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6 Disease and pest control

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Crop production

Crop production, the gradual increase of dry matter in kg per ha, is due to crop growth. The various factors affecting crop growth fall in one of the following three categories: growth-defining factors, growth-limiting factors, and growth-reducing factors.

Growth-defining factors are the physiological, phenological, geometrical, and optical characteristics of the crop and the physical characteristics of the weather. Growth-defining factors determine the potential growth rate of a crop under the prevailing weather conditions. This potential is rarely realized because growth-limiting and growth-reducing factors are normally active.

Growth-limiting factors (Table 6.1), such as lack of water, nitrogen, or phosphorus, or excess of water, are eliminated or reduced by various agronomic measures. Under Dutch conditions, growth-limiting factors are of little importance, unless applied on purpose. At DFS, that is indeed the case with artificial fertilizer application, which is banned from the Organic Farm, and with nitrogen application, which is somewhat restricted on the Integrated Farm.

Growth-reducing factors are the various harmful agents, be they insects, fungi, nematodes, weeds, or others. These can be controlled by prevention and/or by intervention. Prevention takes place by means of adequate crop rotation, good choice of varieties, and various agronomic measures. Intervention takes place by means of weeding, roguing, chemical control, and certain other measures. In the present con-

Table 6.1. Four production situations (after De Wit et al., 1987). The total dry matter production per growing season was calculated for Dutch conditions and expressed in kg/ha.

Production situation	Limiting factor(s)	Growth rate * growth period	Total dry matter production per growing season
1	radiation and temperature	200 kg per ha per day * 100 days =	20 000
2	water	200 kg per ha per day * 50 days =	10 000
3	N		5 000
4	P		3 000

text, seed treatment, usually considered to be a preventive measure, is a chemical intervention.

The Current Farm aims at maximizing yield by eliminating crop growth-limiting factors and controlling crop growth reducing factors as much as possible. A consequence is heavy reliance on intervention by means of pesticides. The Integrated Farm wants to avoid this dependence on pesticides where possible, whereas the Organic Farm simply refuses to apply any pesticide. The Integrated Farm has to compromise with crop growth-limiting factors in order to live with the inevitable crop growth-reducing factors and tries to reduce chemical intervention where possible. The Organic Farm accepts crop growth-limiting factors because it refuses to use artificial fertilizers; it accepts, however, irrigation when the need is high and, of course, drainage. The Organic Farm tries to avoid growth-reducing factors, but accepts them when inevitable.

Such is the philosophical background for the following discussion on crop protection. For weed control, the reader is refered to Chapter 7.

Crop protection measures

Crop protection facts. Whereas the intensity of chemical treatment decreased on the Integrated Farm it increased on the Current Farm (Figure 11.4, Table 9.7). The number of active ingredients also increased on the Current Farm (Table 6.2). The major point is soil fumigation, needed because potato cyst nematodes have gradually invaded the area and because a crop rotation of one potato crop in four years is inadequate to keep the nematodes in check without using resistant cultivars. However, yield and market value of resistant potato cultivars are too low to be profitable on the Current Farm. We fear that in the long run the Integrated Farm will not be able to avoid soil fumigation.

Table 6.2 shows the changes in crop protection tactics during the reporting period. They are:

1. Increase of pesticide applications on the Current Farm, with high yields and good yield stability (Table 4.4).
2. Decrease of pesticide application on the Integrated Farm, with good yields but lower yield stability (Table 4.4).
3. Continuous development of both farming systems with many hits and misses.

Wheat. The choice of a cultivar (mixture) with comprehensive resistance is a pre-season, strategic decision. Several chemical treatments on the Current Farm have the character of an 'insurance premium', as for example seed disinfection which is omitted on the Integrated Farm. Need-based treatments during the growing season are the sequels of tactical, within-season decisions. They can be applied by relying on a warning system such as EPIPRE (Zadoks, 1984a), which necessitates at least four crop observation rounds per season, amounting to a labour investment of at least one hour per ha. EPIPRE is used on both the Current and the Integrated Farm, but on the latter

Table 6.2. Pesticide usage on DFS in 1984. The changes over the period 1980 – 1984 are indicated as + (increase), ○ (no change), – (decrease), blank (data ambiguous). Data provided by F.G. Wijnands, Scientific Co-ordinator.

