer scoring.

Juiciness: Cultivar means for juiciness ranged only between 4.5 and 6.1 (1.6 units) in 2002 and between 4.5 and 5.8 (1.3 units) in 2003. ‘Aroma’ had the highest value in both years but there were few significant differences between the cultivars.

Taste: Cultivar means for taste ranged rather widely, from 4.3 to 7.4 (3.1 units) in 2002 and from 4.6 to 8.7 (4.1 units) in 2003. Significant differences mostly involved the high-rating cultivars. ‘Rubinola’ had the highest mean in 2002, followed by ‘K:1160’ and ‘K:1016’ while ‘Dayton’ had the lowest mean. ‘Rubinola’ had the highest taste score also in 2003 (Tables 4 & 5).

Table 5. The mean consumer scores for overall impression (OI), taste, appearance, texture and juiciness for the year 2003.(Number of consumer scores varied between 197 and 215 for all cultivars except for Aroma (n = 829-839) and Fredrik (n = 418-431))

	OI		Taste		Appearance		Texture		Juiciness	
Cultivar		Stdev		Stdev		Stdev		Stdev		Stdev
Aroma	7.0		6.8		7.0		6.0		5.8	
Co-op 12	6.4	3.3	6.7	4.2	7.2	3.3	2.6	2.6	5.1	3.1
Dayton	6.7	2.6	6.4	3.1	7.2	2.8	6.4	1.9	5.7	1.8
Fredrik	6.4	2.4	6.0	2.9	6.9	2.5	5.9	2.0	5.7	1.9
Frida	5.8	2.2	5.0	2.9	7.2	2.0	6.9	1.9	4.9	1.9
K:1016 B	6.8	2.2	6.1	2.8	6.9	2.1	6.1	1.8	5.6	1.6
K:1016 ÖS	6.5	2.3	5.7	2.7	7.4	2.2	6.4	1.7	5.7	1.6
K:1160	6.6	3.1	6.4	3.6	7.6	2.7	4.6	2.1	5.6	2.4
K:1210	6.1	2.7	5.5	3.4	7.4	2.7	5.9	2.3	5.5	2.3
Redfree	5.5	2.7	5.2	3.4	7.6	2.4	4,0	2.5	4.5	2.5
Reglindis	7.0	2.8	7.0	3.5	7.0	2.7	4.6	2.6	5.8	2.2
Rubinola	8.4	2.4	8.7	3.1	8.7	2.5	6.1	1.9	5.8	2.1
Scarlet O'Hara	6.7	2.4	6.9	3.2	6.6	2.4	6.7	1.9	5.0	2.3
Vanda	5.8	2.3	4.6	3.0	6.6	2.4	6.7	1.8	5.5	1.9
Waleria	5.3	3.0	4.8	3.7	6.3	2.8	5.1	2.4	4.5	2.3
William's Pride	6.0	2.7	5.7	3.0	6.5	2.7	5.5	2.1	5.3	2.0

Overall impression: Overall impression of the different cultivars ranged from 4.8 to 7.5 (2.7 units) in 2002 and from 5.3 to 8.4 (3.1 units) in 2003. ‘Rubinola’ obtained the highest mean value in 2002, followed by ‘K:1160’ while ‘K:1210’ and ‘K:1016’ had the lowest values. ‘Rubinola’ obtained the highest value for overall impression also in 2003, followed by ‘Aroma’ while ‘Redfree’ and ‘Waleria’ had the lowest values (Tables 4 & 5). Taste was the most important factor contributing to overall impression, which agrees with results previously reported by Daillant-Spinner *et al.* (1996) and Jaeger *et al.* (1998).

‘Rubinola’ turned out to be the best liked cultivar both in 2002 and 2003 and can be recommended for organic growing. Based on the consumer evaluation, also ‘K:1160’ and ‘Aroma’ can be recommended but productivity and disease tolerance must first be properly investigated for the relatively new selection ‘K:1160’ (Fig. 1). In a Danish study of 22 scab-resistant apple cultivars, ‘Rubinola’ also emerged as the one having the highest eating quality (Kühn & Thybo, 2001). In a sensory evaluation in Poland, ‘Rubinola’ was considered to be the second best cultivar (Paprstein, Balzek & Michalek, 2006). In a Canadian evaluation with 21 cultivars, ‘Scarlet O’Hara’ was among the cultivars with the highest sensory characteristics (Hampson & McKenzie, 2006).

