Netherlands Journal of Agricultural Science 40 (1992) 257-268

Components and systems research for integrated fruit production

A.M.E. SCHENK & S.J. WERTHEIM

Research Station for Fruit Growing, Brugstraat 51, NL 4475 AN Wilhelminadorp, Netherlands

Received 21 November 1991; accepted 21 February 1992

Abstract

Social and political pressure is forcing fruit growers to limit agrochemical inputs by Integrated Fruit Production (IFP), defined as an economic way of fruit growing aimed at long-term safeguarding of public health and environment. Available components and systems to sustain IFP in the Netherlands are described. The systems research concerns a recently started project to develop and compare three ways of fruit growing: i.e. the current way of production and two systems of integrated production with decreasing inputs of pesticides, fertilizers and growth regulators.

Keywords:
apple, pear, integrated fruit production, integrated pest management, biological control

Introduction

Current fruit growing uses substantial amounts of pesticides to maintain a high production of quality fruit (Table 1). In the 40s the first synthetic insecticides were made to control fruit pests, with unprecedented success. Not very long after the introduction, scientists began to question the benefit of these pesticides. Consequently, in 1958, a working group on 'harmonic pest control' was founded in the Netherlands, which was renamed in 1967 as 'Working Group for Integrated Pest Control' (Minks & Gruys, 1980; de Reede & Alkema, 1981). In 1967 an experimental orchard, called 'De Schuilenburg', was started to develop integrated pest management and, subsequently, integrated fruit production. The uneasiness about the consequences for the environment and human health have become widespread, since there is increasing evidence that many pesticides pollute soils as well as surface water and groundwater. It urged the Dutch government to launch an ambitious new crop protection policy aiming at three goals (Anonymus, 1989; Anonymus, 1990; Anonymus, 1991). The first goal is to decrease dependence on chemical plant protection by introducing and stimulating integrated and sustainable fruit growing. The second goal is to decrease the use of pesticides by replacing them by mechanical or biological measures as is tried in the systems research project (Table 2). A third goal is to

Table 1. Estimate of the current use (kg a.i. ha^{-1} yr^{-1}) of pesticides (1986) and fertilizers (1990) in apple and pear growing, and reductions by the year 2000* as percentage of the use in 1986.

	Apple	Pear	Reduction by 2000
Acreage (ha)	15 300	5 200	
Pesticides			
fungicides	10.3	12.8	24%
insecticides/acaricides	1.8	1	
herbicides	3	3	7%
soil fumigation	1.2	–	11%
growth regulators	0.8	2.3	2%
Total pesticides	17.1	19.1	44%
Fertilizers			
nitrogen (N)	86		
phosphate (P_2O_5)	19		
potassium (K_2O)	48		
Total fertilizers	143		

* According to the Dutch Multi-Year Crop Protection Plan (Anonymus, 1991).

Table 2. Crop protection plan 1991 in the systems research project at Numansdorp and Zeewolde.

	Current	Integrated 1	Integrated 2
Insects and mites			
spider mite	predatory mites chofentezin/ hexythiazox or fenbutatinoxide	predatory mites fenbutatinoxide	predatory mites
capsid	propoxur	–	–
leaf roller	phenoxycarb	pheromones	pheromones
codling moth	diflubenzuron	pheromones	pheromones
apple-leaf-gall midge	fosalone	–	–
aphid	pirimicarb (50%)	pirimicarb (25%)	earwigs
Diseases			
scab			
– before flowering	dithianon (75%) or captan (75%)	captan (50%)	captan (50%)
– after flowering	captan (75%)	captan (50%)	captan (25%)
mildew			
– before flowering	triadimefon (75%)	triadimefon (50%)	–
– after flowering	nitrothalisopropyl (75%)	nitrothalisopropyl (50%)	–
fruit-tree cancer	captan (75%)	captan (50%)	–
storage disease	captan (50%)	captan (50%)	–
Weeds			
during season	all approved products	1 × glyphosate + flamer	polypropylene cloth or no weed control

decrease emissions into the environment through a more severe approval policy, based on strict levels for leaching to surface water and groundwater, persistence in the soil and toxicity for water organisms. Pesticides that greatly exceed these levels will be forbidden in 1995, those that slightly exceed them will be forbidden in 2000, and others will remain admitted. For that very reason a lot of pesticides commonly used for fruit growing will be forbidden, such as the herbicides amitrol, dichlobenil, glufosinate-ammonium, paraquat and simazin as well as the fungicides dithyocarbamates, dodine, captan and bupirimate. The most important insecticides that will disappear are phenoxycarb, propoxur, pirimicarb, fosalone and carbaryl. Unfortunately, many pesticides named above are used in current integrated pest management programmes.

