MINISTRY OF AGRICULTURE, FISHERIES AND FOOD **CSG 15**

Research and Development

Final Project Report

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Project title	Clover:cereal bi-cropping for organic farms
MAFF project code	**OF 0173**
Contractor organisation and location	Institute of Grassland and Environmental Research, North Wyke, Okehampton, Devon EX20 2SB
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Executive summary (maximum 2 sides A4)

Summary

IGER, IACR and others developed a system for growing cereals, especially for whole crop silage, that enables either greatly reduced or zero levels of N fertilizer and agrochemicals to be used. The system is simple and straightforward and relies on direct drilling of the cereal into an established understorey of white clover. The white clover understorey becomes permanent and perennial and successive cereal crops are drilled into it, harvested and re-drilled each year. The clover provides N for the cereal crop and the gross changes in crop architecture that occur (a) encourage large populations of predatory invertebrates that devour pest species and hence obviate the need for insecticide use (b) frustrate the spread of fungal foliar diseases and remove the need to use fungicides and (c) suppress most weeds.

Some of the advantages of the clover:cereal bi-cropping system that are especially relevant to organic farms are

a) simultaneous cropping and fertility building rather than separate seasons for each
b) effective nutrient cycling
c) weeds replaced by clover; limitation of crop area requiring intensive weed control
d) confusion of insect pests and habitat for beneficial insects, spiders etc.
e) improved field access relative to bare soil

The work investigated the agronomic viability and sustainability of bi-cropping in organic farming systems as specified under UKROFS, for both silage and grain production. Experiments were carried out on three UKROF approved sites with contrasting soil types and environmental conditions. Randomised block, small-plot experiments evaluated the most satisfactory ways of modifying the IGER/IACR system for organic farming.

In work at two sites, North Wyke (Drewsteignton) and Long Ashton, an experiment was done in which the bi-cropped areas were established with the cereal drilled in a narrow row spacing (12.5cm) or a wide spacing (25 cm) , and either with clover present or not to investigate plant competition interactions. Plots established well but soon became very weedy.

The key to successful bi-cropping is weed control, which can be achieved easily in conventional systems. However in this work developing an organic system, the strategy of achieving good weed control via crop rotation was investigated at Long Ashton. Whole crop silage yields achieved were comparable with conventional systems initially as were grain yields, but subsequently grass weeds again became a major problem. However in a series of experiments at a third site (Fressingfield) a range of machines and strategies to deal with especially grass weeds were tested and show considerable promise. Strategies tested and developed included (a) rotovating strips within the clover understorey at different times of the year to suppress competition prior to drilling the cereal (b) a comparison of spring *vs* autumn sowing of the cereal, (c) varying seed rates of the cereal. A range of machines (steerage hoes, mechanical hoes and mowers) were also developed to reduce competition between cereal rows from weeds and clover. Strip-cropping with alternate bands of clover and cereals was also tested.

Switching to oats, instead of wheat, seemed to offer a way of suppressing weeds. The mechanisms for this are not understood but may relate to allelopathy, root scavenging for nutrients and shading effects.

The main point to emerge is that although the bi-crop system is well proven and developed for use in a non-organic system, grass weeds remain a problem in translating the system to organic farming as herbicides can not be used to control them. There are a number of strategies that emerged during the course of the present work that indicated ways in which the grass weed problem may be overcome in future. Firstly, oats seem to suppress grass weeds and growing this crop instead of wheat appeared to show considerable promise. Secondly strip drilling alternate 20 cm strips of cereal with 30 cm strips of clover allows separate management of the two crop components, facilitating weed control. The work confirmed that spring-sown cereals are not an option for bi-cropping as they are easily outcompeted by the clover.

An important positive feature of all of the trials was the consistent absence or low levels of diseases and pests despite high levels of airborne pathogen inoculum in the trial area. It is difficult to gauge the relative contributions of the organic system as a whole and the bi-crop system in particular to this feature. There are certainly important theoretical reasons as to why the bi-crop system should help in this direction, including the restriction on spread of splash-borne diseases because of the presence of clover around the cereal plants, green background confusion of insect pests and the probable lack of surplus soluble nitrogen in the cereal plants.

The more positive results in the absence of grass weeds were limited to a single year for cereals (and two seasons for vegetables in another related trial). However, in both cases, there were clear indications that, with a relatively small amount of fine tuning of the system, it should be possible to obtain highly acceptable results from both types of inter-cropping and, indeed, from rotational integration of the two. Further progress would certainly be worthwhile for the organic producer because it seems clear that a modest further adjustment of the competitive balance between crop and clover will lead to a clearer expression of all of the potential advantages of such systems, outlined above. Despite the difficulties encountered, progress was made and the list of advantages and potential advantages of bi-cropping for organic agriculture is so large and significant that further work should be done to capitalise on that completed to date.

Scientific Report

Introduction

There is a substantial need, for economic as well as environmental reasons, to reduce inputs of fertilizer, nitrogen and agrochemicals into arable cropping systems, especially cereals. IGER (North Wyke) and IACR (Long Ashton) have very successfully developed a clover:cereal bi-cropping system which enables crops of winter wheat to be grown with greatly reduced inputs of N fertilizer and markedly reduced levels of pesticides and energy. The clover:cereal bi-cropping system is now well developed for whole-crop silage production in conventionally managed farms. An extensive bibliography is given at the end of this report.

The approach has outstanding potential for organic farms in which the range of permissible fertilizers and agrochemicals is extremely limited. A list of advantages and disadvantages of inter-cropping clover with production crops was formed initially at the start of the project and elaborated somewhat in the light of experience during the project. It was hoped that the many important advantages of such systems would outweigh any disadvantages, as listed below:

Some advantages of cereal/clover bi-cropping:

f) simultaneous cropping and fertility building rather than separate seasons for each
g) effective nutrient cycling
h) protection against wind and water erosion
i) maintaining an open soil structure with increasing organic matter
j) increased water permeation
k) weeds replaced by clover; limitation of crop area requiring intensive weed control
l) stable habitat for deep burrowing earthworms and for mycorrhizae
m) confusion of insect pests and habitat for beneficial insects, spiders etc.
n) reduction of splash dispersed diseases and reduction of disease spread
o) bee habitat with potential for improved crop pollination
p) improved field access relative to bare soil

Some possible disadvantages:

a) possibly more management input required
b) competition by clover for space, light, water, nutrients
c) clover may be allelopathic against other species

The work investigated the agronomic viability and sustainability of bi-cropping in organic farming systems as specified under UKROFS, for both silage and grain production. Experiments were carried out on three UKROF approved sites with contrasting soil types and environmental conditions. Randomised block, small-plot experiments evaluated the most satisfactory ways of modifying the IGER/IACR system for organic farming.

The results will be used to enable the greater adoption of organic cereal growing, promise a very attractive option for growers and will be directly in line with DEFRAs policy focus of encouraging conversion to organic production.

Steering Committee meetings were held at intervals and a report of these is presented in Annex 3.

Materials and Methods
Small plot experiments were carried out at three sites on UKROF/Soil Association registered land - North Wyke (Drewsteignton), Long Ashton and EFRC Fressingfield (Wakelyns).

North Wyke (Drewsteignton)

<u>Experiment 1</u>
1999
An area of *c*. 0.5 ha of long-established pasture was ploughed in spring 1999 and a seed-bed prepared. Four replicates of each of five treatment plots (A-E : A, 12.5cm drill row, No clover "clean" ploughed; B, ", No clover "weed" (d.drilled); C, ", Clover bi-crop; D, 25 cm drill row, Clover bi-crop; E, ", Clover bi-crop + suppression of white clover), size 6 x 20m were marked out and white clover was sown into appropriate plots (treatments C-E) at a rate of 10kg seed/ha on 30 April1999. All plots were drilled with spring barley (131kg seed/ha) on the same day.

Yields of silage and grain were assessed during '99 using a Haldrup plot harvesting technique or a plot combine respectively. All plots were direct drilled with winter wheat on 29 October 1999.

2000
Plots of treatment E were harrowcombed on 13 April 2000. It was intended to apply slurry containing *c*. 60-80 kg N/ha to half of each plot in April/May but no organic slurry was available. Consequently Laws 9% N organic fertilizer was applied instead. Clover stolon length/m^2 and number of wheat shoots/m^2 were assessed on 2 May 2000. Whole-crop silage yield was assessed on 20 July 2000 on the fertilized and non-fertilized half of each plot using a Haldrup plot harvester technique.

The plot areas became heavily infested with grass weeds by early autumn 2000 and the whole area was ploughed and re-seeded with white clover cvs AberHerald, AberCrest, AberVantage, Denmark (equal contributions to the mix) at 10 kg seed/ha on 23 August.

2001
The local outbreaks of Foot and Mouth Disease stifled experimental progress throughout the 2001 season and the area was grazed by sheep. In autumn 2001 (17/10/01) half of the area was direct drilled with winter wheat cv. Shamrock at 160kg seed/ha and the other half with winter oats cv. Dunkeld at 160kg seed/ha, to test the ability of oats to suppress grass weeds as work at EFRC had indicated.