Consumer profile data

A total of 352 and 850 consumers, respectively, participated in the 2002 and 2003 testings. In 2002, there were 193 females and 148 males, and in 2003, 485 females and 350 males. In 2002, 73, 121 and 150 consumers were 10-30, > 30-50 and > 50 years old, and in 2003, the corresponding values were 201, 278 and 362. More than half of the consumers, i.e. 205 in 2002 and 468 in 2003, had access to home-grown apples. More than 90% of the participating consumers ate at least one apple a week, and can therefore be regarded as potential future consumers of the tested cultivars.

The only parameter for which the two years differed appreciably, was interest in organically grown apples. Number of consumers, who prefer to buy organic apples and are prepared to pay a premium of 0.55 €, rose significantly from 2002 to 2003, and showed a strong gender difference. In 2002, 64% of the female consumers and 61% of the male consumers thus preferred organic apples. Forty-two % of the females and 43% of the males were also prepared to pay a higher price. In 2003, 75% of the female consumers preferred organic apples and 64% of the male consumers. This year, a total of 51% and 46%, respectively, were prepared to pay the higher price. In a household survey in the U.S., number of consumers willing to buy eco-labeled apples decreased as the price premium increased, but 40% would still buy eco-labeled apples with a 0.5 € higher price (Blend & Ravenswaay, 1999).

The only consumer characteristic that appears to have had a major impact on consumer evaluation scores was age. Still, it is difficult to find a single variable that explains why some cultivars were more liked by younger consumers and others by older. A certain tendency for older consumers to like (or at least tolerate) more soft-fleshed cultivars was discerned but more data is needed.

Number of consumers required for evaluation

The standard deviation for 100 calculations of the mean score for overall impression of 'Aroma' was plotted against number of scores analysed. From this graph, it appears that raising the number of consumers above 50 will not lower the variance appreciably and may therefore be considered as a sub-optimal use of resources, provided that the sampled consumers are sufficiently homogenous and also representative of the target population (Fig. 2).

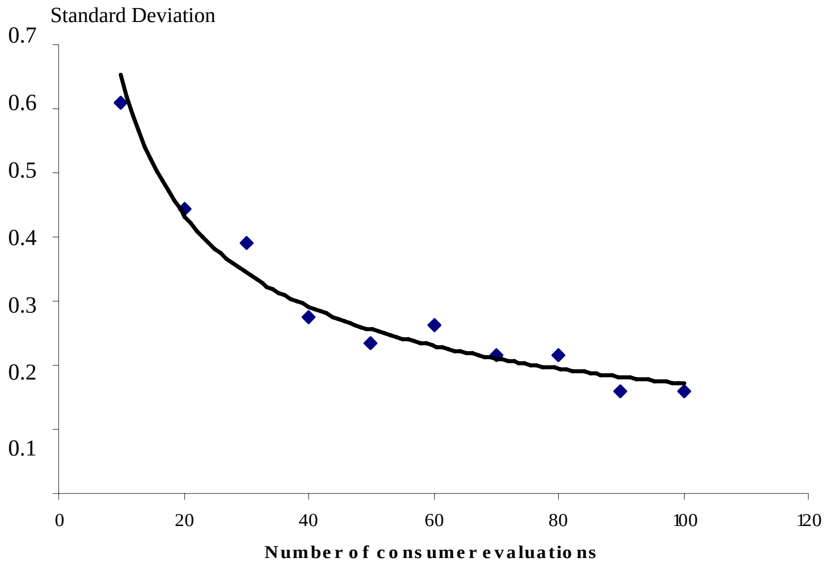

Figure 2. From the 352 scores for overall impression of ‘Aroma’ in 2002, subsets of 10, 20, 30, 40, 50, 60, 80, 90 and 100 evaluation scores were taken at random. Means of 100 subsets for each size class were calculated, and the standard deviation plotted as a function of the number of consumer scores in the group.