In perennial crops such as fruit trees, injudicious use of pesticides can disturb the natural balance between pests and their predators. In the early 80s, pear psylla (*Psylla pyri*) became a big problem because the pyrethroids used against this pest killed its natural enemies, especially *Anthocorus nemoralis*, while the psylla became resistant. (Van der Blom et al., 1985). By stopping treatment with pyrethroids the psylla problem was solved. A few years later the same happened with red spider mites on apple. The red spider mite *Panonychus ulmi* became resistent to pyrethroids but not its major natural enemy, the predatory mite *Typhlodromus pyri*. By converting to more selective pesticides the predatory mites were saved and the problem was solved (Blommers & Overmeer, 1986). Nowadays fruit growers introduce predatory mites and most years they can manage without spraying against red spider mites. Besides, resistance of weeds to herbicides may occur in orchards, e.g. the resistance of *Senecio vulgaris* for simazin (Bandeen et al., 1982; Gressel et al., 1982). In analogy, excessive use of fertilizers may unbalance yield and reduce fruit quality (Forshey & Elfving, 1989). Consequently, fruit growers are willing to accept alternative cropping systems, and integrated fruit production is now rapidly spreading in European fruit areas (Müller, 1990; Sansavini, 1990). Integrated fruit production (IFP) is defined as the economical production of high-quality fruit, giving priority to ecologically safer methods, minimizing undesirable side-effects and use of agrochemicals, to enhance the safeguards to the environment and human health (Dickler & Schäfermeyer, 1991).

Lowering the input of pesticides against key pests by replacing them by natural enemies may increase the chance for new pests and diseases. Most pests and diseases cause external and cosmetic damage but not severe losses of yield. So quality risks will increase with integrated fruit production. How does integrated fruit production cope with lower quality? Partially adopted as it is, fruit produced by integrated production methods will not always get a higher price but the demand still exceeds the supply. So, in case of overproduction, fruit with an IFP (Integrated Fruit Production) label might be less vulnerable to price falls. Within a few years all fruit in the Netherlands will be grown in an integrated way and then this advantage will disappear. For export, however, the advantage of integrated fruit may remain, especially to countries with high demands on pesticide residues.

Research on alternatives for pesticides has always strongly emphasized insecticide use in apples. Fungicides have got less attention, although they account for the bulk of Dutch pesticide use in apple and pear growing (Table 1). Herbicides are, just like fungicides, now also getting more attention, since they are sprayed directly on the soil with important risks for soil life and leaching to groundwater and thus polluting drinking-water (Pawlizky, 1990; Boesten, 1986). The same holds for soil fumigants. Hereafter, research efforts to sustain integrated fruit production in the Netherlands are summarized.

Available components for integrated fruit production

Biological pest control

Currently two pests are successfully biologically controlled in Dutch commercial apple orchards, namely the red spider mite (*Panonychus ulmi*) and the apple rost mite (*Aculus schlechtendali*). This is done by distributing only once the predatory mite *Typhlodromus pyri,* resistant to a number of carbamates and organophosphates, in the orchards. Research in the past indicates that it is also possible to control *Stigmella malella* with *Chrysocharis prodice* (Gruys, 1982; Maier, 1990).

In the experimental orchard 'De Schuilenburg' the effects of natural enemies of eight other harmful insects (Table 3) are being studied. Expectations are highest for the first four antagonists mentioned in Table 3. Against the first two pests named in Table 3, confusion techniques with pheromones will also be studied.

