Plant protection in an organic crop rotation experiment for grain production

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Summary

The plant protection carried out in the Danish crop rotation experiment is described. These measures can be quite different in the different systems. While mechanical weed control can be carried out in systems without catch crops, it is not possible to do so in systems with catch crops without affecting the establishment of the catch crop.

The occurrence of weeds, pests and diseases is recorded, and the results are described. Since the results are only from the two first years of the experiments, it is not possible to conclude anything about the crop rotations as such. There are however differences related to the other experimental treatments in the experiment: the presence or absence of catch crops and manure. Only in very few cases are the differences statistically significant.

Introduction

None of the experimental treatments in the Danish organic crop rotation experiment are directly aimed at plant protection. Within each system, the best possible plant protection is carried out. This means that the plant protection, especially the weed control, in each system can be quite different from the other systems, and also the weed control can differ between locations, since the problems are not identical. The systems can also pose problems regarding plant protection; one example is the occurrence of couch grass (*Elymus repens*) in systems with catch crops. The presence of catch crops prohibits the stubble treatment that is usually the measure used against couch grass. The systems also influence the occurrence of pests and diseases, for example powdery mildew (*Erysiphe graminis*) occurrence on oats is much more pronounced when manure is applied.

Material and methods

The crop rotation experiment is described in Olesen *et al.* (1999) where all combinations of experimental treatments and locations can be seen. In the following, the plant protection measures will be described.

As a general rule, the optimal mechanical weed control is carried out. This includes preventive measures, such as choosing cultivars which are competitive against weeds, placing the manure close to the crop row where possible (Rasmussen *et al.*, 1996) and sowing winter cereals later than what is normally used, preferably around October 1st.

In the spring sown cereals and pulses, where there is no catch crop, weed harrowing is carried out pre- and post-emergence and if necessary, a weed harrowing at the later growth stages is used (Rasmussen and Rasmussen, 1995).

In winter cereals without catch crops, pre- and post-emergence harrowing is carried out after sowing, if the weather permits and if the harrowing can be carried out without covering more than at most 10% of the crop with soil, and one or several weed harrowings are carried out in the spring. These measures proved not to be sufficient on the sandier soils. Therefore since 1998 the winter cereals in rotation 4 at Foulum and the spring and winter wheat and the lupines (since 1999) at Jyndevad have been sown at larger row distances to facilitate mechanical hoeing between the rows (Rasmussen and Pedersen, 1990).

In the winter wheat with catch crops, except for rotation 4, weed harrowing is carried out in the fall (if possible) and in the spring before sowing of the catch crop. At Jyndevad, mechanical weed control is carried out pre- and post-emergence before the catch crop is sown in all cereal and pulse crops. In rotation 4, the white clover and weeds between the rows of winter wheat are cut down several times during the season with a row brush hoe.

The sugar beets are kept weed free by a strategy of pre-emergence flaming, row and hand hoeing.

If perennial weeds such as creeping thistle (*Cirsium arvense),* mugwort *(Artemisia vulgaris),* curled dock *(Rumex crispus)* and others occur, they are removed manually from the plots. In the case of creeping thistle this is done by cutting the stalk as deep under ground as possible at the time of the anthesis of the cereals, which coincides with the time when the thistles are budding. At this time the reserves in the root system are at a minimum (Dock Gustavsson, 1997). If couch grass (*E. repens)* occurs in plots without catch crops above a threshold level of 5 shoots m^{-2}, or white clover (*Trifolium repens)* occurs in plots without catch crops, repeated stubble cultivation is carried out after harvest. If couch grass occurs in plots with catch crops above a threshold level of 50 shoots m^{-2} stubble cultivation will be carried out. Another measure to cope with couch grass is to intensify the cutting of the green manure grass clover. Without occurrence of couch grass the cutting is carried out when the grass clover has a height of about 15-20 cm in mixtures without red clover (at the sandier soils) and about 20-25 cm in mixtures with red clover (at the loamy soils). With occurrence of couch grass in the crop preceding grass clover above a threshold of 5 shoots m^{-2}, the cutting is carried out when the grass clover has a height of about 10-15 cm and 15-20 cm, respectively.