	Current Farm			Integrated Farm		
	dosage (kg/ha)	active ingredient	change	dosage (kg/ha)	active ingredient	change
Seed potatoes						
Tuber treatment	0.03	mercury compounds	○	0.29	validamycin	○
Annual weeds	1.00	metobromuron	○	–	–	○
Aphids	0.25	pirimicarb	–	–	pirimicarb	○
Non-persistent virus	6×	mineral oil	+			
Phytophthora infestans	14.30	maneb (8×)	+	1.80	maneb/fentin	–
	2.45	mancozeb (2×)	–			
Soil fumigation	199.50	dichloropropene	+			
Ware potatoes						
Tuber treatment	0.03	mercury compounds	○	0.29	validamycin	○
Annual weeds	1.50	metobromuron	○	–	–	○
Aphids	0.25	oxydemeton-methyl	–			
Phytophthora infestans	2.00	maneb	+	1.23	mancozeb/fentin	○
	18.00	maneb/fentin (10×)	+	7.20	maneb/fentin (4×)	–
Defoliation	2.25	dinoseb	○	–	–	
Soil fumigation	199.50	dichloropropene	+			
Sugar-beet						
Seed treatment	0.05	thiram	○			
Soil insects	0.05	carbofuran	○	0.55	carbofuran	○
Annual weeds	2.60	chloridazon	○	–	–	○
	1.01	fenmedifam	○	0.55	fenmedifam	–
	0.30	ethofumesate	?	0.30	ethofumesate	○
Perennial weeds	0.36	glyphosate	+			
Insect control	0.38	parathion	?	–	–	○
Seed onions						
Onion fly	0.09	trichloronate	–			
Soil insects	0.02	thiram	○			
Annual weeds	3.83	propachlore	○	0.50	paraquat	○
Potato volunteers	2.50	difenoxuron	○			
Leaf diseases	12.00	chlorothalonil/ maneb (8×)	+			
Anti-germination	1.98	maleine hydrazide	○			

Table 6.2. Continued.

	Current Farm			Integrated Farm		
	dosage (kg/ha)	active ingedient	change	dosage (kg/ha)	active ingredient	change
Winter wheat						
Seed treatment	0.15	guazatine	o			
Growth regulators	0.38	chlormequat	–			
Weeds	2.24	mecoprop	o			
	2.80	2,4-D amine	o			
Diseases	0.13	triadimephon	+	0.13	triadimephon	+
	0.75	captafol	o	0.75	captafol	o
Aphids	0.25	pirimicarb	–	0.25	pirimicarb	–
Winter barley						
Seed treatment	0.12	guazatine	o	–	–	o
Weeds	2.24	mecoprop	o	–	–	o
		azatine	o			

it is applied with arbitrarily higher threshold levels. Thus, a higher risk was accepted, which materialized in 1983 when over 500 kg per ha was lost due to cereal aphids. Nevertheless, DFS has shown that high yields can be obtained with very limited input of pesticides.

The aphids on wheat are primarily *Sitobion avenae*, and also *Metopolophium dirhodum* and *Rhopalosiphum padi.* The exponential increase of aphid populations on wheat of the Integrated and Organic Farms did not differ significantly (Figure 11.5). On the Current and Integrated Farms, pirimicarb is used to stop the aphid epidemics.

Natural enemies of aphids still offer few prospects. Several spider, carabid and staphylinid species occur in the field, but the variability in species and numbers is high, possibly due to local and temporal absence of prey. Over ten species of aphid parasites have been found, often so heavily hyper-parasitized that they cannot prevent an upsurge of the aphid populations. Natural enemies are impredictable and unreliable as biological control agents. Moreover, the Integrated Farm uses only pirimicarb, which has few undesirable side-effects.