Table 3. Pests and their predators investigated in 'De Schuilenburg'

Pest	Natural enemies
Summer-fruit tortrix moth (*Adoxophyes orana*)	*Colpoclypeus florus*
Rose tortrix moth (*Archips rosana*)	*Apanteles ater*, *Tranosema arenicola*
Apple-leaf-gall midge (*Daniseura mali*)	*Platygaster demades*, *Torymus* sp.
Apple leafminer (*Nepticula malella*)	*Chrysocharis prodice*
Apple tentiform leafminer (*Phyllonorycter blancardella*)	*Holcothorax testaceipes*
Apple-blossom weevil (*Anthonomus pomorum*)	*Syrrhizus delusorius*, *Scambus pomorum*
Apple sawfly (*Hoplocampa testudinea*)	*Lathrolestes ensator*
Mussel scale (*Lepidosaphes ulmi*)	*Aphytis mytilaspidis*, *Aphytis proclia*

Supervised chemical control of diseases

In order to reduce the amount of fungicides, decision schemes for the control of apple scab (*Venturia inaequalis*) and powdery mildew (*Podosphaera leucotricha*) have been recently developed (Van der Scheer, 1991); see Figures 1 and 2. After flowering, a reduction of the number of sprays seems possible by careful monitoring of the occurrence of both diseases as prescribed by the schemes. On the dates announced in Figures 1 and 2, fruit growers have to check the leaf whorls or shoots and, based on the assessment, they have to decide to spray or not. However, such an approach will only be successful as long as good fungicides remain available. Also a good scab warning system is very important (MacHardy, 1989). The schemes are currently being evaluated in several commercial orchards.

Results of trials with regulated disease control have been published by Van der Scheer (1991). The results lead to a reduction of 3-4 fungicide applications each season.

Resistant cultivars

At the Centre for Plant Breeding Research in Wageningen, and at our research station, much attention is given to the breeding and evaluation of scab-and mildew-resistant apple cultivars (Van der Scheer, 1989). So far, all resistant cultivars from foreign origin were unsuitable with respect to yield and/or fruit quality. Currently some new resistant crosses are being evaluated. Such work can give an idea of the consequences of the omission of fungicide sprays against scab- and mildew example for other diseases, storage disorders and pest-predator balance.

Alternatives for herbicides

Various alternatives for herbicides are currently being tested: i.e. mechanical weed-control with rotor hoes, burning of weed with propane burners, covering the soil with black, woven polypropylene cloth or with bark chips (Gut et al., 1990; Ollig, 1989; Niggli, 1989; Weibel, 1991). At our research station other covering materials, such cloth made of flax fibre, jute or paper are also being evaluated.

Narrowing the weed-free tree strips by widening the grass alleys is also under study. Narrowing the weed-free strip to 50 cm also seems possible, provided that competition for water and nutrients is mitigated by fertigation. Trickle irrigation alone is not sufficient (Wijsmuller & Baart, 1989).

Alternatives to soil fumigation

The growth reduction caused by specific apple replant disease on clay soils, the cause of which is still unknown, is overcome by dense planting, using high-quality plant material and potted soil in the planting hole (8-10 l), and fertigation of the newly planted trees. On sandy soils, however, replant problems due to the root-lesion nematode *Pratylenchus penetrans* are mostly solved by soil fumigation with metam-sodium or 2-dichloropropene, both suspect substances with regard to the environment. Therefore an experiment was started with nematicidal *Compositae* (Gommers, 1973) in the experimental garden at Horst (Table 4). The plants of these species were sown or planted in the spring of 1990 in 10 replications. On half of each plot, the