Weed occurrence is monitored in cereals and pulses around the time of anthesis (growth stage 59, Lancashire *et al.*, 1991). The three dominating weed species and the remaining weeds in each plot are counted, dried and weighed in 3 samples of 0.25 m^2. Shoots of couch grass are counted in five samples of 0.1 m^2 each approximately 2 weeks after anthesis and the occurrence of this weed is also assessed in the whole plot at this time and after the growing season. Number and location in the plot of creeping thistle and other perennial weed plants are registered if present at the time of their hand weeding, and if applicable, again after harvest.

Choosing crop cultivars that have a high degree of resistance against the most important diseases, wherever possible prevents plant diseases. In order to avoid seed borne diseases all seed material is tested prior to sowing, and seed lots that are prone to display seedborne diseases are rejected. In rotation 4, with two subsequent years of winter wheat, there have been very severe attacks of take-all *(Gaumannomyces graminis)* at Foulum and Flakkebjerg. Because of this, the second year of winter wheat has since 1999 been substituted by winter triticale at Foulum, as this is expected to be less damaged by take-all.

One measure taken again insect pests is that the beets are sown at a plant density of 21 plants m^{-2}, which is twice the final plant density. If up to 50% of the germinating beets are devoured by insects, then it is still possible to reach the desired plant density. Another measure taken to prevent leather jackets (*Tipula paludosa)* is that the grass clover sward at the sandier soils is left uncut in a period between August 15th (where the grass must be at least 10 cm high) and September 15th. The flies prefer to lay their eggs in short grass during this period.

The most common and serious diseases and insect pests are monitored twice in wheat and triticale and once in the other cereals and pulses and when applicable in the beets. The occurrence of leaf disease in the cereals (mildew (*E. graminis)*, net blotch (*Drechslera teres)* and scald (*Rhyncosporium secalis)* in barley and oats and brown rust (*Puccinia hordei)* in barley; mildew (*E. graminis)*, yellow rust (*Puccinia striiformis)*, glume blotch (*Septoria nodorum)* and leaf spot (*S. tritici)* in wheat and triticale) is registered as the percent coverage of the two or three top leaves on ten plants two places in each plot. Takeall (*G. graminis)* is monitored on 25 plants of wheat and triticale dug up with roots. Leaf diseases (beet virus yellows, mildew (*Erysiphe betae)*, rust (*Uromyces betae)* and ramularia (*Ramularia beticola))* on the beets are registered as percentage plants with the disease on twenty plants. Occurrence of insect pests (aphids (*Rhopalosiphum padi, Sitobion avenae* and *Metopolophium dirhodum)* in cereals and cereal leaf beetles (*Oulema melanopus* and *O.lichenis)* in barley and oats; pea weevil (*Sitonia lineatus)* in peas, lupines and undersown clover and pea aphids (*Acyrthosiphon pisum)* in peas and lupines; field thrips (*Thrips angusticeps*), pygmy beetles (*Atomaria linearis*) and aphids (*Aphis fabae* and *Muzus persicae*) in sugar beets) is registered as the percentage of shoots/plants injured or habitated in each plot or as a grade of insect devouring two places in the plot.

Results and discussion

Weeds

The greatest amount of weeds, in numbers as well as biomass, was found on the sandier soils (Figure 1). The most common species were chickweed (*Stellaria media),* fat-hen *(Chenopodium album)* and shepherds purse *(Capsella bursa-pastoris)* at Jyndevad, scentless mayweed (*Tripleurospermum inodorum)* and chickweed at Foulum, black bindweed (*Polygonum convolvolus)* and chickweed and in 1998 creeping thistle (*C. arvense)* at Flakkebjerg and scentless mayweed in 1997 at Holeby.