Entomophthora spp. occurs at times on aphids, but becomes effective only after flowering, when aphids are less damaging than before. The fungicides in use may have adverse effects on *Entomophthora* and on various saprophytic yeasts and fungi that may compete with pathogenic fungi.

Potatoes have a high cash value but also a huge need for pesticides. Nematicides are mentioned elsewhere in this paper. *Phytophthora infestans* requires up to ten treatments per season, because the highly susceptible variety Bintje is grown for cash. Aphids, especially *Myzus persicae*, must be controlled as they are the vectors of potato Y and X virus, among others. Up to ten insecticide treatments per season may be needed. As biological control of nematodes, aphids and fungi is not yet feasible, varieties with a comprehensive resistance should be chosen, but these have less cash value. On the Integrated Farm, the varieties Pimpernel and Irene have been grown with good agronomic but usually poor financial results.

Sugar-beet did not suffer much from pests and diseases during the reporting period.

Onions were part of the rotation on DFS. They require considerable amounts of pesticides, herbicides foremost. To control the onion fly (*Delia antiqua*), chemical treatment and treatment by sterile male technique are available. The latter technique was applied on the Integrated Farm; it is reliable, requires some investment of labour, and fits well in integrated farming. Various fungal diseases can be very troublesome in onions and there is no solution but chemical treatment. When the sterile male technique is applied, other chemical treatments must be onion fly-friendly.

Scaling problems. An interesting point gradually becomes apparent. Various cultural measures interfere with crop protection measures in such a way that they can hardly be studied at the present near-farm scale of experiments. Current farming is interested in early sowing of winter wheat. The Current Farm, and also the Organic Farm, grows ryegrass sown under wheat for green manure. Both practices lead to shortening and broadening of the 'green bridge' (Zadoks, 1984b) used by various pathogens for oversummering. The consequence is a greater risk of early mildew, rusts, aphids, and barley yellow dwarf virus in winter wheat.

As the three DFS farms are relative small, they may influence each other in unknown ways. One glimpse of this mutual influence was seen during an outbreak of the pea weevil (*Sitona lineata*), with evidently the permanent pasture of the Organic Farm as its source, which spread out over the Integrated Farm in one year. In the fall of 1986, a wheat crop of the Organic Farm was heavily attacked by slugs, particularly at the side of the permanent pasture of the Organic Farm.

Considerations of risk

The three farming systems differ markedly in risk behaviour and they show considerable differences in the amounts of pests and diseases. The Current Farm mimics the risk-averse behaviour as seen in the surrounding area. The Integrated Farm is somewhat more risk-accepting. The Organic Farm follows a system with its own intrinsic risks. Such is the situation at first glance.

A second look shows a different picture. The Current Farm is designed to maximize income. The avenue chosen is the maximization of yield. By investing so much in the promotion of growth-defining factors and in the reduction of crop growth-limiting factors, a considerable amount of money is at stake when crop growth-reducing factors appear. That is why so much money has to be invested in crop protection, either in the preventive or in the interventive way. The answer to the question whether the Current Farm is risk-avoiding or risk-accepting depends on the emphasis given by the observer to the strategic planning (before crops are planted) or to the tactical actions (interventions during the growing season). If the observer looks mainly at the tactical actions just before or during the season, then the Current Farm is risk-averse, indeed. If, however, the observer evaluates the strategy of the Current Farm rather than its tactics, then the Current Farm must be considered to be risk-seeking. The major reason is that crops with a high nitrogen status are relatively vulnerable to aphids and to pathogens, especially biotrophic pathogens such as rusts and mildew. Another reason is that, at the high production levels reached, damage may be superproportional; the damage suffered per unit of harmful agent (e.g. 1 aphid, 1 mildew lesion) increases with the increase of yield above a certain level (Rabbinge et al., 1981). The conclusion is counter-intuitive but obvious: from the planners' point of view the Current Farm is risk-seeking.