2002
Assessment of weed infestation, bare ground and crop cover was made on 29 January 2002 by determining the proportion of each in 10, 60 x 60 cm quadrats in the oat and wheat areas. Cereal tillers present in five adjacent pairs of 50 cm row lengths were also counted in the oat and wheat areas. Plots were inspected on 7 April 2002 and a visual assessment made.

Long Ashton
<u>Experiment 2</u>
Experiment 2, sited at Long Ashton had the same treatments A-E, number of replicates and general approach as Expt. 1 at North Wyke (Drewsteignton), the plots were established into ploughed and cultivated ground after a two year clover/ryegrass fertility building ley.

1999
All plots were sown on 26 March 1999 with spring barley cv. Chariot @ 112kg/ha (259 seeds/m^2), Trts. C-E were undersown with white clover (4 variety mix) @ 10kg/ha. On 13 July strips were cut in each plot using a Haldrup to determine whole crop silage yield. Grain yields were taken from each plot using a Claas Compact on 4 August. A mown 1m x 3m strip in each plot was weighed on 2 September to assess regrowth – the “bonus” production from the clover understorey (Trts. C-E).

2000
Trt. A plots were ploughed and cultivated prior to drilling all plots with winter wheat cv. Shamrock @ 235kg/ha (500 seeds/m^2) on 18 Oct 1999. Wheat plant populations were counted on 24 March 2000 and plots of treatment E were harrowcombed on 30 March. Available soil Nitrogen to 90cm depth was determined on 5 April and half of each plot received 50 kg/ha N of Laws 9%N organic fertilizer on 17 April. Whole crop silage yields were taken on 17 July and grain yield on 11 August 2000. The grain samples were significantly contaminated with ryegrass seed; the % contaminant in each treatment was assessed.

2001
Trt. A plots were ploughed on 20 September 2000, but the very wet weather precluded drilling until the New Year. Trt. A plots were cultivated to produce a seedbed and Trt.B (direct drill, no clover) plots were rotavated in an attempt to control the mat of weeds present; all plots were then drilled on 19 January 2001 with winter wheat cv. Shamrock @ 217kg/ha (432 seeds/m2). However, due to the prevailing wet weather, except for Trt. A all other plots failed to establish properly and a decision was made to resow Trts B-E with spring wheat. The clover in Trts C-E was topped and Trt. B power harrowed; spring wheat cv. Paragon was sown @ 155kg/ha (343 seeds/m^2) on 19 April.
All plots were again sampled for soil available N in March prior to applying 50 kg/ha N (Laws 9%N) to the relevant half plots on 26 April. The clover in the plots Trts C-E continued to grow vigorously and was out competing the establishing wheat, thus on 22 May the clover in these plots was topped above the height of the wheat in an attempt (mainly unsuccessful) to encourage competition from the wheat.

Whole crop silage yield assessments were done on 16 July and a botanical analysis of the forage from each treatment was carried out. There being no or very little wheat present in Trts C-E, only Trts A & B were combined for grain yield on 21 August 2001.

Experiment 3

This experiment (also at Long Ashton) is investigating the use of white clover:cereal bi-cropping as an alternative to using a red clover/ley to build fertility for organic arable cropping. Four rotations (treatments) were compared (please see Table 1 below), the different understories (Red clover in Trts (a) & (b) and white clover for treatments (c) & (d)) were established by undersowing spring barley. Each plot is 12m x 20m and there are four replicates. Provision is also made to split the plots in half to receive differing fertiliser regimes.

Table 1 Experimental treatments Experiment 3, Long Ashton

Rotation year	(a)	(b)	(c)	(d)
	Stockless arable	Typical arable	Replace ley/clover	Continuous bi-crop
1999	Spring barley + red clover	Spring barley + ley/red clover	Spring barley + white clover	Spring barley + white clover
2000	Red clover (mulched)	Ley/red clover (conserved)	Winter wheat + white clover	Winter wheat + white clover
2001	Red clover (mulched)	Ley/red clover (conserved)	Winter wheat + white clover	Winter oats, winter oats or triticale + white clover
2002	Winter wheat	Winter wheat	Winter wheat	Split plot of Winter wheat, Winter oats & Triticale + White clover
2003	Potatoes	Potatoes	Potatoes	Split plot of Winter wheat, Winter oats & Triticale + White clover

1999

The understories and spring barley cv. Chariot were sown on 27 March 1999 after ploughing in a grass/clover ley (established the previous autumn). Silage and grain yields were assessed during the 1999 season using a Haldrup plot harvester or plot combine respectively, on the same dates as Experiment 2. A quantitative assessment of the forage produced as an after cut was done on 22 September 1999.

2000

Treatments (a) & (b) (red clover) grew satisfactorily through the season and forage production was measured on 17 May and 27 June with a final cut (together with the after harvest cut on Trts.(c) & (d)) on 22 September 2000. After each cut the forage on Trt. (a) plots was removed whereas the forage on Trt. B was chopped with a flail mower and left on the plot as a mulch.
Treatments (c) & (d) (white clover understorey) were sown with winter wheat cv. Shamrock @ 235kg/ha (500 seeds/m^2) on 18 October 1999, Laws 9% N granular fertilizer was applied at 50kg N/ha to half of each plot on 5 May 2000. Whole crop silage yields were taken on 25 July from a strip in each plot of these two treatments, but grass weed infestation was becoming very serious causing all the wheat in these plots to lodge severely, thus making it impossible to combine the plots for grain yield.
Available soil N to 90cm was assessed on 5 April.

2001

Treatments (a) & (b) (red clover) again grew through the season, forage production was measured on 30 May and together with Trts (c) & (d) on 16 July 2001. Trt (a) & (b) were then ploughed and power harrowed on 6 August to produce a stable seedbed for a following crop of winter wheat.
The sowing of winter cereals in Treatments (c) & (d) was delayed by the continuous wet weather, but were finally sown on 20 January 2001, Trt. (c) to winter wheat and Trt. (d) to winter oats. However these crops failed to establish due to the continued wet weather and so the plots were flailed mown and Trt. (c) sown with spring wheat cv. Paragon @ 155kg/ha (343 seeds/m2) and Trt. (d) with spring oats cv. Banquo @ 158 kg/ha (396 seeds/m^2) on 19 April. The plots were then ring rolled and 50 kg/haN (Laws 9%N) was applied to the same half (as in 2000) of each plot on 26 April 2001. A strip from each plot (also on Trt. (a) & (b)) was cut for whole crop silage yield on 16 July and a botanical analysis was done on the forage. These spring sown crops were poor, although the oats did try to compete with the vigorous white clover and grass weed understorey. Consequently it was worthwhile combining the meagre yield from Trt. (d) only (spring oats) on 21 August 2001.

The plots were then mown (forage yield assessed on Trt (d)) on 23 August and Trt. (c) ploughed and ring rolled on 7 September.
Available soil N on all plots was sampled and measured during March 2001.

2002

The ploughed plots of Trts (a), (b) and (c) were cultivated and stale seed-bedded during the early autumn of 2001 and drilled to winter wheat cv. Shamrock @ 252 kg/ha (440 seeds/m^2) on 6 November. Trt (d) plots were topped and then longitudinally split into 3 and, in randomised design, the following cereal crops were sown in 4m width strips; winter wheat cv. Shamrock @ 252kg/ha (440 seeds/m^2), triticale cv. Fiddle @ 224kg/ha (393 seeds/m^2) & winter oats cv. Millennium @ 157kg/ha (391 seeds/m^2), enabling a comparison to be made of the weed suppressing effect of these three cereal species.

EFRC, Fressingfield Agroforestry (Wakelyns)

In practice, the practical application of the system under organic conditions required considerable attention to the competition aspect. Much time and energy was needed to develop a practical approach and, particularly, the range of machinery needed for field application. The machinery developed is listed in Appendix 1; photographs are available in the report on OF 0181.

Earlier results (1998/9) and experience showed first that grass/clover leys were unsuitable for cereal bi-cropping, mainly because of the intense competition from the grass component in the ley. Second, white clover itself can be highly competitive against cereals, more so than we had thought at the beginning of the project. Among the cereals, it was also clear that oats appeared more competitive than other species, with triticale better than wheat. There was also a need to further improve cultural and mechanical weed control both for weeds and clover.

With these considerations in mind, a series of six winter and spring trials was planned or set up for 2000-2001, as follows:

(i) *Main winter trial*: using the Wakelyns strip drill (20 cm cereal strips separated by 30 cm clover strips), two randomised block trials were laid down (25 October, 2000) one with a winter wheat mixture (cvs Hereward, Malacca, Shamrock as previously) and one with a winter oat mixture (cvs Solva, Kingfisher, Dunkeld, Millennium). Five treatments were applied to each trial: a) full rotavation of the whole bed before cereal planting, b) rotavating the cereal strips in the early spring, c) rotavating late spring (all followed by clover strip mowing), d) clover strip mowing alone, and c) a control with no treatment of the clover.