At all locations and in both years the greatest amount of weeds occurred in the winter wheat (Table 1). For the spring sown crops, the pea/barley mixture was most infected with weeds at all locations in 1997. Oats was among the crops with the lowest amount of weeds at all locations in both years. In both years there was a tendency for more weeds, in numbers as well as biomass, in the fertilised treatments at Foulum and Flakkebjerg (Table 2). At Jyndevad, there was a tendency for most weed biomass in the unfertilised treatments in the winter wheat in 1997.

In the winter wheat in 1997, the weed control was very successful at Foulum, with significant differences in the weed biomass of treatments with full weed harrowing or brush weeding, as compared to weed harrowing carried out only before the sowing of the catch crop (Table 3). At Jyndevad, there was a tendency towards more weed biomass with the full weed harrowing, while there were no differences at Flakkebjerg, where there was not a very strong weed pressure. In 1998, the brush weeding at Foulum was less successful than all the other treatments, while row hoeing was the most successful there as well as at Jyndevad. The differences were smaller at Flakkebjerg, but the brush weeding treatment resulted in the most weed biomass. The differences in spring wheat at Jyndevad in 1998 were very small.

The differences of weed biomass with different weed control measures in the pea/barley mixture and lupines were not very large and in no case significant.

The treatments with weed harrowing in oats in all cases reduced the biomass as well as the numbers of the weeds, in one case significantly (Table 4). However, the yield was also decreased. It should be noted that the effects of weed harrowing cannot be separated from the effects of the catch crop, because the catch crop effect was confounded with the weed harrowing treatments such that plots without a catch crop were harrowed and those with a catch crop were not.

In 1998, couch grass (*E. repens*) was found at three locations. The weed was never found in all plots of any one crop, but at Jyndevad it was almost exclusively found in block two, and in most of the plots. In several cases the threshold for stubble treatment was exceeded in plots without catch crops (Table 5). The threshold has not yet been exceeded in plots with catch crops, but this could happen soon. To preserve the effect of the catch crop, the stubble treatment in plots with catch crops might be a shallow plowing followed by sowing of a fast growing competitive crop, such as fodder radish (*Raphanus sativus*). The decision of how to carry out the treatment is not final.

In 1998 creeping thistle (*C. arvense)* was found at Flakkebjerg. At harvest the thistles appeared significantly more often in plots without a preceding catch crop than in plots with a preceding catch crop. At anthesis they had appeared in equal numbers of plots with or without preceding catch crops (Figure 2).

Diseases and pests

The attack of leaf diseases on the cereals has not been very severe in 1997 and 1998, except for powdery mildew (*E. graminis)* in oats and Septoria (*S. nodorum* or *S. tritici)* in wheat and in 1998 mildew (*E. graminis)* in spring wheat. The attack of mildew in oats was worst in the treatments that had received manure (Figure 3). The attack of septoria (Table 6) in wheat was most severe at the latest registration, but there were no differences between treatments. In 1998, the attack was much worse at Flakkebjerg compared with the locations on the sandier soils. In the spring wheat, 40% of the leaves were covered with mildew in the middle of July (growth stage 70). A better protection against diseases may be obtained through the of use a mixture of different varieties. This would increase the resistance of the crop against diseases, because the different varieties could represent different levels of resistance against different diseases, and also because the resistance could be based on different genes. The reason this is not done is that it would make many of the registrations of growth stage, disease level etc. more difficult (Askegaard *et al.*, 1999).

Take-all (*G. graminis)* was found at all locations in both years. In 1997 the attack was worst at the sandier soils (Table 7). Apparently the combination of the preceding crop of spring barley and the sandier soils was conducive to the disease, whereas the loamy soils, in spite of a long history of cereals, did not react as profoundly. At Foulum, the experimental area had different cropping history. In the area, where there had been grass within three years before the experiment, only 1 % or less of the roots was infected with take-all. In the area, where grass had not been grown within five years before the experiment, 22% of the roots were infected. In 1998, the heaviest attacks were found in rotation 4, where one out of two years of winter wheat had a preceding crop of winter wheat. In the other rotations there were not very severe attacks, and it appears that one year of grass-clover was the reason for this. At Holeby, even rotation 4 was not very affected. In the second year winter wheat in rotation 4, where the heaviest attacks were found, there was interaction between the manure and the catch crop (Table 8). Without manure, the difference between the attack with and without catch crop was small, but with manure, the attack was twice as severe with catch crop as without. It was expected that the attack would be worst with catch crop, since this system was not ploughed between the two years of wheat.