The Integrated Farm is, in appearance, risk-accepting because it invests less in pre-emergence treatments of soil, seeds and planting stock, and it applies higher threshold levels for intervention (chemical treatment). However, if we shift our attention from the tactical actions to the strategic planning, we may conclude to the contrary. The best illustration is provided by wheat. Wheat varieties are chosen for comprehensive resistance rather than for top yield. Sometimes, variety mixtures are used, which provide an additional reduction of risk due to rusts and mildew. Nitrogen application is decidedly lower than on the Current Farm, thus making the wheat crop less vulnerable to aphids, rusts and mildew. With crops other than wheat, the tendency is the same though the results are not so convincing. We fear that soil fumigation against nematodes will be inevitable in the long run, if the 1 to 4 rotation is maintained. A wider rotation is needed to avoid soil fumigation, but this solution disturbs the experimental design of DFS.

In the case of weed control, our present knowledge fails. If pre-emergence weed control is not applied and if the right moment for post-emergence intervention is missed, the Integrated Farm is in trouble. At the present time in the development of DFS, the Integrated Farm is definitely risk-seeking with respect to weeds. This involuntary situation possibly came about because the management, jumping from decision to decision, lost its grasp of the general picture.

The Organic Farm emphasizes preventive strategy. Weed control is fairly successful though sometimes annual weeds cause a surprise that necessitates the input of much manual labour not reported in the farm records on which this book is based. The relatively low nitrogen status of the crops makes them less vulnerable to aphids and several pathogens; the open stands probably reduce the number of hours suitable for infection by fungal diseases. Late blight, nevertheless, remains a problem in susceptible potato cultivars. The choice of cultivars suited to the objectives of Organic Farming is a problem that has not yet been adequately addressed. Tactical interventions on the Organic Farm are limited to careful weeding and weed burning, and, in the case of carrots, to careful planting, thinning, and earthing up to avoid carrot fly (*Psila rosae*). Though the tactics of the Organic Farm seem to be risk-seeking to the degree of negligence, the strategic planning of the Organic Farm is an extreme case of risk-avoidance.

The conclusion is that we have to reconsider our concepts about risk-acceptance and risk-avoidance. From the point of view of strategic planning, the Current Farm is the risk-seeking farm.

This conclusion is also correct if we look at the problem from the point of view of sustainability. The Current Farm uses far more pesticides than the other two farms, which in the long run threatens environment and thus sustainability. A simple example is the number of spiders, carabids and staphylinids found in different farming systems (Table 11.4). These animals, which have a role in the biological control of aphids, are least abundant on the Current Farm.

Current agriculture is continuously adapting to new circumstances. Society will impose minimization of negative side-effects of agricultural practices, and farmers will strive for sustainability of farming. In the near future, the present Current Farm will be little more than a caricature of current farming, and the Integrated Farm will be current. A new Integrated Farm, more flexible than the present one, will have to be designed.

Farm income

In the present economic situation, the farm income of the Integrated Farm is slightly lower than of the Current Farm (Chapter 8). We believe, but we have no way to substantiate this belief in a scientific way, that the sustainability of the Integrated Farm is better than that of the Current Farm. For the average Dutch farmer sustainability offers insufficient incentive to accept a decrease of income. If the European Community or the Dutch Government want to steer the farmers' decisions in the direction of integrated farming, changes in price and subsidy policies and regulatory actions have to be considered (Zadoks, 1978).

Conclusions

1. Considerable reduction of pesticide application is already possible.
2. Pest and disease prevention and control are major agronomic activities.
3. Pest and disease prevention strategies can be further developed for integrated farming.
4. The improvements due to supervised control and to restored natural biological control are small in comparison to the improvements due to agronomic measures such as choice of cultivar and restricted application of nitrogen.

5. Future efforts to develop farming systems with very restricted inputs of pesticides should be oriented towards the effects of agronomic measures.
6. The present structure of DFS with its fixed crop rotation scheme is too rigid to further explore crop protection for integrated farming.