(ii) *Subsidiary winter trial*: a small four replicate trial was strip drilled on 24 October 2000 in a different field (North Field) in which an almost pure white clover ley had been established with few grass or other weeds. The same wheat and oat mixtures were used as in the main trial, together with cv. Trinidad triticale to compare the performance of this species. The plots were sown at two seed rates either low (80 kg/ha, equivalent to 200 kg/ha within the cereal strip) or high (200 kg/ha, equivalent to 500 kg/ha within the cereal strip). The only clover control applied was regular strip mowing during the growing season.

(iii) *Main spring trial*: a strip drill trial to compare spring wheat and spring oats was planned for the same field (Hazel field) as the main winter trial.

(iv) *Subsidiary spring trial a)*: a seed rate trial, using the same two rates as for the winter trial, was planted adjacent to the winter trial in North field. Three wheat and three oat varieties were planted as pure stands to compare varietal performance under the bi-cropping system. As with the winter trial, the only clover control applied was regular strip mowing during the growing season. There were two replicates (12 plots each) with 18 m plots.

(v) *Subsidiary spring trial b)*: a spring wheat trial was laid down in North field using the same two seed rates, low and high, applied to a mixture of cv. Axona, Imp and Paragon. Three clover treatments were applied at each seed rate, namely, whole bed rotavated prior to drilling the wheat, plots mowed regularly for clover control during the season, and a control with no treatment of the clover. There were four replicates using 11 m plots.

(vi) *Subsidiary spring trial c):* a spring oat trial was also laid down in North field as a mirror of the wheat trial (ii). The mixture used was cvs Amigo, Banquo and Melys, drilled on 18 m plots.

All spring trials were drilled on April 2, 2001. The winter trials were drilled on October 25, 2000.

1. Seed was supplied by Roger Wyartt Seeds or Organic Seed Producers either as organically-produced seed or as re-cleaned, untreated conventionally produced seed.

2. All plots were planted as 1.5 m wide beds as shown in Appendix 2 allowing 20 cm wide strips for the cereal and 30 cm wide strips for the permanent white clover. These are the same dimensions as used for vegetable inter-cropping trials (OF 0181) so that the systems are inter-changeable in terms of crop rotation. The drill used for the cereals is a specially adapted rotavator in which the blades cultivate only the cereal strips. Cereal seed, fed by gravity, falls into the rotavated strip under the arc made by the soil thrown up by the rotavator blades. This ensures both random distribution and even coverage of the seed as the tractor moves forward at constant speed.

3. **Clover treatments a) fully rotavated**. This means that shortly before drilling, the whole bed width was rotavated with a standard rotavator to severely damage the clover. This was intended to limit competition from the clover during the sensitive period of cereal germination and early establishment. Later, these plots were mowed to keep the clover down to 5 cm, as below.

4. **Clover treatments b) mowed.** Depending on the stage in the season, the clover was mowed at intervals to maintain growth at no more than about 5 cm. Mowing was effected by a front-mounted strip mower using 30 cm rotary mower blades mounted so as to cut the clover without disturbing the cereals. Vertical discs mounted behind the mower units cut clover stolons along the interface between the clover and cereal strips.

5. **Clover treatments c) control.** In the control plots, the clover was left untouched except for any damage caused at the time of rotavating and drilling the cereal strips.

6. All plots were checked for diseases and pests on several occasions during the growing season.

7. Head assessments: All plots were assessed in late July for the numbers of healthy grain-filled heads which were potentially harvestable. Scoring was based on a 0 – 15 scale from 0 (no heads) to 15 (sufficient heads for a spring crop yield of at least 5 – 6 t/ha). From scores up to 3 – 4, the value of harvesting would be questionable, at 7 – 8 the crop should provide a moderate yield and from 10 – 11 yield should be satisfactory.

8. Harvest: plots were harvested with a Wintersteiger plot combine into paper bags. Yield was weighed electronically and checked for moisture content. All yields were adjusted to 15% moisture.

9. From the data consistency and range, it was considered unnecessary to analyse the visual scores: main effects were large, obvious and consistent. Yield data were analysed by anova based on a randomised block design of the trial.

Results

Experiment 1 (North Wyke)

1999

The clover and barley established well in 1999 but yields of silage (t DM/ha) and for grain (y ± t/ha @15% mc) did not differ between treatments.

2000

Clover stolon length. There were no significant differences between treatments, (2 May 00), but the average stolon length of 5.22 m/m^2 is low compared to that present in a vigorous clover/ryegrass sward.

Wheat shoot counts. Nos of wheat shoots in bi-cropped areas were disappointingly low, (2 May 00) but were highest on the ploughed treatments.

Wheat whole-crop silage. Yields were lower on bi-cropped plots than for those that had been ploughed. The N application had no significant affect on yield. Weed invasion of bi-cropped areas was great, with only, on average, 20.4% of the harvested material being cereal - the remaining *c.* 80% was weeds. However, even on ploughed, non bi-crop areas almost 30% of the harvested material was weeds (see Table 2). Application of 50 kg N/ha of Laws fertilizer had had no effect on yield

No assessment for grain yield was taken as most of the plots were too badly infested with grass weeds, and all plots suffered badger damage post-silage harvest.

2001

No assessments were made during the 2001 season as staff were excluded from the site by foot and mouth disease restrictions.

Table 2 Results Summary for North Wyke (year 2000) Experiment No. 1 (NW 290)

Treatment			Clover stolon length m/m^2 2/5/00	Wheat shoot counts shoots/m^2 2/5/00	Whole crop silage, harvested 20/7/00					
					DMY t/ha	% DM	% contribution to DM			
							Wheat	Clover	Grass	BLW*
A	No clover "clean" ploughed	12.5cm drill row	-	581	10.14	45.0	71.8	-	27.8	0.4
B	No clover "weed" (d.drilled)	"	-	251	8.00	39.5	11.8	-	85.0	3.2
C	Clover bi-crop	"	3.77	202	9.22	41.2	22.1	1.5	74.5	1.8
D	Clover bi-crop	25 cm drill row	6.21	163	7.74	39.6	16.6	2.8	78.7	2.0
E	Clover bi-crop + suppression of white clover	"	5.68	196	7.56	37.8	22.7	4.6	69.8	3.0
	LSD 5%		NS	88.3	1.398	2.31	9.65	2.36	9.41	NS
* broad-leaved weeds										

2002

When assessed in January 2002, there were 52.4 oat seedlings/me of drill row and 21.0 wheat seedlings/m of drill row. The proportions of ground covered by clover, cereal and bare ground and weeds are given in table 3 below and show a trend for there to be fewer weeds and more clover in the oat areas. This trend appeared to be continuing when the plots were inspected in early April 02.

Table 3 Assessment of ground cover (%clover, cereal, bare ground and weeds) Drewsteignton 29th January 2002

	% clover	% cereal	% bare ground	% weeds
Oats	33.5	7.5	10.5	48.5
Wheat	16.0	4.5	11.5	68.0

Experiment 2 (Long Ashton)

1999

The clover and barley established well in 1999, but the experiment was infested with charlock (*Sinapis arvensis*) which was hand rogued. Yields of the whole crop silage (6.19 ± t DM/ha) and for grain (2.81 ± t/ha @15% mc) did not differ significantly between treatments, but second/after cut silage yields did differ with clover plots (treatments C, D and E) giving significantly higher yields 3.20 t DM/ha compared with 0.44 t DM/ha for treatments A & B.

2000

Cereal plant population - There had been satisfactory cereal establishment on all treatments; ploughing and narrow row drilling into clover gave highest % establishment.

Soil Mineral N – The results were in no explainable pattern, Trt. D/E was the lowest at 26.3kg/haN and Trt.C the highest at 69.2 kg/haN.

Wheat whole crop silage - Results were as expected, bi-crop yields were comparable with "conventional" treatment A, but weeds (low DM) appear to be constraining yield of treatment B.

Wheat grain yield - Yield was significantly depressed by weeds in B, and clover bi-crop C-E; harrowing in E seemed to do more damage (through wheeling) than good. Although the 1.4 t/ha bi-crop grain yield is not impressive, grain produced was worth £280/ha, and still benefited the build up of fertility. Plots were split for ± N application, applied as 50 kg N/ha Laws organic fertilizer but, as at North Wyke (Expt 1), the addition of this fertilizer had no effect on either silage or grain yield, perhaps because the application timing was too late in the season, for what is probably a slow release product (see Table 4).

Table 4 Results summary for Long Ashton (year 2000) Experiment 2 (00.611)

Treatment			Cereal plant population plants/m^2 24/3/00	Whole-crop silage yield t/ha DM 17/7/00		Grain yield† t/ha @ 15% 11/8/00		% DM ryegrass †† seed in harvested sample 11/8/00	
				0N	50 kg N/ha	0N	50 kg N/ha	0N	50 kg N/ha
A	No clover "clean" ploughed	12.5cm drill row	412	7.54	7.54	4.16	4.51	2.6	2.2
B	No clover "weed" (d.drilled)	"	344	6.66	6.66	0.61	0.62	9.5	1.2
C	Clover bi-crop	"	422	7.63	7.01	1.36	1.73	6.6	6.0
D	Clover bi-crop	25 cm drill row	318	7.36	6.61	1.49	1.39	6.2	6.1
E	Clover bi-crop + suppression of white clover	"	300	7.43	6.81	1.29	1.19	8.2	6.3
	S.e.d (16df)			1.52	1.52	0.415	0.415	1.7	1.7

† cleaned grain †† as a contaminant of wheat grain

2001

Soil Mineral Nitrogen – All treatments were very similar at c22 kg/haN and no differences showed between the + and – N half plots.