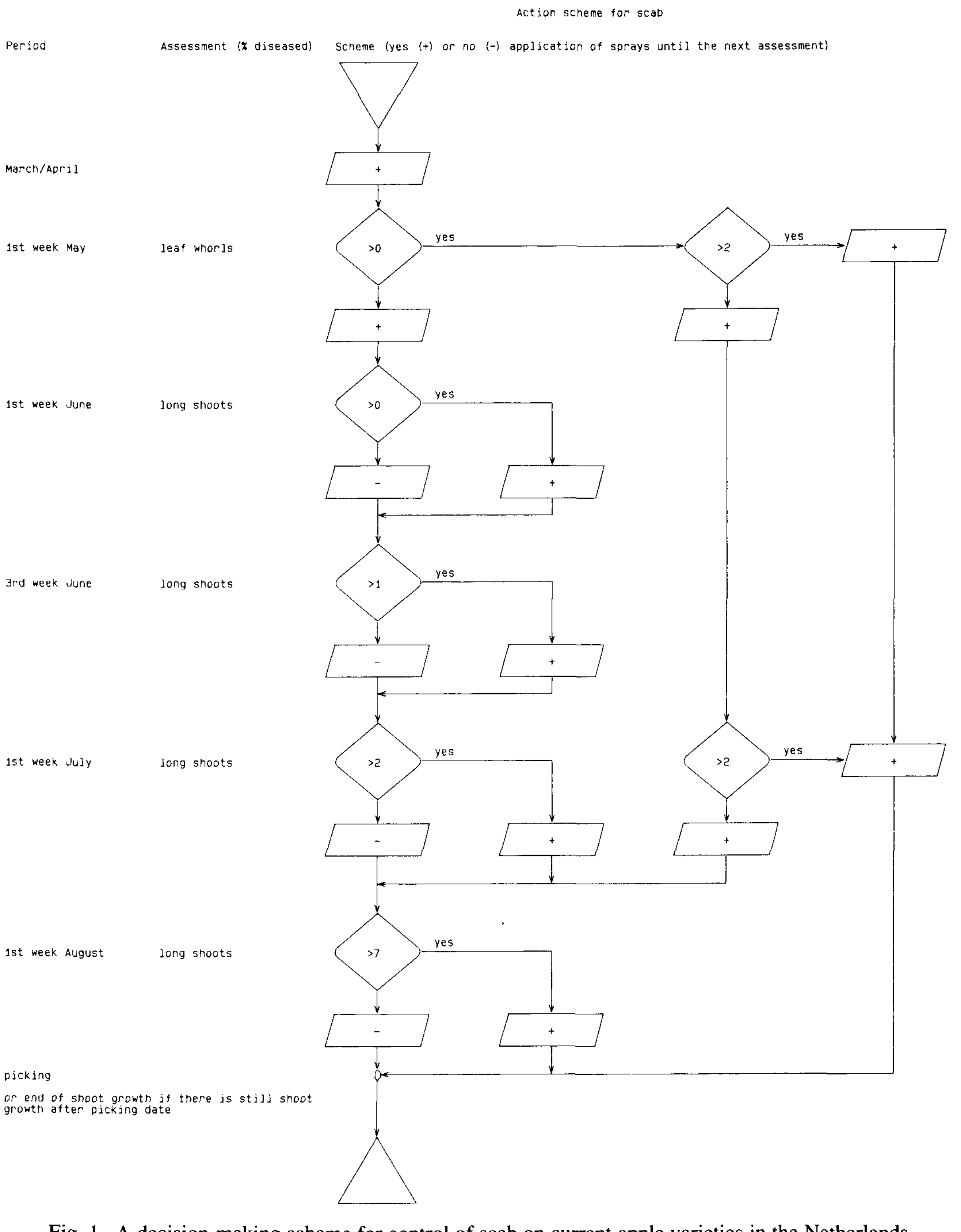

Fig. 1. A decision-making scheme for control of scab on current apple varieties in the Netherlands (After Van der Scheer, 1991).