Concluding remarks

Organic apple production

Overall yield was similar in organic and IFP-managed parts of the conversion trial, while a lower number of fruits per tree in the organic sections may have been caused by the use of sulphur-containing compounds. No treatment-related differences were found in outer or inner fruit quality parameters. Fruit growers must, however, be extremely observant on diseases and pests since these cause severe problems in organic orchards. Collection of beating tray samples, daily supervision of pheromone traps, searches for ants in the trees and control of the foliage for nutrient deficiencies is advised. Still, the presently available means for controlling diseases and pests in organic orchards may be insufficient. Pheromone traps for codling moths do not monitor all the other moths causing damage. Better means to control NTG are also needed since these cause considerable damage. Thinning of damaged fruitlets should help to minimize damage from brown rot and apple sawfly.

The amount of insects and insect damage was higher in the IFP-close section compared to the IFP-distant section in the conversion trial. Obviously insects from the organic sections and the IFP-close section influence one another; pests that are kept at acceptable levels with spraying in the IFP fields, can easily invade the organic sections, multiply and become major pests there. Results from my study suggest that there was considerable migration of insects and mites between the organic and IFP-close sections. The establishment of a healthy balance between pests and predators (with some help from permitted insecticides) should be easier to achieve in an organic orchard if it is placed far away from other apple orchards.

Choice of cultivars

Both ‘Aroma’ and ‘Karin Schneider’ could probably become profitable in an organic production system if the smaller fruits can be used for manufacturing of e.g. organic baby-food and high-quality apple juice. When planting a new orchard, cultivars with strong resistance towards especially scab and bull’s-eye rot may, however, be a better choice. An option is the scab-resistant ‘Rubinola’ with the highest percentage of I-class fruit in the cultivar trial and the highest taste score and overall impression in the consumer evaluation. Another interesting cultivar is ‘Scarlet O’Hara’; the yield was above medium in the cultivar trial, it is late ripening and keeps well in storage. ‘Rajka’ is also interesting since it appears to be resistant towards the rosy apple aphid, but thorough thinning is probably needed since this cultivar had the second highest amount of small fruits. The selection ‘K:1160’ was best liked after ‘Rubinola’ in one of the two years of the consumer evaluation. Data on yield and fruit quality of ‘K:1160’ are needed before it can be recommended for organic growing. In the cultivar trial aimed at industrial use, the most promising cultivars were ‘Blenheim Orange’, ‘Bramley’, ‘Holsteiner Cox’, ‘Ingbo’, ‘Queen’ and ‘Vanda’. ‘Vanda’ is scab-resistant but had problems with bitter pit in the other cultivar trials. Bitter pit is unacceptable for the fresh fruit market but is not a large problem in processing.

Future research needed

Development of cultivars that have several resistance genes for both fungi and insect pests, and that are well adapted for the Swedish climate, would be very useful in organic growing. One of the most important aspects is to pyramidize different scab resistance genes in the same cultivar since scab resistance can be overcome by new or mutated scab strains.

Plant protection means targeting specific fungi or insects without affecting predators or indifferent insects are also much needed. Improvement of storage conditions for organic fruit is also desirable. Improvements could consist of more efficient storage facilities and/or postharvest treatments that can remove or destroy fungal spores deposited on the fruit. A new set of different pheromone traps, monitoring either specific moths or several species simultaneously, would be very useful for anticipating time of treatment.

Acknowledgements

With all my gratitude I thank my supervisor Hilde Nybom. With a fast, sharp mind she gave tons of good advice. I find it hard to believe that there can be anyone better.