In the sugar beets at Holeby in 1998, there were rather severe attacks of mildew (*E. betae)* (35% plants attacked), rust (*U. betae)* (90 % plants attacked) and ramularia (*R. beticola)* (50 % plants attacked) in September. At Flakkebjerg, the diseases were seen, but less than 10 % of the plants were attacked by the end of September.

In 1997, there were no serious attacks by insect pests in the cereals. At the sandier soils the winter wheat had attacks of aphids (*R. padi, S. avenea* or *M. dirhodum)* on up to 64% of the shoots in July (growth stage 72-75). The attacks on the loamy soils were below 15% of the shoots. In 1998, up to 87% of the shoots of pure spring barley at Jyndevad were inhabited by aphids by the end of June (growth stage 59), while the attacks at the other locations were around 10% or less. The attacks on the spring barley grown in mixture with peas were less than 20%. In oats, 24-38% attacks were found at the same growth stage at Foulum and

Flakkebjerg. In the winter wheat, up to 38 % of the plants had aphids at growth stage 59, and 2-3 weeks later op to 86% were attacked, and in the spring wheat 75% of the shoots had aphids at growth stage 59, but they had all disappeared 2-3 weeks later.

One insect pest that could be feared in systems, where nitrogen fixing plants is the main source of nitrogen, is the pea weevil (*S. lineatus)* which not only harm the plants by eating the leaves, but also devour the nodules containing the nitrogen fixing bacteria on the roots. In 1997, up to 25% of the leaf area of the peas had been eaten 10 days after germination, while there appeared to be much less infection in the undersown clover. In 1998, the attacks were registered on a scale of 1-10, and did not pass 2 in the peas at any location, were less in the undersown clover, and not found at all in the lupines. In 1997, up to 38% of the peas were infected with aphids at Holeby, with attacks below 5% at the other locations. In 1998, no location had above 16% attack and the lupines only 1%.

In the sugar beets, there were heavy attacks of pygmy beetles (*A. linearis)* at Holeby in both years. In 1997, where the crop was sown at final plant density, the beetles reduced this very much. In 1998, 50% of the plants were damaged, but this was not as severe, since there were twice as many plants as needed for the final plant density.

The plant protection carried out in the Danish crop rotation experiment has not been sufficient to avoid the presence of weeds, pests and diseases. In some cases, there has been a tendency towards a difference between the treatments. It is not yet possible to conclude much about the crop rotations or the other experimental treatments in the experiment: presence or absence of catch crops and manure. In addition to this, the experimental treatments might influence the results of the crop protection: for example the presence of a catch crop reduces the possibilities of mechanical weed control.

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Table 1. Biomass (g m^{-2}) of weed in the different crops.

Crop	**Jyndevad** 1997	**Jyndevad** 1998	**Foulum** 1997	**Foulum** 1998	**Flakkebjerg** 1997	**Flakkebjerg** 1998	**Holeby** 1997	**Holeby** 1998
Pea/barley	30	13	11	16	3	13	5	8
Spring barley	21	16	6	16	3	13	2	6
Winter wheat	35	27	25	32	8	15	31	8
Oats			7	10	2	14	4	4
Lupine		15						
Spring wheat		21						

Table 2. Weed biomass (g m^{-2}) in crops with (+) or without (-) manure.

Crop		Barley		Winter wheat		Oats		Spring wheat	
Location	Manure	1997	1998	1997	1998	1997	1998	1997	1998
Jyndevad	-	20	17	43	23	-	-	-	20
	+	22	14	28	31	-	-	-	21
Foulum	-	6	13	21	17**	3	4	-	-
	+	6	19	29	45**	11	16	-	-
Flakkebjerg	-	1	5	4*	9	3	5	-	-
	+	4	15	11*	19	2	21	-	-

Significant differences between manure level within location, year, crop: * = 5% level, ** = 1% level.