Whole crop silage yield – Yields of treatments A & B were poor, but treatments C, D and E were 12.9, 11.5 and 13.1 tDM/ha respectively, with no N input. Applications of N had no significant benefits on yield.

Botanical Analysis – There were only very small differences between 0N or +N half plots, therefore the results in Table 5 are given as a mean of the two figures. The results show the grass weed problem, ploughing and cultivation do reduce the problem, but the undisturbed clover understorey allows them to proliferate whilst smothering the broad-leaved weeds.

Grain Yield – Only Trts A & B produced any grain to harvest but yields were poor.

Table 5 Results summary for Long Ashton (year 2001) Experiment 2

Treatment				Whole-crop silage yield t/ha DM 16/7/01		Grain yield t/ha @ 15% 21/8/01		Botanical Analysis of silage samples as % dry matter			
				0N	+N	0N	+N	Wheat	Clover	BLW	Grass weed
A	No clover "clean" ploughed	12.5cm drill row		6.25	6.16	1.11	1.10	53.1	0	13.9	33.0
B	No clover "weed" (d.drilled)	"		9.57	10.06	0.81	0.96	44.6	0	1.4	54.0
C	Clover bi-crop	"		12.86	11.50	-	-	4.0	23.8	<1.0	71.2
D	Clover bi-crop	25 cm drill row		11.53	12.41	-	-	0.9	17.9	<1.0	80.2
E	Clover bi-crop + suppression of white clover	"		13.08	13.26	-	-	0	25.5	<1.0	73.5
	S.e.d (16df)			1.850	1.850						

Experiment 3 (Long Ashton)

1999

A spring barley crop has been grown in each rotation:
Whole crop silage – Yields were taken on 13 July and produced over 7 t/haDM
Grain Yield – The spring barley produced a yield of 2.5+ t/ha @ 15% mc, creditable considering that this field had had only 7 months of a fertility building ley before sowing the barley.
Post-harvest forage yield – Useful quantities of quality forage were produced.
With regard to forage the red clover (a & b) plots always yielded better than the white clover (c & d) plots (often statistically significantly) but with regard to grain the red clover plots produced less barley than the white clover ones (Table 6)

Table 6 Results summary for Experiment 3 Long Ashton 1999

Treatment	Whole crop Silage t/ha. DM	Grain Yield t/ha. @15%MC	After-cut Forage Yield t/ha. DM
a	7.95	2.50	4.41
b	7.66	2.51	4.23
c	7.08	2.90	2.64
d	7.21	2.86	3.01
LSD 5%	0.674	0.255	

All of the plots were vigorous and weed free

2000

Soil Mineral Nitrogen – In early April the red clover plots (Trts. a & b) had 153 kg/haN compared with 49kg/haN for the white clover plots (Trts c & d).
Forage yield - The red clover fertility building phase of rotations a & b produced c. 22 t/ha of dry matter from 3 cuts during the season, the white clover/wheat bi-crop c & d produced c. 8 t/ha from 2 cuts.
Grain yield of bi-crop - No grain yields of wheat (rotations 3 & 4) were taken, due to the wheat lodging and the high incidence of grass weeds. The grass weeds were not apparent until later in the season - too late for weed harrowing.
+50 kg N - No significant effect of N application on yield of the bi-crop rotations c & d.

2001

Soil Mineral Nitrogen – In March 2001 the available soil nitrogen was the same c.47kg/ha (+/-1.5) for all treatments; it is not readily apparent why treatments a & b did not show a higher level in comparison to c & d as they did in 2000. Although the preceding autumn and winter had very high rainfall, leaching does not really explain the lack of difference.
Whole crop silage yield – See table below, there were no significant differences between treatments and the addition of the extra N also had no effect (Table 7).
Botanical Analysis – The red clover plots (Trts a & b) were virtually a pure stand of clover, with only a minor infestation of grass weeds, a few docks could also be seen in the plots. The white clover plots (Trts c & d) had

allowed high levels of grass weeds to build up, the spring sown cereals were not really competing although the oats were much more abundant than the wheat. The applied extra nitrogen had no (if any) consistent effect on forage composition.

Grain Yield – No yields were taken from the sparse wheat plots (c) but a meagre yield of 0.33 t/ha was obtained from the spring oats, but this would not repay the cost of combining them.

Table 7 Results summary for Experiment 3, Long Ashton 2001

Treatment		Whole-crop silage yield t/ha DM 30/05/01		Whole-crop silage yield t/ha DM 16/7/01		Grain yield t/ha @ 15% 21/8/01		Botanical Analysis of silage samples as % dry matter 16/07/01			
				0N	+N			Wheat	Red Clover	White Clover	Grass weed
a			5.73	4.40	-	-		-	99	-	<1
b			5.47	4.48	-	-		-	99	-	<1
c				4.08	4.11	-		19.2	-	39.8	41.0
d				4.47	4.83	0.33		47.2*	-	22.7	30.1
	S.e.d (12df)			0.309							

*Oats

EFRC, Fressingfield Agroforestry (Wakelyns)

Results

1. The main winter and spring trials in Hazel field (nos. (i) and (iii) above) were abandoned in the late spring 2001 because of the accumulation of grass weeds. It was clear at this stage that strip mowing was inadequate and that harvest would be extremely difficult with the danger of further widespread distribution of grass seeds.

2. In North field, the subsidiary winter trial (trial (ii)) looked poor during the winter and early spring. To a large extent, this was due to grazing and seedling excavation by rooks in the late autumn. However, the crop revived during the late spring and was assessed for pests and diseases at intervals – none were recordable. During the summer (25 July 2001), the crop was assessed on a 0-15 scale for numbers of harvestable heads. The data are summarised in Table 8.

Table 8. Mean scores (0-15 scale) for potential numbers of harvestable heads in plots of mixtures of wheat varieties, oat varieties or Trinidad triticale sown as clover bi-crops at low (80 kg/ha) or high (200 kg/ha) seed rates (Fressingfield).

	low	high
wheat	1	1
triticale	1	1.4
oats	5.3	7.3

Values among the four replicates were consistently similar and show clearly that oats produced a far better crop than either wheat or triticale. Wheat and triticale were much more similar than expected. Although the low seed rate was only 40% of the high rate, the low seed rate plots produced about 75% of the numbers of grain-filled heads as the high seed rate plots.

Unfortunately, the short stature of the plants encouraged severe grazing by pheasants, particularly, before the potential harvest date. As a result, it was decided not to harvest the plots. However, it was clear that harvesting would have simply reinforced the results shown in Table 8.

3. In an adjacent area, the spring-sown seed rate trial also suffered from grazing, which mean that the plots could not be harvested. Again, checks for disease and pest development showed that the plants remained healthy throughout the growing season. Assessments of potential harvestable tillers are summarised in Table 9.

Table 9. Mean scores (0-10 scale) for potential numbers of harvestable heads in plots of wheat and oats sown at low (80 kg/ha) or high (200 kg/ha) seed rates (Fressingfield).

Wheat			
seed rate	Axona	Imp	Paragon
low	1	1	1.8
high	2	1.5	3
Oats			
seed rate	Amigo	Banquo	Melys
low	4.8	7	5.3
high	6	9	8.3

As in the winter seed rate trial, the oats overall grew much better than the wheat. Also, in terms of seed rate, the effect was similar with the overall mean of the low seed rate plots achieving about 70% of the head number of the high rate plots despite a reduction to 40% of the seed rate.

In this trial, there was a clear varietal effect. For both wheat and oats, the best performing varieties, respectively Paragon and Banquo, were the varieties that were expected to give the highest yield.

4. Subsidiary spring trial (iii) to compare different clover treatments on spring wheat, also at two seed rates, was partly harvested. Unfortunately, bad weather then stopped the harvest for two weeks, by which time the remaining plots were too badly affected for further data to be taken. However, the yields that were measured showed that the relative levels were of a similar magnitude to the assessments of potentially harvestable heads noted earlier in the season (25 July 2001).

Table 10. Estimates of harvestable heads and actual yields (t/ha) from plots of a wheat mixture, sown at low (80 kg/ha) or high (200 kg/ha) seed rates, that had been rotavated fully at drilling then mown regularly, or mown regularly without rotavation, or not treated.