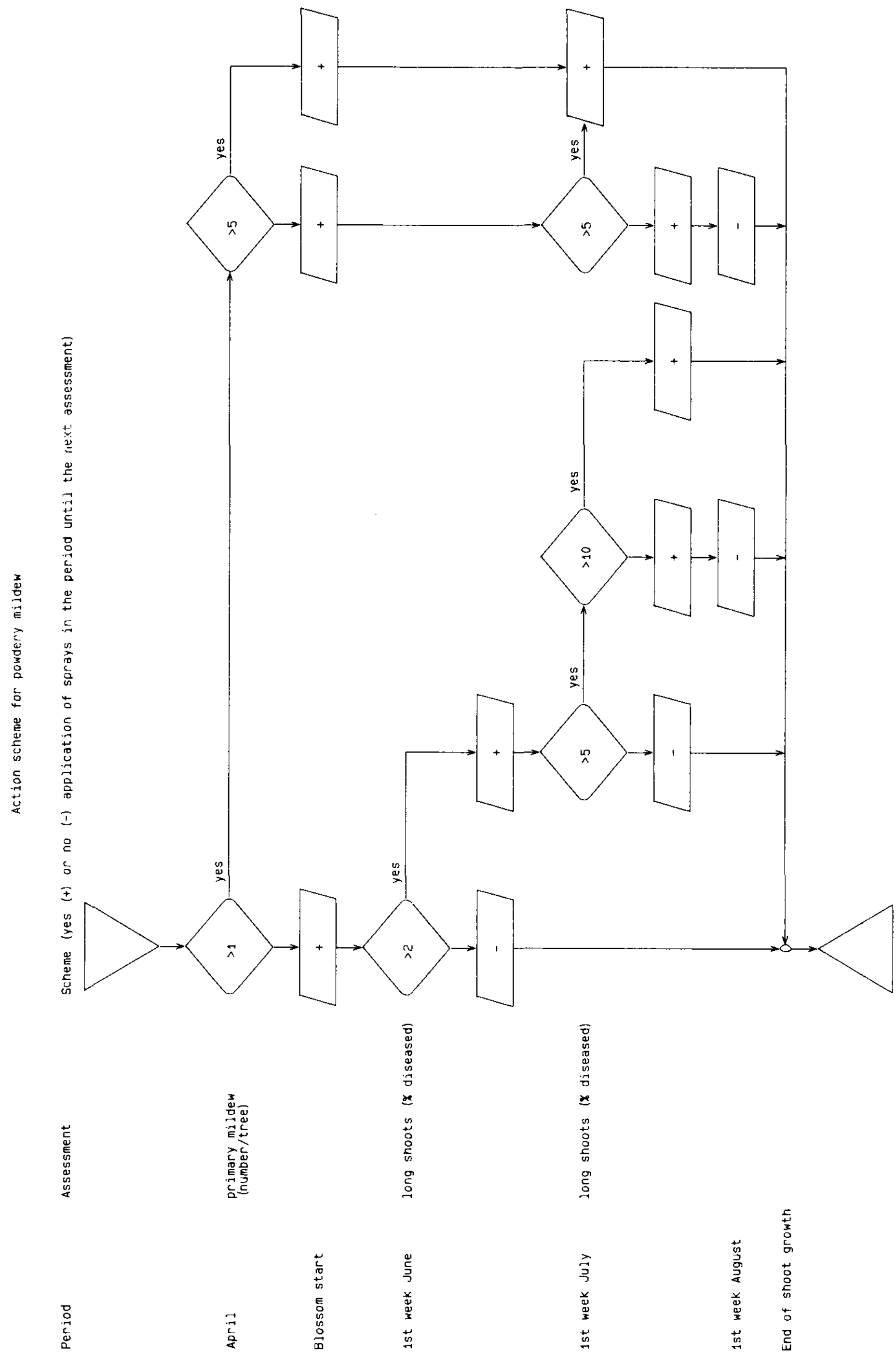

Fig. 2. A decision-making scheme for control of powdery mildew on current apple varieties in the Netherlands (After Van der Scheer, 1991).

plants were ploughed back in the winter of 1990-1991. In the spring of 1991, on all plots apple trees of Elstar and Jonagold on rootstock M. 9 were planted to evaluate the effects of the plants, as first crop or undercropping, on growth and productivity of the trees and on the nematode populations in the soil. The first results at Horst were published recently (Schenk & Wijsmuller, 1991). They indicate that *Tagetes patula* 'Dwarf Bonita' lowered the population density of *Pratylenchus penetrans* below the damaging level. The other crops given in Table 4 were not significantly different from the bare soil treatment. Effects on growth of the apple trees will be established annually.