Table 3. Biomass (g m^{-2}) of annual weeds with different weed control in winter and spring wheat. Results in the same row with the same (or no) index le tter are not significantly different at the 5% level.

	Weed control			
Location	Harrowing only before sowing of catch crop	Weed harrowing	Brush weeding	Row hoeing
	1997 – winter wheat			
Jyndevad	31	39	-	-
Foulum	44^{a}	24^{b}	16^{b}	-
Flakkebjerg	8	8	-	-
	1998 – winter wheat			
Jyndevad	38	-	-	16
Foulum	27^{bc}	23^{c}	55^{ab}	16^{c}
Flakkebjerg	11	13	19	-
	1998 – spring wheat			
Jyndevad	23	-	-	19

Table 4. Biomass (g m^{-2}), number m^{-2} of annual weeds and yield with different weed control in oats.

	Weed biomass g m^{-2}		Weed density number m^{-2}		Yield (85% dry matter) hkg ha^{-1}	
	None	Weed harrowing	None	Weed harrowing	None	Weed harrowing
Location			1997			
Foulum	11	3	91	58	36	31
Flakkebjerg	3	1	70***	16***	36	23
			1998			
Foulum	16	4	81	29	53	49
Flakkebjerg	15	11	80	47	38	37

Significant differences between weed control within location, year: *** = 0.1% level.

Table 5. Percentage of plots with couch grass (*E. repens)* in spring or winter sown cereals and pulses with (+) and without (-) catch crop and the average number of shoots found in plots with couch grass.

		Jyndevad		Flakkebjerg		Holeby	
Crop sown	Catch crop	% of plots	shoots m^{-2}	% of plots	shoots m^{-2}	% of plots	shoots m^{-2}
Spring	-	35	17	6	34	20	2
	+	40	12	22	5	-	-
Winter	-	50	19	33	7	50	24
	+	50	16	50	8	-	-

Table 6. Percent leaf coverage of septoria in wheat at two registration times.

		First registration (growth stage 59)		Second registration (2-3 weeks later)	
Location		Flag leaf	Second leaf	Flag leaf	Second leaf
			Winter wheat		
Jyndevad	1997	0	1	5	16
Foulum	1997	0	0	8	29
Jyndevad	1998	1	1	2	12
Foulum	1998	0	0	2	11
Flakkebjerg	1998	0	0	30	80
			Spring wheat		
Jyndevad	1998	0	0	16	20

Table 7. Percent roots of wheat with take-all (*G. graminis)*.

	Crop rotation			
	1	2	3	4
1997				
Jyndevad	8	16		
Foulum		7		5
Flakkebjerg		1	0	1
Holeby		4	0	0
1998				
Jyndevad*	1	3		
Foulum		2		15
Flakkebjerg		3	3	11
Holeby		0	0	0

* Spring wheat in rotation one.

Table 8. Percent roots with take-all in second year winter wheat in rotation 4 1998 with (+) or without (-) manure and with and without catch crop.

Location	Manure	No catch crop	Catch crop
Foulum	-	26	25
Foulum	+	19	41
Flakkebjerg	-	22	18
Flakkebjerg	+	14	29