	Seed Heads (est.)		**Yield (t/ha)**	
	Seed rate		Seed rate	
Treatment	Low	High	Low	High
None	1.25	2.25	0.15	0.21
Mowed	1	1.5	0.05	-
Rotavated	4.5	8.5	0.93	1.92

Although all yields were low, there was a large difference between the fully rotavated plots and the other two treatments. This was predicted from the visual assessments which also showed a much better performance from the fully rotavated plots. In contrast to the earlier seed rate trials, the low seed rate plots produced only about 50% of the yield of the high rate plots, showing only a small increase relative to that observed in the other trials. The mowed plots appeared to perform less well than the untreated controls.

Again there were no observable pests or diseases in any of the plots.

5. Subsidiary spring trial d. was set up in a similar way to the previous trial but using an oat mixture rather than wheat and 18 m rather than 11 m plots. The appearance of most of the oat plots during the growing season was excellent; in most cases there was a solid stand of tall, vigorous, dark green plants showing no pests or diseases. Bad weather severely delayed harvest, which, together with associated grazing, led to an estimated yield loss of more than 50%. The data are shown in Table 11; the standard error for the difference between treatment means for yield was 0.37, which illustrates the large positive effect of whole bed rotavation on yield. In fact, the non-rotavated plots yielded considerably less than anticipated from the appearance of the plots earlier in the season.

If a more timely harvest had been possible, yields from the fully rotavated plots would have been above average for organic spring oats. In this trial, average yields from the low seed rate plots were of the order of 80% of the high rate plots, showing a considerable compensation from the 40% of seed in the low rate plots.

The data for the two clover treatment trials with spring wheat and spring oats are averaged to compare main treatments together in Table 12. At least for the estimation of head numbers, this underlines the better performance of oats compared with wheat. It also underlines the greater ability of the oats to compensate for a low seed rate. These differences were reflected partly in the yield data. However, the limited correlation between head estimates and final yield was clearly due to extraneous effects (weather, grazing).

Table 11. Estimates of harvestable heads and actual yields (t/ha) from plots of an oat mixture, sown at low (80 kg/ha) or high (200 kg/ha) seed rates, that had been rotavated fully at drilling then mown regularly, or mown regularly without rotavation, or not treated.

	Heads (est.)		**Yield (t/ha)**	
	Seed rate		Seed rate	
Treatment	Low	High	Low	High
None	5.4	6.4	0.13	0.2
Mowed	6.1	8.3	0.3	0.59
Rotavated	13	14.3	1.61	1.91

Table 12. Comparisons of the effects of seed rate and clover treatment on the visual appearance and yields of mixtures of either spring wheat or spring oat varieties.

Means	Seed rate		Clover treatment		
Heads (est.)	low	high	control	mowed	rotavated
Wheat	2.3	4.1	1.8	1.3	6.5
Oats	8.2	9.6	5.9	7.2	13.6
Yield (t/ha)	low	high	control	mowed	rotavated
Wheat	0.38	(0.74)	0.18	(0.7)	1.43
Oats	0.68	0.9	0.17	0.45	1.76

Discussion

At North Wyke (Drewsteignton) all plots established well in the first year (1999). However, during 2000 because of the overwhelming invasion by grass weeds in the plots and the low incidence of clover it was decided that the trial area should be ploughed and clover re-established. Clover was sown on 24 August 00 at the original rate and using the same mixture as before. The clover re-established well, but grass weeds and some broad leaved weeds became a significant problem. The Steering Committee agreed that drilling a winter cereal without taking drastic action would result in a massive weed invasion and loss of the crop. Consequently the area was ploughed when conditions permitted and a fresh start made i.e. clover sown under a barley nurse crop in spring 2001. Unfortunately the local foot and mouth outbreak prevented any assessments being made at the site during 2001. Grass weed invasion was severe and the whole area was drilled with either oats or wheat in October 2001, to determine if the former had any weed-suppressing effect. Assessments made in January 2002 showed there was more oat plants than wheat present and there was apparently less weeds in the oat area, but grass weed growth was still significant. By April 02, the oats appeared to be growing well with fewer weeds than there were in the wheat areas.

At Long Ashton, after the initial establishment year, subsequent grain yields of the bi-crop in both experiments were disappointing and sometimes non-existent due to the rapid build up of competitive grass weeds. However, in Experiment 2 in 2000 the bicrop did yield c.1.4 t/ha of wheat worth £280/ha and still benefited the build up of fertility. Experiment 3 in 2001, when cereal crops were spring sown, suggests that oats may be a better competitive crop than wheat, but as previous work has shown we need well established autumn sown crops to keep ahead of the clover.
Taking the bi-crop (Trts. c & d) as whole crop silage worked well, producing good and reliable yields of what should be high quality silage. This system is likely to be sustainable as mowing and removing the crop before the grass weeds set seed each year would stop their build up as happens when the crop is left through the season for grain harvest.

At EFRC, Wakelyns, the change from Hazel field (severe grass weed problems) to North field (background of almost pure white clover) led to a major improvement in the growth and development of winter and spring cereals during the major part of the growing season. Nevertheless, the main treatment effects were similar, showing that it was possible to produce reasonable cereal crops only from the 'fully rotavated' treatment. Mowing alone was inadequate, which illustrated the strong competitive effect of the clover on the cereals. This interpretation was reinforced by the observation of a tendency for the wheat plots in which the clover had been mown, to yield less than the control, unmown plots, probably because clover recovery after mowing intensified the competitive effect. In the oat trial, where oats are clearly more competitive against the clover, the 'mown' plots outyielded the controls.

With the exception of one oat spring trial, yields even from the 'fully rotavated' treatment were modest, suggesting that the clover needs to be further restricted in order to obtain a suitable competitive balance. It is important to note here that the control of clover under the single full bed rotavation is only temporary. As the season progressed, the clover tended to recover across the whole bed, which meant that there were actively growing clover plants within the cereal strips, which presumably maximised the competitive effect of the clover, even on established cereal plants.

Other cereal trials have confirmed for many varieties, that modern wheat varieties in particular, having been bred under non-organic conditions with standard herbicide applications, have tended to lose any inherent ability to compete with weeds. The newly established DEFRA project AR0914 will investigate this problem by developing composite cross populations of wheat which will be selected under both organic and non-organic conditions.

The seed rate treatments in several trials showed that for oats at least, there is a potential for reducing the cereal seed rate which would help to reduce production costs. Even a modest reduction would be worthwhile because of the likely increase in cost of organic cereal seeds if the derogation for the use of non-organic seed is lifted at the end of 2003.

An important positive feature of all of the trials was the consistent absence or low levels of diseases and pests despite high levels of airborne pathogen inoculum in the trial area. It is difficult to gauge the relative contributions of the organic system as a whole and the bi-crop system in particular to this feature. There are certainly important theoretical reasons as to why the bi-crop system should help in this direction, including the restriction on spread of splash-borne diseases because of the presence of clover around the cereal plants, green background confusion of insect pests and the probable lack of surplus soluble nitrogen in the cereal plants.

Two important features of the mixture in the bi-crop trial were:

a) It was free from all diseases except for some infection by *Septoria tritici* (which experience shows does not develop further in bi-cropped wheat).
b) The 1000 grain weight was relatively high (46g) compared with that of the same mixture and its components in the EFRC trial (respectively, 36 and 35g).

Clearly, there is a problem with organic bi-cropping at the moment because of competition from the clover and, more particularly, grass weeds, against the cereal due to the difficulty of finding appropriate cultural or mechanical control of clover and weeds.
However, wheat yields generally under organic conditions tend to be considerably lower than those obtained under non-organic regimes. The yields of oats and triticale are relatively much higher. There are several possible explanations for this including differences in the ability to scavenge for soil nutrients, differences in disease resistance but more likely differences in weed competition: modern wheats are not competitive against other plants, whereas modern oats particularly, but also triticale varieties, are highly competitive. This raises the question as to whether the organic bi-crop approach would be better aimed at oats and triticale rather than wheat production.

Conclusions

Despite the long list of potential advantages of the clover cereal bi-crop system, and with the advantage of hindsight, the poor results from the first two years of trials at EFRC Wakelyns Agroforestry especially, showed that insufficient attention had been paid to the problem of competition from grass weeds in the system. This was similar to the initial problems experienced with the clover vegetable inter-cropping experiments (OF 0181).

Removal of the grass weed problem highlighted the strength of the pure clover competition. Measures are now in hand, in terms of increased early cultivation, to limit further the competitive effect of the clover on cereals and vegetables. In addition, it was clear from both projects that there are considerable differences among species of cereals and vegetables, and among varieties within those species, in their ability to survive competition with white clover.

The more positive results in the absence of grass weeds were limited to a single year for cereals (and two seasons for vegetables). However, in both cases, there were clear indications that, with a relatively small amount of fine tuning of the system, it should be possible to obtain highly acceptable results from both types of inter-cropping and, indeed, from rotational integration of the two. Further progress would certainly be worthwhile for the organic producer because it seems clear that a modest further adjustment of the competitive balance between crop and clover will lead to a clearer expression of all of the potential advantages of such systems, as outlined in the introduction.