I thank my family for their patience. My husband, Ingemar, has provided support during all years. Thank you for digging, picking apples, counting apples, lifting heavy crates, tractor driving, encouraging people to answer question forms, taking care of baby Elmer in France while I attended a symposium and all other things you did to facilitate my work. I am most grateful towards my children for being born thus extending the period of information collecting with several years. As everyone knows, one year does not prove anything, while two or hopefully more years provide trends, sometimes confusing and at other times supporting the expected. My mother has taken care of the children and the household on several occasions so that I've been able to concentrate on my work, especially during maternity leave when chores still had to be done. I would like to thank my father for lending me mum during whole weeks. Since he is a skilled cook who likes his own food, at least, he has not physically starved meanwhile. My in-laws have helped with harvesting trials, counting apples and tending their grandchildren.

Gustav Redalen gave advice on manuscripts and how to design the score sheet in the consumer evaluation. Together with Boel Sandskär I have made several trips to apple gene banks in Sweden. Since she has become an apple scab specialist I coordinated my scab evaluation according to her instructions. Ibrahim Tahir helped me with how to evaluate damaged apples and to check the quality of undamaged ones. Paul Ilg managed the trials and helped with the harvest. I also thank Christer Tornéus who helped me with how to identify the insects in the beating tray samples. Kimmo Rumpunen supervised my work with malic acid and finally ran the samples in the HPLC system. Bengt-Olof Bjurman provided computer knowledge. Jan-Eric Englund answered all my questions considering statistical calculations. I thank all my colleagues at Balsgård for companionship and advice.

References

Alford, D. 1984. *A colour atlas of fruit pests their recognition, biology and control.* Wolfe Publishing Ltd, London, 320 pp.

Aly, E. 2000. Effect of foliar application of different calcium forms on quality of Anna apple fruit at harvest and during cold storage. *Annals of Agricultural Science, Moshtohor 38*, 1687-1699.

Andrews, P., Fellman, J., Glover, J. & Reganold, J. 2001. Soil and plant mineral Nutrition and fruit quality under organic, conventional and integrated apple production systems in Washington State, USA. *Acta Horticulturae 564,* 291-298.

Andrews, P., Glover, J. & Reganold, J. 2001. Horticultural performance, soil quality, and orchard profitability of integrated, organic, and conventional apple production systems. *Integrated Fruit Production 24*, 393-400.

Balázs, K., Molnár, M., Bujáki, G., Gonda, I., Karácsony, D. & Bartha, J. 1997. Possibility and problems of organic apple growing in Hungary. *Biological Agriculture and Horticulture 15*, 223-232.

Bauchot, A., Reid, S., Ross, C. & Burmeister, D. 1999. Induction of apple scald by anaerobiosis has similar characteristics to naturally occurring superficial scald in 'Granny Smith' apple fruit. *Postharvest Biology and Technology 16*, 9-14.

Bengtsson, M., Lindhard, H. & Grauslund, J. 1999. Occurrence of races of Venturia inaequalis in a scab race screening orchard in Denmark. 5th Workshop on Integrated Control of Pome Fruit Diseases, 24-27 August, France, 44.

Bertelsen, M. & Grauslund, J. 1995. Ökologisk aebleproduktion (Organic apple production). *Frugt og Baer 5*, 133-135.

Bertschinger, L., Mouron, P., Dolega, E., Höhn, H., Hollinger, E., Husistein, A., Schmid, A., Siegfried, W., Widmer, A., Zürcher, M. & Weibel, F. 2004. Ecological apple production: a comparison of organic and integrated apple-growing. *Acta Horticulturae 638*, 321-332.

Biggs, A. 1990. Apple Scab, pp. 6-9. In: *Compendium of apple and pear diseases*. American phytopathological society, St Paul Minnesota, 100 pp.

Blazek, J., Krelinova, J. & Blazkova, J. 2003. Results of a trial with 17 apple cultivars bred in the Czech Republic that was evaluated 1996-2002 at Holovousy. *Vedecke Prace Ovocnarske 18*, 7-23.

Blend, J. & Ravenswaay, E. 1999. Measuring consumer demand for ecolabeled apples. *American journal of agricultural economics 81*, 1072-1077.

Brown, S. & Maloney, K. 2003. Genetic improvement in apple: breeding, markers, mapping and biotechnology, pp. 32-59. In: *Apples - Botany, Production and Uses*. CABI Publishing, New York, 660 pp.

