Low-residue production: an innovative and consumer friendly fruit production

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Abstract: Pesticides in fruit production are necessary to reduce yield and quality losses and to ensure a long-term profitable fruit production. However, in Switzerland and several other European countries, consumers and retailers are demanding a large reduction of pesticide residues on fruit to minimize the risk to human health and the environmental impact. Fruit growers need research results and advice to establish sustainable production systems that reduce the use and the residues of pesticides. Agroscope tested and evaluated a low-residue (LR) plant protection strategy that allows the production of residue-free apples. With regard to the incidence of apple scab and powdery mildew, the LR strategy was comparable to the integrated production (IP) strategy and superior to the organic production (OP) strategy. Losses of fruit during storage due to bull's eye rot (*Neofabraea* sp.) were a weakness of the LR and OP strategies. With regard to economical sustainability, the new LR strategy was linked to higher production risk and lower profit than the IP and OP strategies. A price premium for LR production, which is justified by environmental advantages, could have a positive effect on the economical sustainability of the LR strategy. Future long-term experiments in model orchards should evaluate how to combine and optimize the effects of robust or resistant varieties, different cultivation systems, weather influences (hail net, rain shelter, etc.) and a LR pest management system.

Key words: apple crop protection, low pesticide residue, innovative integrated pest management, fruit production, economic evaluation

Introduction

Fruit production involves a high input of plant protection products (Spycher & Daniel, 2013). Especially the application of pesticides helps to reduce yield and quality losses and allows long-term profitable fruit production. However, consumers and retailers in Switzerland and several other European countries demand that producers reduce or eliminate pesticide residues on fruit and minimize the number of applied pesticides to reduce the risks to human health and the environment by 50% (Bundesrat, 2017). To achieve this goal and nevertheless be able to produce a high-quality product, fruit growers need information and advice on designing and operating innovative, sustainable and reliable production systems (Gölles *et al.*, 2015). Therefore, Agroscope developed and tested during a five-year period a low-residue (LR) crop protection strategy for apples. The objective was to produce quality fruit without detectable residues and with yields comparable to those of the integrated production (IP) strategy. The LR strategy was compared with the IP and organic production (OP) strategies in an apple orchard in Wädenswil (Switzerland) with a total surface of 1.05 ha. The level of plant protection, the produced fruit quality and yield, and attributes of economic sustainability were evaluated to compare all three strategies (Gölles *et al.*, 2015).

Material and methods

In 2008, a trial was started to investigate possibilities of minimizing fungicide residues suitable for professional apple production. Three crop protection strategies were compared: IP, OP and LR. The new LR strategy is a combination of the IP and OP strategies: In the first half of the season (bud break to ca. mid-June), the trees were treated according to IP standards to achieve an optimal control of apple scab (*Venturia inaequalis*) and powdery mildew (*Podosphaera leucotricha*). After mid-June, the application switched to authorized OP fungicides to minimize residues detectable on fruits at harvest (Gölles *et al.*, 2015). In Figure 1 «Description of production systems», implemented crop protection, fertilizing, thinning and other measures are described in detail.

The trial was performed on the variety 'Golden Delicious' (0.30 ha) and the scab resistant (Vf gene) varieties 'Ariane', 'Otava' and 'Topaz' (0.75 ha) in Switzerland (Wädenswil). The trial was run from 2008 until 2013. Because the LR strategy was optimized after 2008, only the years 2009 to 2013 were included in the evaluation. The size of the individual plots was chosen to enable customary production. The whole plantation was protected by a hail net and an exclusion netting (sides and headland), which was installed to prevent the intrusion of insects. Additionally, pheromone dispensers were applied on the entire area to distract codling moths (*Cydia pomonella*). Pest control, thinning, fertilization and weed control were carried out equally in the LR and IP strategies. The OP strategy was conducted according to the guidelines of Swiss organic farming. Control trees received no pesticide treatments. For evaluation, data on the occurrence of diseases, pest infestation, labour time, used machines, physiological damages, yield and fruit quality were collected.