Table 4. Compositae used for *Pratylenchus penetrans* control

Tagetes patula 'Dwarf Bonita'
Echinops ritro
Eriophyllum caespitosum
Gaillardia hybride 'Burgundy'
Helenium hybride 'Moerheim Beauty'

Replacement of growth regulators

Growth of apple and pear is often retarded chemically by daminozide and chloromequat, respectively. For existing orchards, mechanical root pruning is being tried out as an alternative. For new orchards more dwarfing rootstocks/interstems and/or higher budding on the rootstock might prove to be useful alternatives. Considerable research efforts are made in these fields at our research station. Since there is a wide variation in growth vigour between various dwarfing apple rootstocks (Wertheim, 1989), it seems possible to avoid the use of chemical growth-retardants. However, for a proper rootstock choice it is essential that future growth can be correctly predicted. Methods are not yet available.

For many red-coloured apple cultivars more intensely coloured mutants exist or may be tracked down. Use of such mutants can rule out applications of ethephon, a chemical that enhances red-colour formation. The search for red-coloured mutations in some main apple cultivars has provided a wealth of material (Goddrie, 1990). Therefore the necessity for the use of colour-promoting sprays will diminish or disappear.

For the moment it seems hardly possible to abandon the use of blossom or fruit-thinning chemicals, but research on ecologically safer products, such as urea, has been started (Link, 1991).

Other spraying techniques

To avoid inefficient spraying and high levels of spray drift, the use of transverse flow designs is a positive development. Spraying with these machines will certainly lead to lower product concentrations (Wiedenhoff, 1991).

Another development is the tunnel sprayer, with which spray not deposited on the tree is collected and recycled. First results are very encouraging.

Fertilizers

In Dutch fruit growing it is estimated that only 35 kg N ha^{-1} yr^{-1} and 2 kg P ha^{-1} yr^{-1} are lost. Potassium losses are also low because on average the current supply is smaller than the demand. Fertigation is increasingly being used and may not only limit nutrient losses but also supply the right amount of fertilizer at the right moment.

Production systems research

Stimulated by the new government crop protection policy, in 1989 our research station started a project of Integrated Plant Production to support the introduction of integrated plant production. Various existing research programmes were assembled in this project. The project integrated fruit growing comprises development and comparison of various systems of fruit growing that differ in inputs of chemicals and analytical research on detail questions.

Three systems of apple growing with varying input of chemicals were laid out on a semi-practical scale on two sites (regional experimental stations at Numansdorp and Zeewolde) (Table 2). Per system, eight apple cultivars have been planted at 3 × 1.25 m in a single-row design in the spring of 1990 whereby two to four rows per cultivar alternate. The cultivars comprise six current ones (Alkmene, Cox's Orange Pippin 'Queen Cox', Discovery, Elstar, Jonagold 'Jonica', and Red Boskoop 'Schmitz Hübsch') and two scab- and mildew-resistant crosses (78039-18, 78039-27) from the CPRO at Wageningen.

A more detailed outline of the plant protection schemes is given in Table 2. In the current system all legal treatments and techniques are used with concentrations of chemicals according to actual recommendations of the advisory service. In the system 'Integrated 1' less chemicals are used, while avoiding compounds forbidden in groundwater protection areas. So, a number of insecticide sprays is left out or replaced by other means (for example, pheromones for mating disruption of summerfruit tortrix moth (*Adoxophyes orana*)). Fungicide sprays are applied at 50% of the recommended concentrations (Cross & Berry, 1990). Contact herbicides will be partially substituted by mechanical weed control. So a fair amount of risk will be taken, although the system is expected to be feasible for a motivated and skilled grower. In the system 'integrated 2' the use of chemicals will be reduced to an absolute minimum and therefore much risk will be taken. As much as possible, chemical measures are replaced by biological or other means, or simply left out. Fungicides will be sprayed at 25% of their normal concentrations. In 1990, weed control was done by mechanical means and by special burners. These methods were so labour intensive that in 1991 the tree strips were covered with black, woven polypropylene cloth to control weeds. For every pest a certain biological control method is envisaged. This approach is not yet feasible for growers. All systems are dynamic and will be regularly improved, based on an agronomic and environmental evaluation.