The main points to emerge were that although the bi-crop system is well proven and developed for use in a non-organic system:

- Grass weeds, and to some extent broad leaved weeds, are a problem in translating the bi-crop system to organic farming as herbicides cannot be used to control them.
- It should be noted though that the grass problem at LARS was a carry over from the grass/clover ley sown to build fertility during the organic conversion period. In a stockless arable system, a pure clover sward is imperative; if the white clover/cereal bi-crop is used as the fertility building phase it should be taken as whole crop silage to counter the build up of grass weeds. The grass weed problem at North Wyke (Drewsteignton) was a carry-over from the previous crop (a long-term sward).
- Spring sown cereal bi-crops are not an option in organic systems as without chemicals to suppress the white clover during cereal crop establishment, the clover will easily out compete the cereal.
- Further work is required to develop other strategies to control especially grass weeds. These could include crop rotation, use of flame-gun, various mowing/defoliation strategies of bi-crop areas. However, probably more practical are:
    - Growing oats (or triticale) which forms a tall and dense canopy instead of winter wheat which allows more light to penetrate appears to suppress weeds better and is being tested currently at all three sites.
    - "Strip drilling" (alternate 20 cm strips of cereal and 30 cm strips of clover) instead of bi-cropping may be a way of suppressing weeds where herbicides can not be used.
- The competitive balance between cereals and clover also needs further investigation and there are at least three ways of improving this:-
    a) Increasing the number of cultivation passes prior to drilling, particularly in the cereal strips.
    b) This effect would be achieved automatically by bringing cereals into the vegetable inter-cropping rotation (OF 0181). A possible sequence would be potatoes, followed 4 – 5 years of the vegetable/clover inter-crop rotation, followed by 1 – 2 years of cereals planted into the same cropping strips as the vegetables, which would then be clover-free.
    c) Careful selection of species and varieties. Several trials showed consistently the better performance of oats compared with other cereal species, presumably because of the well-known competitive ability of oats against weeds and other crops. One trial also indicated that, within species, potentially higher yielding varieties tended to be better able to compete with clover than lower yielding varieties.

Other options involve reducing the amount of clover (which would also reduce the potential benefits of inter-cropping) or changing to another species. However, no other species appear to match the convenience and sustainability of white clover.

Scientific report (maximum 20 sides A4)

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APPENDIX 1

MACHINERY AND PROCESSES DEVELOPED FOR BI-CROPPING

Primary cultivation

a) strip rotavator: standard rotavator with square shaft modified to form 20 cm crop strips alternating with 30 cm not rotavated for the clover strips. The rotavator blades are of the speed blade type to minimise pan formation and are shielded by rubberised sheet skirts to retain the cultivated soil within the 20 cm crop strip.
b) rigid chisel tine cultivator with 3 narrow legs set at 50cm spacing so that each leg follows down the centre of each crop strip in a single bed. The unit is designed for relatively deep working, up to 20-30 cm so as to break up any pan caused by the rotavator.

Secondary cultivation

Tool bar equipped with flat discs that run along the clover/crop interfaces (3 pairs per bed). Sprung A-shears or other tines can then run between the discs with the moving soil kept within the crop strip.

Seeding

a) underground strip broadcaster fitted to strip rotavator. Seed is delivered to the ground within the protective skirts while rotavated soil is airborne. Each of the three crop strips is fed from a different hopper to allow planting of different species or varieties through individual metering units into each of the three crop strips The hopper unit can be replaced by an Ojyord header for plot trials.
b) the seed delivery tubes can be turned inwards into the spaces between the rotavated crop strips for broadcasting clover seed.

Mowing

The four-head rotary strip mower, hydraulically powered and mounted on the front of the tractor, has been developed specifically for mowing the clover strips while avoiding the crop strips. Two rotary blade sizes are available, 33 cm for a full cut and 30 cm for when crop plants are larger. The mower is also fitted with a hand control for allowing the clover mulch to be deposited either on the clover strips only or, mostly, on to the crop strips.

Vertical, flat discs are fitted on the machine behind the mower units. These have the action of cutting clover rhizomes that may be spreading into the cereal strips.

Irrigation

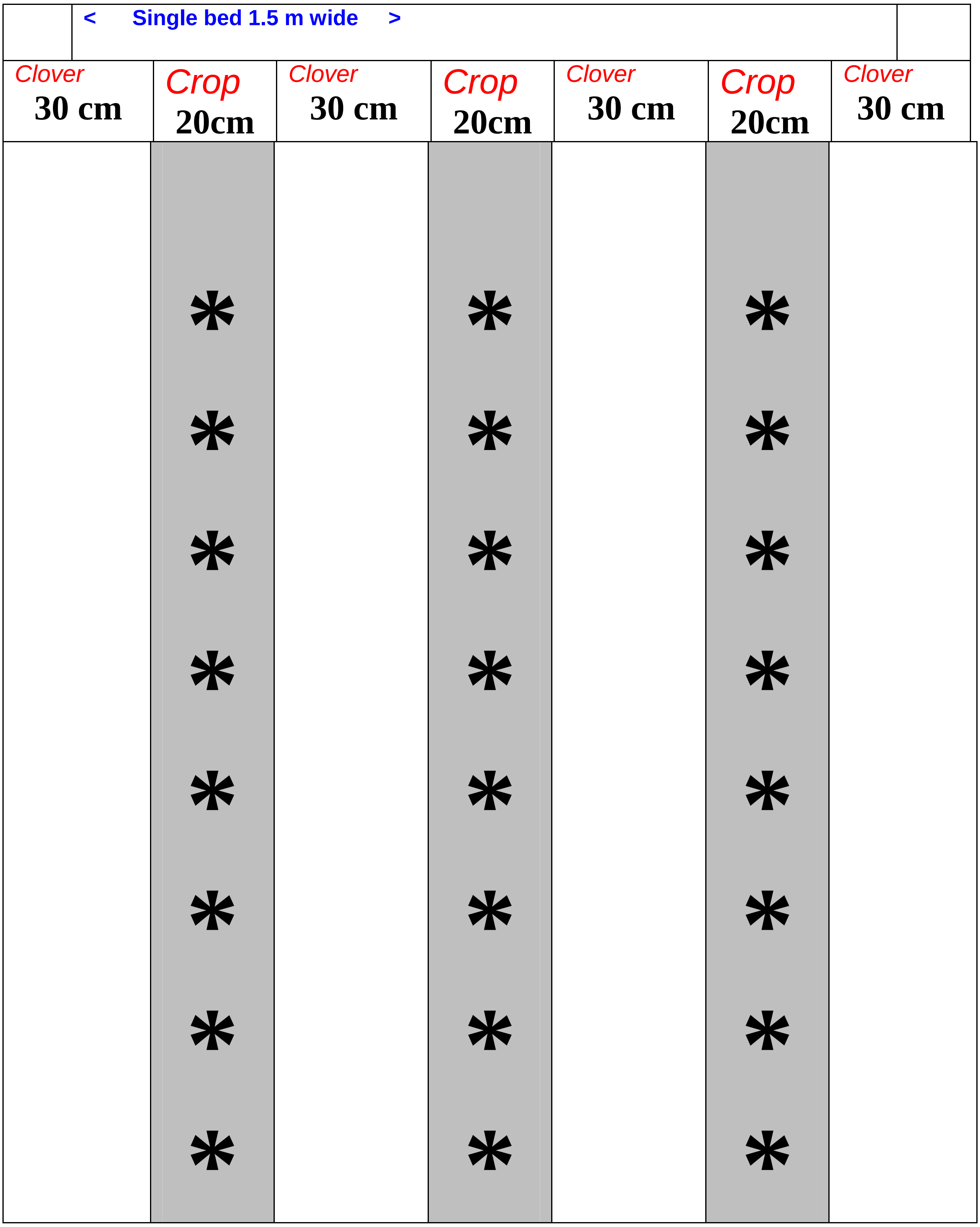
The simple irrigator consists of a water tank drawn behind a tractor. Water from the tank is fed into a manifold from which three downpipes are set at 50 cm centres. The pipe exits are about 10 cm above the soil surface. This system ensures that water is delivered directly to the crop rows only. The pressure of delivery ensures soil penetration. Rate of delivery is determined by tractor forward speed.

Composting

Compost/manure is delivered by a modified rear discharge manure spreader. The modification consists of a metal sheet cover which restricts the spread to the width of a bed. Two inverted V-shaped metal baffles held in the cover ensure that compost delivery can be further restricted to the crop strips only. This helps to direct competition in favour of the crop rather than the clover, to ensure that nitrogen fixation is maintained, and to provide economy of use of the compost/manure.

APPENDIX 2

Individual Bed Structure



APPENDIX 3

Notes on a Steering Committee Meeting, held at Long Ashton, 27th November 1998
OF 0173 Clover:cereal bi-cropping for organic farms

Present were:

R O Clements	(IGER, North Wyke)	G Donaldson	(IACR, Long Ashton)
T M Martyn	"	S Dixon	"
A Parkinson	"	V Jordan	"
M Wolfe	(Elm Farm Research Centre)	J Hughes	"
		M Fox	"

1. ROC thanked GD for making his room available and for his and SD's help with domestic arrangements. ROC said how pleased he was to have received written confirmation of the contract from MAFF before work starts in January 1999 on this three year contract. ROC has already sent a letter to GD and MW detailing how to claim their monies from IGER (essentially this was to claim £6 k quarterly). MAFF would be invited to attend subsequent meetings of the Steering Committee.
Action ROC
2. Establishment of trials.