After harvest, apples of all strategies and varieties were graded according to Swiss guidelines (first-class fruit: graded by size, colour and parasitic and physiological damages after storage), and a random sample of 100 kg apples was stored for seven months under controlled atmosphere (1 °C, 1.5% CO_2, 1.5% O_2). Afterwards, fruits were examined for storage rots and physiological disorders. Samples from the LR and IP strategies were tested for pesticide residues (sampling: 1 kg apples at harvest; analysis: multi-method of UFAG Laboratories, Switzerland).

The economic sustainability of the different strategies was calculated only for the cultivars 'Golden Delicious' and 'Topaz' with data from the trial (plant protection and fertilization costs, labour and machine time) as an input of the economic calculation model Arbokost (Agroscope, 2014). Machinery unit costs were calculated according to the Swiss machine costs catalogue of Agroscope (Gazzarin & Lips, 2012). Costs for labour were defined according to Swiss Fruit Association standards. The profit was calculated by using the packout, i.e. the first-class fruit, and the growers-indication prices for first-class apples (Agridea, 2011, 2013). The same price (IP grower price) was used for the IP and LR strategies, whereas the grower price for organic apples was used for the OP strategy. The family income was calculated by using the outputs of the model Arbokost.

Results

The disease incidence of leaf scab and fruit scab on 'Golden Delicious' at harvest, averaged for all years (2009–2013), was below 0.5% with the IP and below 1% with the LR strategy. It was remarkably higher, up to 25%, with the OP strategy. Similar differences between the three strategies were found for powdery mildew. The results of the disease incidences are shown in Figure 2. Furthermore, the pest incidence was low in all varieties, in all strategies and all years

(Figure 3). The biggest losses due to storage diseases were detected with the OP strategy (Figure 4). Bull’s eye rot (*Neofabraea* sp.) caused the biggest stored-fruit losses in all strategies. Especially the varieties ‘Otava’ and ‘Topaz’ were highly susceptible to this fungal disease (Gölles *et al.*, 2014). In both varieties, no statistical differences in storage rots could be detected between the untreated control, the OP strategy and the LR strategy, with losses ranging from 14 (LR) to 35% (control). With the IP strategy, storage rot losses of about 5% occurred for these varieties. In contrast, the variety ‘Ariane’ was very robust to storage rots (2 (IP) to 15% (control)). ‘Golden Delicious’ showed similar losses with the IP and LR strategies (8 and 12%, respectively), but higher losses with the OP strategy (45%). The losses in this variety were mainly due to infestation with fruit scab.

In IP samples, residues of one or two pesticides could be detected, whereas no residues were found in LR samples. However, all residues in IP samples were within legal limits.

The IP plots achieved, averaged for all varieties and years, higher yields (38’032 kg/ha) than the LR plots (37’103 kg/ha) and the OP plots (20’657 kg/ha). The results after storage showed that production with the IP strategy had a higher average packout (77%) than production with the LR (68%) or OP strategy (62%). In particular, organic ‘Golden Delicious’ achieved on average a very low packout (38%), whereas ‘Ariane’, ‘Otava’ and ‘Topaz’ had about 70% packout.

The evaluation of the economic sustainability (Table 1) shows that the OP strategy had higher profitability but also higher production risk than the IP strategy. The newly developed LR strategy had slightly lower profitability and more production risk than the IP strategy.