In each system, all pests (and their predators) and diseases will be monitored. Growth, production, fruit quality, fruit-storage behaviour and necessary labour will be recorded annually so that the systems can be compared economically. Samples of drainwater will be investigated several times a year for the occurrence of simazin (persistent herbicide), pirimicarb (semi-persistent insecticide) and fertilizers. For that purpose a special drain pit is provided in each system. For 'Integrated 2', simazin residues are assessed to evaluate the effects of the former orchard in Numansdorp. In Zeewolde, which is on recently reclaimed land, this is not relevant. For the experiment the government has provided extra manpower and finance.

Intial results of systems research

Inputs of pesticides and labour

Since the system comparison has just been started, there are only few results to report. In 1990, 1.2, 0.6, and 0.0 kg a.i. of herbicides has been used in the treatments 'standard', 'Integrated 1' and 'Integrated 2', respectively. For fungicides these figures were 3.9, 3.2, and 1.9 kg a.i., respectively and for insecticides 0.2, 0.1, and 0.0 kg a.i., respectively For scab control it appeared that 25% of the standard dosage is insufficient in the early season. The current way of growing required 65 hours of labour against 100 and 109 hours for the treatments 'Integrated 1' and 'Integrated 2', respectively. It became clear that in the integrated systems more time is needed, especially for weed control with burners.

Leaching of nutrients and pesticides

In February 1990, from each parcel soil samples were taken and analysed for simazin. The samples we analysed by gaschromatography on a mediumbore column OV-17, stationary phase 50% methyl-/50% phenylsilicone; 25 m × 0.25 mm film thickness. The results indicate that there was no difference in pesticide content between the different treatments at the beginning of the experiment.

Perspectives

The system development and comparison experiment will last from 1990 to 1996. In the meantime, knowledge and experience gained can be passed on to practical growers. Moreover, in 1991, four commercial holdings have been appointed to serve as demonstration orchards for integrated fruit production. Each of these holdings is in an important fruit area and can become an example for other growers in the area. For the dissemination of integrated fruit growing, the advisory service has been extented with specialised advisory officers.

Organisations such as the Dutch Fruit Growers Organisation support the idea of integrated fruit growing, and the government stimulates new developments. Growers are willing to cooperate, because competing countries are already selling fruit grown in an integrated way and buyers are begining to ask for it. The speed with which 'integrated fruit growing' will supersede traditional fruit growing will largely depend on the results of ongoing research and certainly also on the pressure of the new crop protection policy, through which a lot of pesticides will be forbidden.

References

Anonymus, 1989. Additional plan for research in integrated plant production 1989-1993. (In Dutch). NRLO-rapport no. 89/21.

Anonymus, 1990. Report of working group for fruit growing. Back-ground document for the Multi-Year Crop Protection Plan. (In Dutch). Ministry of Agriculture, 76 pp.

Anonymus, 1991. Multi-Year Crop Protection Plan. Government decision. (In Dutch). Ministry of Agriculture, Nature Management and Fisheries. SDU, The Hague. (Essentials available in English).

Bandeen, J.D., G.R. Stephenson & E.R. Cowett, 1982. Discovery and distribution of herbicide-resistant weeds in North America. In: H.M. Le Baron & J. Gressel (Eds): Herbicide resistance in plants, p. 9-30. Wiley-Interscience, New York.

Blommers, L. & W.P.J. Overmeer, 1986. On the fringes of natural spider mite control. International Organisation of Biological Control. West Paleartic Region Section Bulletin 1986/IX/4: 48-61.

Boesten, J.J.T.I., 1986. Behaviour of herbicides in soil: simulation and experimental assessment. Doctoral Thesis, Wageningen Agricultural University, 263 pp.

Cross, J.V. & A.M. Berry, 1990. Efficacy of reduced volume and reduced dose rate spray programmes in apple orchards. *Crop Protection* 9: 207-217.

De Reede, R.H. & P. Alkema, 1981. Integrated pest control in commercial orchards. (In Dutch). *Bedrijfsontwikkeling* 12: 81-88.

Dickler, E. & S. Schäfermeyer, 1991. General guidelines, principles and standards for integrated production of pome fruits in Europe. International Organisation for Biological Control. West Paleartic Region Section Bulletin 1991/XIV/3, 67 pp.