Bryk, H. & Kruczynska, D. 2005. The occurrence of postharvest diseases on apples resistant to scab. *Acta Agrobotanica 58*, 205-212.

Chevalier, M., Lespinasse, Y. & Renaudin, S. 1991. A microscopic study of the different classes of symptoms coded by the Vf gene in apple for resistance to scab (*Venturia inaequalis*). *Plant Pathology 40*, 249-256.

Cliff, M., Sanford, K., Wismer, W. & Hampson, C. 2002. Use of digital images for evaluation of factors responsible for visual preference of apples by consumers. *HortScience 37*, 1127-1131.

Daillant-Spinner, B., MacFie, H.J.H., Beyts, P.K. & Hedderley, D. 1996. Relationships between perceived sensory properties and major preference directions of 12 varieties of apples from the southern hemisphere. *Food Quality and Preference 7*, 113-126.

DeEll, J. & Prange, R. 1992. Postharvest quality and sensory attributes of organically and conventionally grown apples. *HortScience 27*, 1096-1099.

Edland, T., Hofsvang, T., Haukeland Salinas, S., Stensvand, A., Amundsen, T., Langnes, R., Sletten, A., Blystad, D., Netland, J. & Ystås, J. 1999. *Skade og skadegjerar i frukt.* The Norweigan Crop Research Institute, 133 pp.

Fischer, C., Büttner, R. & Fischer, M. 1998. Testing of the scab resistancestability of new resistant cultivars. *Erwerbsobsbau 40*, 130-135.

Gianfranceschi, L., McDermott, J., Seglias, N., Koller, B., Kellerhals, M. & Gessler, C. 1994. Towards a marker assisted breeding for resistance against apple scab. *Euphytica 7*, 93-96.

Gonda, I., Holb, I. & Bitskey, K. 2000. Rate of scab infection and quality parameters of apple fruit in organic and integrated production systems. *International Journal of Horticultural Science 6*, 63-67.

Hampson, C. & McKenzie, D. 2006. Sensory characteristics of 21 new apple cultivars after short-term cold air storage. *Journal of the American Pomological Society 60*, 9-19.

Hampson, C. & Quamme, H. 2000. Use of preference testing to identify tolerance limits for fruit visual attributes in apple breeding. *HortScience 35*, 921-924.

Harker, F., Gunson, F. & Jaeger, S. 2003. The case for fruit quality: an interpretive review of consumer attitudes, and preferences for apples. *Postharvest Biology and Technology 28*, 333-347.

Holb, I. 2005. Effect of pruning on apple scab in organic apple production. *Plant Disease 89*, 611-618.

Ingle, M. & D'Souza, M. 1989. Physiology and control of superficial scald of apples: a review. *HortScience, 24*, 28-31.

Jaeger, S., Andani, Z., Wakeling, I. & MacFie, H. 1998. Consumer preferences for fresh and aged apples: a cross-cultural comparison. *Food Quality and Preference 9*, 355-366.

Janse, J. 1993. Breeding of resistant apple varieties in the Netherlands. *Acta Horticulturae 347*, 143-148.

Judd, G., Gardiner, M. & Thomson, D. 1997. Control of codling moth in organically-managed apple orchards by combining pheromone-mediated mating disruption, post-harvest fruit removal and tree banding. *Entomologia Experimentalis et Applicata 83*, 137-146.

Juhlin P. 2004. *Äpplesorter för ekologisk fruktodling*. Jordbruksinformation 4, pp 15.

Kaak, K. & Grauslund, J. 1991. Apple cultivars for manufacturing of stewed apples. *Danish Journal of Plant and Soil Science 95*, 449-457.

Kellerhals, M., Dolega, E., Dilworth, E., Koller, B. & Gessler, C. 2000. Advances in marker-assisted apple breeding. *Acta Horticulturae 538*, 535-540.

Kellerhals, M., Mouron, P., Goerre, M., & Gessler, C. 1997. Breeding apples for disease resistance - an integrated approach towards sustainable and economic orchard ecosystems, pp. 134-140. Proceedings of the 4th workshop on Integrated control of pome fruit diseases, Croydon.