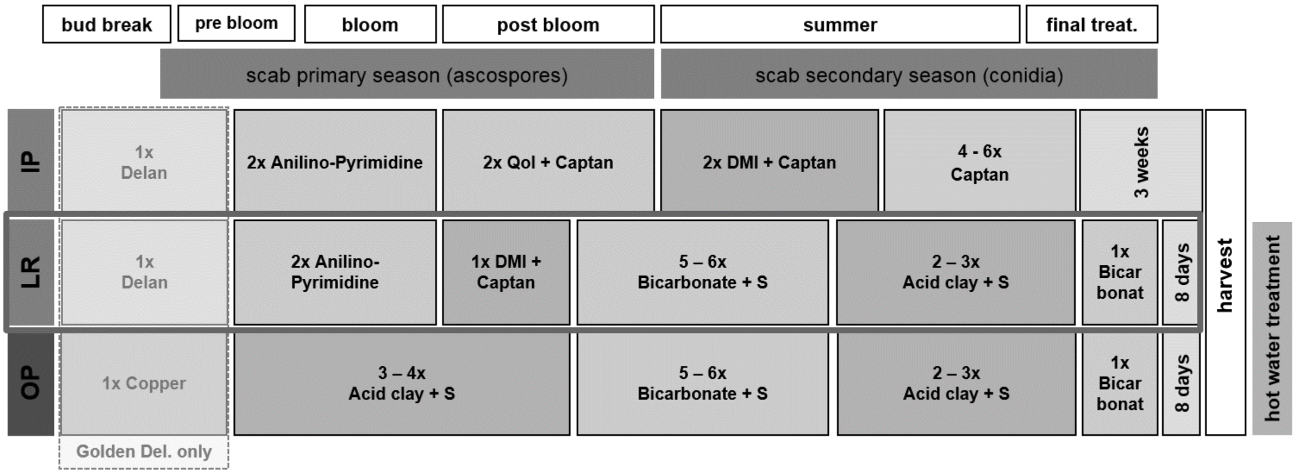
Discussion

With this trial, the Agroscope research team was able to develop a new crop protection strategy for production of residue-free Swiss apples. With the chosen plant protection, fertilizer and thinning programs in the LR strategy, it was possible, even with susceptible cultivars such as ‘Golden Delicious’, to reach a yield comparable to that of the IP strategy. However, the packout for ‘Golden Delicious’ was about 10% and for ‘Topaz’ even 20% lower in the LR than the IP strategy. All varieties showed significant losses due to storage diseases (mainly bull’s eye rot) in the LR and OP strategies. ‘Ariane’ was the most robust variety in all strategies.

The incidence of bull’s eye rot could be reduced with post-harvest hot water treatments (Good *et al*., 2012). However, this energy- and capital-intensive measure results in economic disadvantages for the LR strategy compared with the established integrated production because minimizing residues gives no price premium.

The low packout for the LR strategy adversely affects the profitability. In contrast to the OP strategy, the LR strategy receives no price premium to compensate the lower yield and the higher production risk. A price premium for low-residue production might be justified by environmental advantages.

The development and the evaluation of improved LR strategies are continuing with different scab-resistant varieties and an optimized LR crop protection management such as reduction of applied herbicides and insecticides. By choosing the most adapted cultivar or variety, growers should be able to increase the packout after storage and minimize the years with dramatic packout loss. The positive consequences on the income variability could lead to a better economic sustainability.



	thinnig	fertilization	fire blight		codling moth	other pests	weeds
IP	chemical thinnig + handish	according to Swiss IP-guidelines	Streptomycin according to Maryblight	hail net + exclusion netting (barrier for bees)	exclusion netting + mating disruption	1 - 2x insecticides (IP)	1 - 2x herbicides (IP)
LR							
OP	mechanical thinnig (Darwin) + handish	according to Swiss OP-guidelines	Myco-Sin according to Maryblight			1 – 2x insecticides (OP)	mechanical weeding (Ladurner)

Figure 1. Description of production systems, IP = integrated production, LR = low-residue production, OP = organic production