2.1 Trials would be established at EFRC (Wakelyns Farm, Fressingfield), IACR, Long Ashton and on a UKROF registered farm near IGER, North Wyke. AP and TMM to confirm location of last mentioned site by 31 January 1999. ROC to agree rental terms by 15th February 1999.
Action AP & TMM
Action ROC
2.2 It was agreed to undersow an area of spring barley (compatible varieties to be suggested by MW) with a mixture of four varieties of white clover – AberCrest, AberHerald, AberVantage and Demand. Seed rates should be c. 125 – 150 kg/ha for the barley and c. 8 kg/ha for clover. . The barley area at the Wakelyns site would also be used for a variety mixture trial, incorporating the pure stand variety used in the other trials. ROC to obtain and distribute clover seed to ensure all trials use same seed date.
Action ROC
MW to obtain and distribute the barley seed.
Action MW
The barley should be drilled and the clover broadcast and rolled in on the same day, as soon as becomes feasible in spring – probably this would be in late March/early April. An area of c. 1.0 ha would be required.

2.3 At harvest half of the area of the barley crop would be removed for whole crop silage (done by contractor at Wakelyns if feasible) and the remaining half for grain. Subsequently the whole area would be managed to ensure that the clover understorey remained weed free and had a dense clover cover. Different options to achieve this would be appropriate at each site and include (a) frequent mowing and leaving a mulch, (b) cut and remove clover, (c) cut and bale clover, (d) graze-off with sheep. Experience had shown that option (c) was probably the most appropriate one as it would encourage slugs less than the other options.

3. Drilling and Management of First Wheat Crops
3.1 Cv. Hereward would be used at all the three sites unless cv. Shamrock becomes available in time. At the Wakelyns site, Hereward (and/or Shamrock) would be grown as a pure stand but also incorporated in a variety mixture layout (3 pure stands plus one mixture stand per replicate). MW to obtain seed from appropriate (recognised) source and distribute.
Action MW
The sites at Long Ashton and North Wyke would be drilled with a Moore drill (or similar). At Wakelyns, twin experiments would be done – one with a Moore drill and one with Wakelyns

specially developed drill. The clover suppression treatment (iii) and (iv) (see para 10 (a) of CSG 7 form) may be difficult to achieve on large areas drilled with the Moore drill, and would need to be hand hoed while machinery was developed. Alternative methods of manipulating clover:cereal ratios would be investigated i.e. drilling with a Moore drill at 6, 12 and 24 cm spacings.

3.2 Treatment (i) of the CSG 7 form was to be achieved by ploughing-in the clover. GD and VJ thought there was also a need to include a further treatment where the clover was destroyed, e.g. by harrowing, but not ploughed-in, to differentiate between the effect of ploughing plus killing the clover on soil N cycling v. killing clover without soil inversion.

4 Assessments

4.1 Silage dry matter yield, components of yield and silage quality (to include D value, (NCGD), % CF, % Ash, total N, and starch) at harvest time and on all plots and of the initial 1999 barley "nurse" crop.

4.2 Grain dry matter yield, grain quality and % N , % starch at harvest time of all plots and of the initial 1999 barley nurse crop. Also assess dry matter yield of all removals/mulches whenever the clover is mown. Grain quality (i) nutritional: % starch, % N; (ii) qualitative: Hagberg falling number, SDS sedimentation, milling hardness, TGW, hectolitre, (specific wt), sieving fractions.

4.3 Emergence. Count number of seedlings in 50 cm adjacent row at full emergence when plants have two leaves i.e. before tillering

4.4 Diseases. All diseases to be assessed at flag leaf emergence GS39 and top three leaves and stem. Ditto at GS75, use standard protocols to be supplied by GD and VJ.

Action GD and VJ

4.5 Pest Observation and record BYDV at GS40 (as an indicator of aphid damage)

4.6 Weeds Use quadrats and make counts in three categories (none, few, large numbers) of each weed species, in each plot in November, March/April and summer. Use standard protocols.

Action GD & VJ

4.7 Other Record any other relevant details.

4.8 Earthworms Assess earthworm population in spring each year. ROC to advise on technique.

Action ROC

4.9 Soil Obtain soil series identification/description for each site. Also NPK and organic matter status at outset (say March 1999) and at end of work.

5 Fertilizer

Apply slurry (if available) at 50 kg N/ha to whole-crop area only each spring. Apply Maxi-crop at flag-leaf emergence (controls aphids as well as adding plant nutrient).

6. Other points

6.1 Comparison with other organic systems. GD, MW & TMM to consider in detail the need for and how best to compare (i) barley nurse crop followed by bi-cropping as above (ii) bi-cropping with relevant component of seven year cycle and interactions with fertility building phase of existing organic systems., (iii) exploit bi-cropping for continuous cereal production, perhaps by alternating wheat with oats.

Action GD, MW, ROC and TMM

6.2 Plot size, layout. Number of replicates probably needs increasing to five, so that reps x treatments is 20 or more. Need to consider plot size to accommodate harvesting machinery. Need to draft outline of experimental layout for work beginning in Autumn 99. ROC to do a first draft and circulate it by 18th January 99 as a "cock-shy" for comment. Mark Measures (EFRC) to be consulted.

Action ROC

Distribution

Attendees of meeting (9)
Peter Costigan (MAFF)
Mark Measures (EFRC)
Roger Wilkins (IGER)

(Note that slurry has to be aerated before use and any FYM from non-organic sources should be composted for 3-6 months and SA Cert agreement)

Notes on a Co-ordination Visit to Prof Martin Wolfe, at Elm Farm Research Centre's outstation at Wakelyns Farm, Fressingfield, Suffolk (March 1999)

OF 0173 Clover:cereal bi-cropping for organic farms

Introduction

I was keen to visit Wakelyns Farm, before the start of the growing season to discuss some points of detail with Professor Martin Wolfe before the experiments were laid out. We both felt this to be important as MW was not able to attend the Steering Committee meeting on 9th March.

MW introduced me to his two field operators (Paul and Mark).

We discussed a number of points.

1. Invoicing

MW had invoiced IGER for Elm Farm's sub-contract and they had received this money. I reiterated to MW that Elm Farm should invoice IGER quarterly.

2. Clover growth in E. Anglia

A concern that several cereal farmers had expressed regarding clover:cereal bi-cropping was that white clover would not survive in the cereal growing region of East Anglia as it is too dry. MW dismissed this as nonsense, and as I was to see for myself later, white clover positively thrives at Fressingfield and had done so even during the drought year of 1992.

3. Approaches

MW and I agreed that there would be several advantages in not necessarily doing identical experiments at each site, but to accept that there are site differences environmentally and also differences in local traditions and practice. This could mean that some experimental treatments would be adapted and may differ between sites, but that all experiments would still be focussed on the common goal of developing and applying the bi-cropping approach.

Two examples of treatment differences would be to not apply slurry* at Wakelyns since it is a stockless farm and to not take a silage cut for the same reason.

4. Assessment of growth yield

Cereal grain yields would be assessed at Wakelyns using their own plot combine harvester.

5. Experiment 1:

MW's 6 main experimental treatments would be:

(i) weed bi-crop; narrow Moore drill row spacing
(ii) weed bi-crop; wide " " " "
(iii) weed bi-crop; Wakelyns rotavator drill, spacings 20 cm for wheat strips, 30 cm for non-clover strips
(iv) clover bi-crop; narrow Moore drill row spacing
(v) clover bi-crop; wide " " " "
(vi) clover bi-crop; Wakelyns rotovator drill, spacings 20 cm for wheat strips, 30 cm for clover strips

These six planting systems would have the clover (or weed) inter-crop suppressed early or late, giving a total of 12 treatments. These would be fitted into six replicates of 50 x 1.5 m plots on four of Wakelyns between-trees cropping alleys.

6. Experiment 2

At Wakelyns, MW would use a single stockless rotation with five or six courses and run this on a bed system between alleys of trees. This means that, from the first season, different beds could carry different phases of the rotation. At the end of the season, each bed would move on to the next stage of the same rotation. The advantage of this approach is that all phases of the rotation are exposed in each season which makes treatment comparisons more numerous and effective. The single rotation would be modified in two different ways:

a) in one form, the rotation would include, for example, one year of red clover as the fertility-building phase, but no inter-cropping.

"Standard" stockless rotation

Red clover — Potatoes or Row crops — w. wheat – spring beans – spring cereal + clover

b) in the second form, the red clover phase of the rotation would be omitted. Instead, white clover inter-cropping would be used as far as possible.