Knight, A. 1994. Insect pest and natural enemy populations in paired organic and conventional apple orchards in the Yakima Valley, Washington. *Journal of the Entomological Society of British Columbia 91*, 27-36.

KRAV, 2006. Växtodling: Regler för KRAV-godkänd produktion januari 2006. www.krav.se

Kühn, B. & Thybo, A. 2001. Sensory quality of scab-resistant apple cultivars. *Postharvest Biology and Technology 23*, 41-50.

Leser, C. & Treutter. D. 2006. Resistance of apple tres to Venturia inaequalis under the influence of N-supply. In: *Pome Fruit Health Research in Europe: Current Status 2006*, Eds. Stich K, Steffek R, Halbwirth H & Persen U., pp. 134-136.

Lester, G. 2006. Organic versus conventionally grown produce: quality differences, and guidelines for comparison studies. *HortScience 41*, 296-300.

Norusis, M. 1990. SPSS ® Base Systems User's Guide. SPSS inc, Chicago, pp. 507.

Palmer, J., Davies, S., Shaw, P. & Wünsche, J. 2003. Growth and fruit quality of 'Braeburn' apple (Malus domestica) trees as influenced by fungicide programmes suitable for organic production. *New Zealand Journal of Crop and Horticultural Science 31*, 169-177.

Pavicic, N., Jemric, T., Kurtanjek, Z., Cosic, T., Pavlovic, I. & Blaskovic, D. 2004. Relationship between water-soluble Ca and other elements and bitter pitoccurrence in 'Idared' apples: a multivariate approach. *Annals of Applied Biology 145*, 193-196.

Paprstein, F., Blazek, J. & Michalek, S. 2006. Effects of climatic conditions of fruit quality of apple cultivars assessed by public sensory evaluations in the Czech and Slovak Republics 1999-2004. *Journal of Fruit and Ornamental Plant Research 14,* 219-227.

Peck, G., Andrews, P., Reganold, J.P. & Fellman, J. 2006. Apple orchard productivity and fruit quality under organic, conventional, and integrated management. *HortScience 41*, 99-107.

Persson, D. 2006. *Trädgårdsproduktion 2005. The 2005 Horticultural Census*. Statens jordbruksverk, 82 pp.

Richards, T. 2000. A discrete/continuous model of fruit promotion, advertising, and response segmentation. *Agribusiness 16*, 179-196.

Sandskär, B. 2003. Apple scab (Venturia inaequalis) and pests in organic orchards. Ph D dissertation, *Agraria 378*, SLU, Sweden. ISBN 91-576-6416-1.

Sansavini S., Donati F., Costa F. & Tartarini, S. 2004. Advances in apple breeding for enhanced fruit quality and resistance to biotic stresses: new varieties for the European market. *Journal of Fruit and Ornamental Plant Research 12*, 13-52.

Schawlann, M. 1999. Handbok i økologisk fruktdyrking. Økoringen Vest. 168 pp.

Suckling, D., Walker, J. & Wearing, C. 1999. Ecological impact of three pest management systems in New Zealand apple orchards. *Agriculture, Ecosystems & Environment 73*, 129-140.

Tahir, I. 2006. Control of pre- and postharvest factors to improve apple quality and storability. Ph D dissertation, *Acta Universitatis Agriculturae Sueciae, 2006:35,* SLU, Sweden. ISBN 91-576-7084-6.

Velimirov, A. 2004. Integrative methods of product quality assessment in connection with the P-value-determination (3 examples: food preference test, sensory evaluation and self-decomposition test). *Horticultural Science 31*, 17-21.

von Alvensleben, R. & Meier, T. 1990. The influence of origin and variety on consumer perception. *Acta Horticulturae 259*, 151-161.

Woese, K., Lang, D., Boess, C. & Bogl, K. 1997. A comparison of organically and conventionally grown foods–Results of a review of the relevant literature. *Journal of Science and Food Agriculture 74*, 281-293.