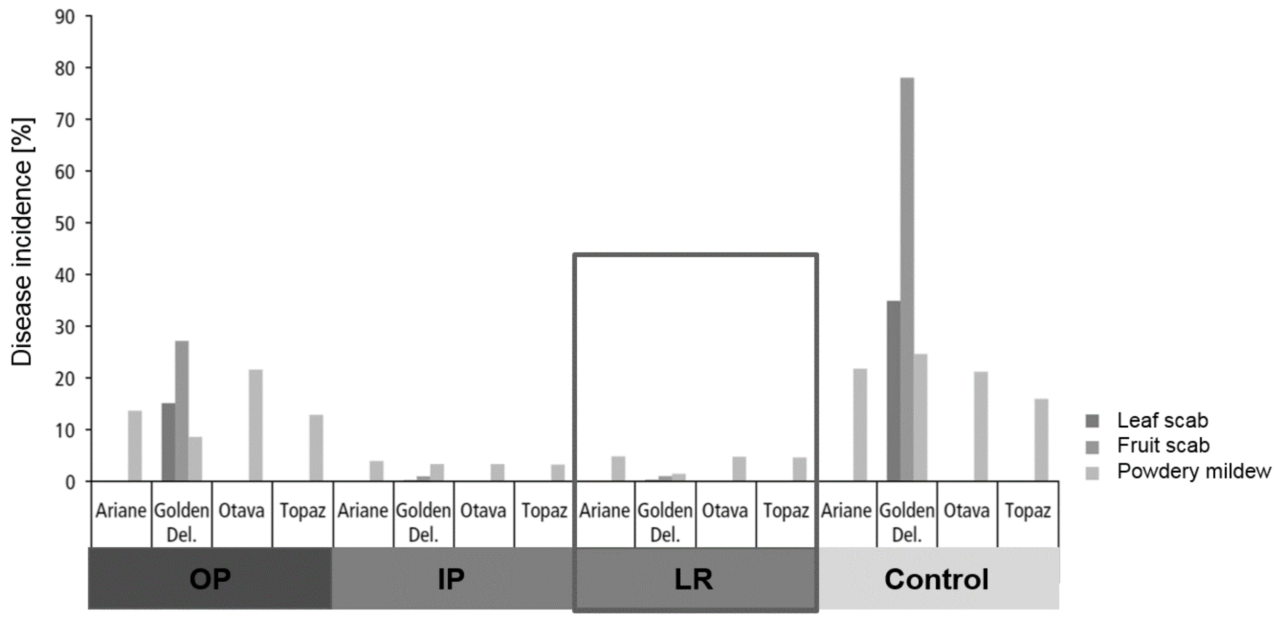


Figure 2. Apple scab and powdery mildew incidence (mean value of 2009–2013), OP = organic production, IP = integrated production, LR = low-residue production, control = untreated