Forshey, C.G. & D.C. Elfving, 1989. The relationship between vegetative growth and fruiting in apple trees. *Horticultural Reviews* 2: 229-287.

Goddrie, P., 1990. Mutants of Jonagold in the Netherlands (In French). *Le Fruit Belge* 432: 288-292.

Gommers, F.J., 1973. Nematicidal principles in *Compositae*. Mededelingen Landbouwhogeschool Wageningen No. 73.17, 71 pp.

Gressel, J., H.U. Ammon, H. Fogelfors, J. Gasquez, Q.O.N. Kay & H. Kees, 1982. Discovery and distribution of herbicide-resistant weeds outside North America. In: H.M. LeBaron & J. Gressel (Eds), Herbicide resistance in plants, p. 31-55. Wiley Interscience, New York.

Gruys, P., 1982. Hits and misses. The ecological approach to pest control in orchards. *Entomologia Experimentalis et Applicata* 31: 70-87.

Gut, W., W. Jäggi & F. Weibel, 1990. Auswirkungen von Abdeckmaterialen auf die Bodenfruchtbarkeit. *Schweizerische Zeitschrift für Obst- und Weinbau* 126: 685-691.

Link, H., 1991. Apfelanbau ohne Wachstumsregler? *Obstbau* 6: 308-310.

MacHardy, W.E., 1989. Research needs for improving apple scab warning systems. International Organisation for Biological Control. West Paleartic Regional Section Bulletin 1989/XII/6: 2-12.

Maier, C.T., 1990. Potential for the biological control of apple leafminers by parasitic wasps. Proceedings Annual Meeting, Massachusetts Fruit Growers Organisation Inc., 96: 60-74.

Minks, A.K. & P. Gruys, 1980. Integrated control of insect pests in the Netherlands. Pudoc Wageningen, 304 pp.

Müller, W. (Ed.), 1990. First symposium on integrated fruit production. Acta Horticulturae 285, 193 pp.

Niggli, U., 1989. Unkrautbekämpfung in Obstplantagen durch Bodenbedeckung mit organischen Materialen. *Besseres Obst* 2: 29-33.

Ollig, W., 1989. Alternativen zur Herbizidbehandlung in den Baumstreifen. *Obstbau* 14: 14-16.

Pawlizky, K.-H., 1990. Ursachen der Grundwasserbelastung durch Herbicide und Möglichkeiten der Verminderung. *Erwerbsobstbau* 32: 69-75.

Sansavini, S., 1990. Integrated fruit growing in Europe. *HortScience* 25: 842-846.
Schenk, A. & J. Wijsmuller, 1991. First crops decrease nematode population. (In Dutch). *De Fruitteelt* 8: 34-35.
Van der Blom, J., B. Drukker & L. Blommers, 1985. The possible significance of various groups of predators in preventing pear psylla outbreaks. Mededelingen Faculteit Landbouwwetenschappen Rijksuniversiteit Gent 50: 505-510.
Van der Scheer, H.A.Th., 1989. Susceptibility of apple cultivars and selections to scab and powdery mildew in The Netherlands. International Organisation for Biological Control. West Paleartic Regional Section Bulletin 1989/XII/6: 205-211.
Van der Scheer, H.A.Th., 1991. Management of scab and powdery mildew on apple with emphasis on threshold values for control of both diseases. International Organisation for Biological Control. West Paleartic Regional Section Bulletin. (In press).
Weibel, F., A. Husistein & U. Niggli, 1991. Bodenbearbeitung ist auch in Obstanlagen eine sinnvolle Alternative zur Herbizidanwendung. *Obstbau* 2: 77-80.
Wertheim, S.J., 1989. Preliminary results of trials with dwarfing apple and pear rootstocks. *Acta Hortuculturae* 243: 59-70.
Wiedenhoff, H., 1991. Optimisation of spraying methods for fruit trees with reduced use of chemicals. Symposium on air assisted spraying in crop protection Swansea, UK. BCPC Monograph 46: 219-223.
Wijsmuller, J. & J. Baart, 1988. Possibilities for a smaller weed-free strip. (In Dutch). *De Fruitteelt* 10: 20-21.