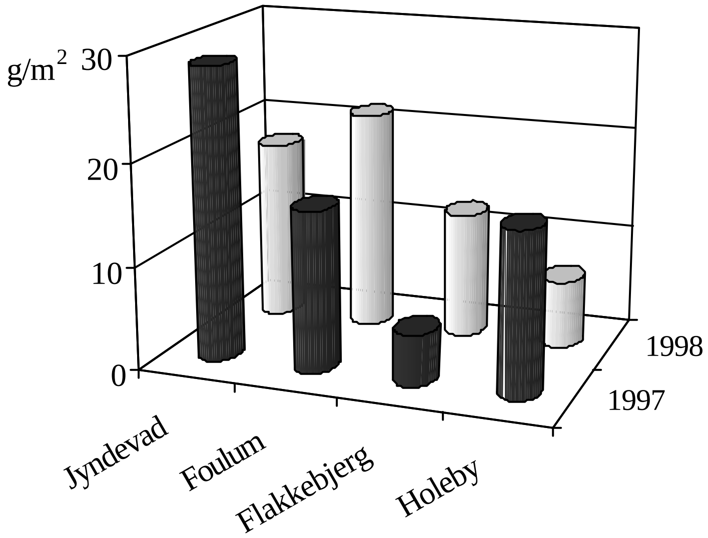

Figure 1. Biomass of weeds at the four locations in two years.

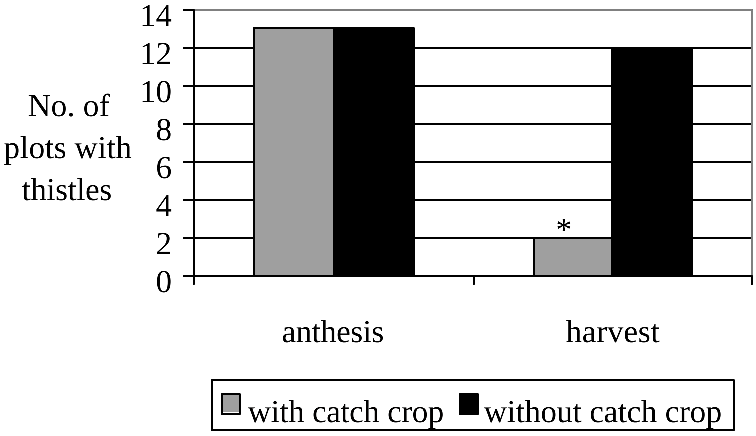

Figure 2. Number of plots with thistles at anthesis and after harvest in Flakkebjerg 1998. At harvest there are significantly more plots with thistles without a preceeding catch crop.

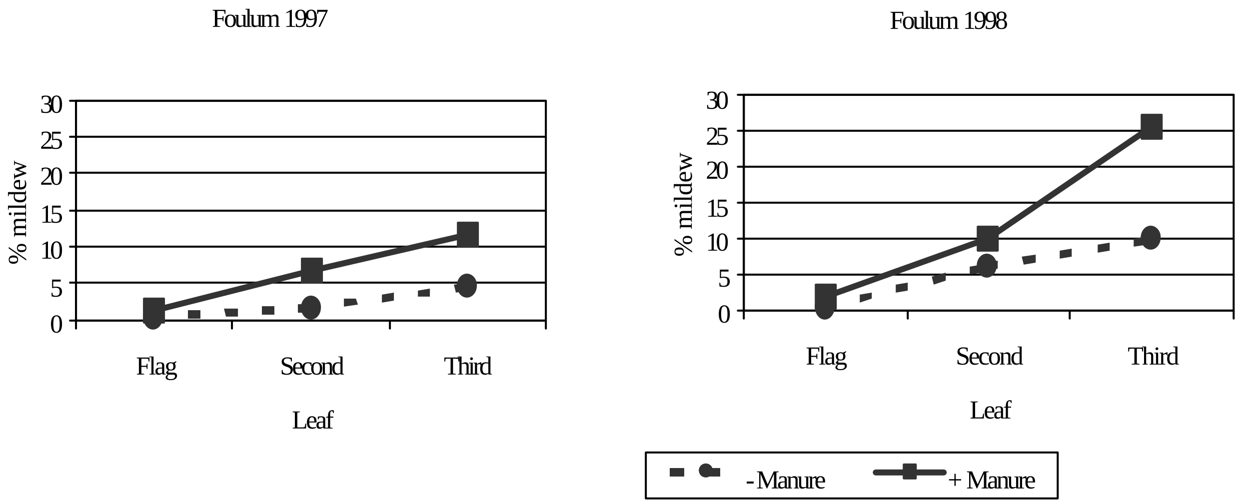

Figure 3. Attack of mildew, % leaf coverage, in oats with (+) and without (-) manure.