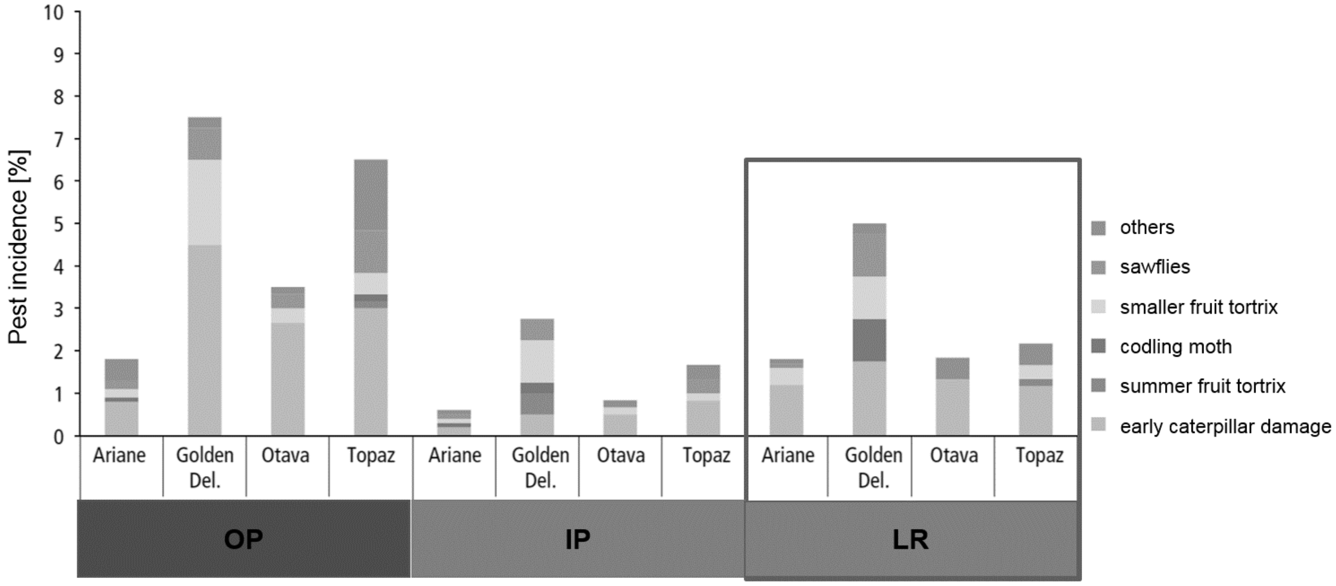


Figure 3. Fruit damages from pest incidence (mean value of 2009–2013), OP = organic production, IP = integrated production, LR = low-residue production

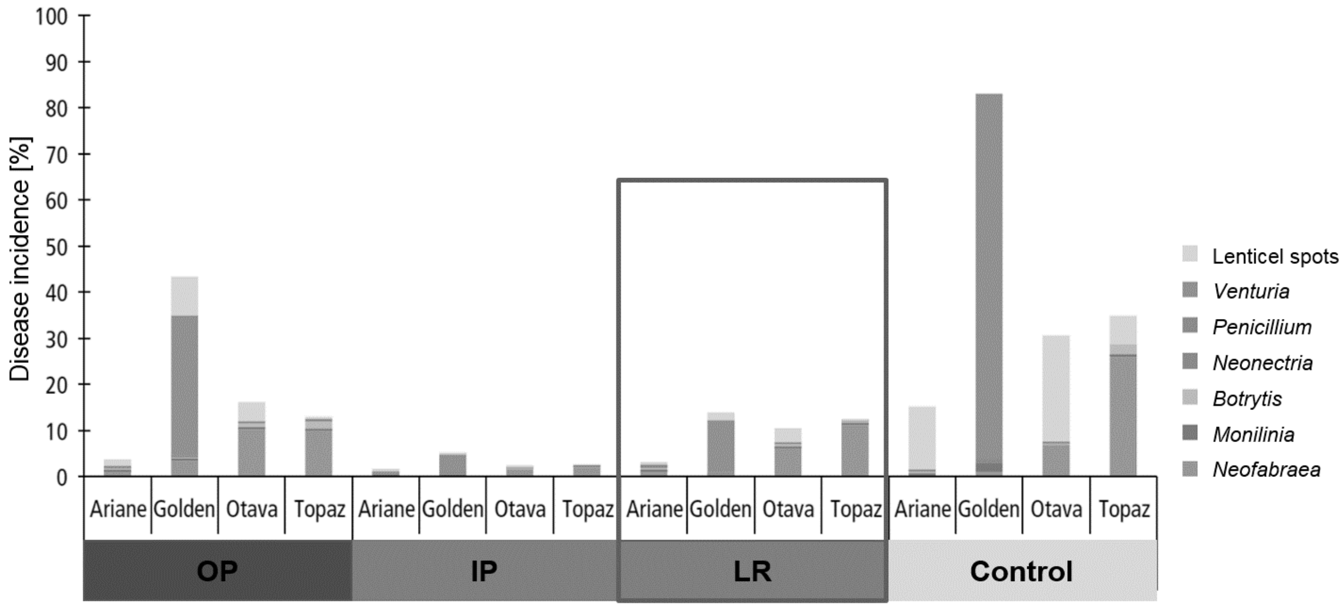


Figure 4. Storage rot incidence after 7–8 months of controlled atmosphere storage (mean value of 2009–2013), OP = organic production, IP = integrated production, LR = low-residue production, control = untreated

Table 1. Calculated economic attributes for ‘Golden Delicious’ and ‘Topaz’ (2009–2012), LR = low-residue production, IP = integrated production, OP = organic production

		LR	IP	OP
Profitability	Family income (€/h)	15.50	15.00	20.00
	Production costs first class (€/kg)	1.44	1.18	2.11
	Net income (€/ha)	−9’914	−7’230	627
Production risk	Income variability (€/h)	17.00	9.00	22.00
	Probability of dramatic yield loss	13%	0%	50%

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