Novel, bi-crop system (with white clover bi-crop)

White clover + w. wheat – spring beans – spring cereal - row crop

This system would have the great advantage of omitting the first "fertility building" part of the rotation and enable high value crops to be grown in year 1.

c) Experiment 2 at Wakelyns will link closely with a companion cropping project (OF 0181) using a field-cropping rotation to compare nil, vetch or white clover as the inter-crop. This trial will already include spring wheat and spring oats as two phases of a 7-course veg. rotation with no fertility-building phase. This second project is being carried out in field space adjacent to the OF 0173 plots.

7. Other work

We discussed other work at Wakelyns e.g. that relating to growing potatoes as a mixture of varieties and different distances between crops (filled-in with clover) to try and prevent attacks by blight arising - or spreading. We also discussed work with wheat and lupins.

8. Tour

MW took me on a tour of the machinery development area and we saw the "Lancaster Bomber" multi-mower – a series of four 30 cm rotary mowers mounted on a frame to mow-off between rows of crops and also the Wakelyns rotovator drill and a variable seed-drill for sowing rows of different combinations of crops.

We also saw the willow coppice alley crop and other tree alley crop areas. Finally I saw the spring barley being sown for Experiment 1.

9. Hospitality

It was a fascinating day with a lot of innovative schemes and machinery development underway. Also I was given excellent hospitality for which I thank MW and his wife Anne. A very worthwhile trip.

R O Clements
16th March 1999

Distribution:

G Donaldson
T Martyn
R Unwin
R J Wilkins
P A Costigan

Notes on a Steering Committee Meeting, held at Long Ashton, 9th March 1999
OF 0173 Clover:cereal bi-cropping for organic farms

Present were:

R O Clements(IGER, North Wyke)
T M Martyn "
G Donaldson (IACR, Long Ashton)
S Dixon "
J Hughes "
R Unwin (FRCA)
Apologies for absence were received from M Wolfe

1. ROC welcomed RU as the MAFF representative to the meeting.

2. Establishment of trials.

The trials work would be progressed rather more quickly than the milestones laid down in the CSG 7 form.

2.1 Site 01 (North Wyke) ROC reported that TMM had located a site near Drewsteignton (c. 8 miles from North Wyke) and an agreement regarding rental of the site, cultivation, fencing etc had been reached with the site owner (Mr Martin) and his manager (Mr Edwards). Mr Martin and Mr Edwards were both interested in the proposed work. The farm has had UKROFs registration/approval for 8 years and is currently and had been under permanent pasture for at least 8 years. The site is level and has good access

Site 02 (Long Ashton) Two fields are currently under a conversion licence of the Soil Association, they are both in grass/clover rich leys, the field in which Experiment 1 will be carried is it its 2nd year and will gain Organic status on 1/9/99; the other field is one year behind, it will site Experiment 2 this spring, the fertility building phase for all treatments will thus start at the same (low) level.

Site 03 (Wakelyns) was not discussed in detail.

3. Drilling and Management of First Wheat Crops

Experiment 1 – North Wyke and Long Ashton. The treatments for Expt 1 are detailed in Annex A (GD's note of 10/12/98). There was discussion about row-spacing for Treatment B, but it was

decided to keep this to 12.5 cm (could be widened, by hoeing, to 25 cm subsequently if weed-control became a problem). It was decided that slurry would not be applied to the S/barley crop in year 1 (1999), but in future years + or – slurry should become a sub-treatment of each main treatment. (It will be particularly important for arable silage to replace P & K offtake). To accommodate this extra treatment, plot length will be increased to at least 20 m. Date of sowing of the autumn crop could be critical if avoiding weed problems.
Experiment 2 (not covered by CCG 7 form) – Long Ashton only. A longer fertility building period would be needed for the Stockless Arable rotation, especially since the area selected for the work had not had a lengthy fertility building treatment/history already. Suggested that treatment 1 (Stockless Arable) would be the same as treatment 2 (Typical Arable) for the first two years at least, except that treatment 1 would be mulched and treatment 2 conserved. May even be better to leave treatments 1 & 2 this year and wait until end of LARS conversion period (2001) before proceeding. Guidance needed.

Action GD

Once this experiment was underway, the Steering Committee may seek further funding for its continuation in 2-3 years time.

4. ROC would discuss today's meeting with MW.
Action ROC

5. Suggested date of next meeting Tuesday 8th June, at Wakelyns.

Distribution

Attendees of meeting (6)
Martin Wolfe (EFRC)
Peter Costigan (MAFF)
Mark Measures (EFRC)
Roger Wilkins (IGER)
Vic Jordan (LARS)

Notes on a Co-ordination Visit to Terrington EHF and Wakelyns Farm, Fressingfield, 7th & 8Th June, 1999
OF 0173 Clover:cereal bi-cropping for organic farms

7th June at Terrington EHF
Introduction

The scientists involved in the above project were, very kindly, invited to join the Terrington EHF Steering Committee on their field tour of stockless organic systems at Terrington in the afternoon of 7th June. We met some members of the Steering Committee (Roger Unwin, Martin Wolfe, Bill Cormack, John Elliott, Bill Darling, Richard Thompson and David Leach) and I outlined the clover:cereal bi-cropping sytem to them and the work that we have in hand within OF 0173 and other related studies.

Tour of plots

We then toured the experimental areas and saw areas of cereal and clover, cereals and vetch, brassica crops (calabrese), potatoes and onions being grown organically. All were impressively weed, disease and pest free, although there may be a burgeoning thistle problem in some areas that would require swift attention if it is not to increase rapidly.

I was concerned that the clover component of the undersown clover/barley crop was poorly developed, but other members of the party gave me re-assurance that it would almost certainly begin to flourish soon.

8th June at Wakelyns Farm, Fressingfield
Tour of plots etc.

Martin Wolfe led the tour. We viewed the clover:cereal plots of OF 0173. A mixture of four varieties of white clover (the same as used in the work at LARS and IGER, cvs. Demand, AberHerald, AberCrest, AberVantage) had been undersown to barley (cvs Chariot and Optic), sown both together in a mixture and separately, in mid March. All of the barley crops looked even, vigorous and weed-free and were beginning to head. I was again concerned that the clover understorey was thin and patchy but was given re-assurance that it would soon develop and become vigorous. Perhaps the clover at Wakelyns and Terrington had been sown too early?

We were then shown some of the other work at Wakelyns including (a) a companion cropping project which includes bi-cropped cereal as part of a 7 course vegetable rotation, each element being 1.5 m wide within an overall 12 m band or alley, (b) wheat/lupin mixture bi-cropped with vetch or white clover, (c) potatoes grown in a variety of mixtures and at different spacings to frustrate blight, (d) wheat pure stands and variety mixtures bi-cropped with vetch or white clover. The experiments were all clearly developing very successfully, although in the wheat/lupin bi-crop, the lupins had not grown well, probably because weather conditions had prevented them being sown early enough last autumn.

Martin Wolfe re-iterated a point he has made several times before that there is a desperate need to mechanise weeding and other operations in the novel crop systems he and EFRC are developing, and that existing equipment is often inadequate. He has therefore devised and developed a range of prototype machines to carry out a range of tasks. Four in particular are: (i) a rotary mower that mows off and mulches four strips each 30 cm wide between rows of crops, (ii) a steerage disc machine that cultivates between rows, (iii) a rotavator for cultivating and seed sowing, similar in principle to the Hunter Rotaseeder and (iv) a precision drill for sowing alternative/individual rows of companion crops. All are very interesting and clearly work effectively albeit on the small scale.

Discussion session

Following our tour we had a brief round-table discussion session.

1. I reported that the trial at North Wyke (Drewsteignton) and especially the clover was developing well, despite prevailing weather conditions preventing us sowing the plots as early as we would have liked.
2. No problems were reported from Long Ashton.
3. Assessments - I reminded those present of the need to make an assessment of whole-crop silage by cutting at least one 60 x 60 cm quadrat per plot at the 'soft dough' stage. MW and GD would send material dried at 85^0C from each quadrat to ROC for quality analyses (protein and D value). Grain yield assessment would be done at the appropriate time. Earthworm numbers and biomass would be determined when the winter cereal is drilled (Sept/October) by taking one spade-spit sample per plot and wet sieving it. ROC suggested MW and DC purchase a 45 cm diameter 0.85 mm mesh sieve.*

   Action ROC, GD & MW
4. MW said he would advise us on choice of winter wheat variety and/or mixture for drilling in the autumn.

   Action MW
5. We agreed to hold our next meeting on Thursday 28th October, starting at Long Ashton at 09.30 and would also visit North Wyke that day.

R O Clements
North Wyke, 16th June 1999

Distribution

G Donaldson
T Martyn

M Wolfe
R Unwin
R J Wilkins
P A Costigan

Notes on a Steering Committee Meeting, held at Long Ashton and North Wyke 28th October 1999
OF 0173 Clover:cereal bi-cropping for organic farms

Present were:

R O Clements(IGER, North Wyke)
T M Martyn "
G Donaldson (IACR, Long Ashton)
S Dixon "
R Unwin (FRCA)
M Wolfe (Elm Farm/Wakelyns)

1. The major purposes of this meeting were to visit the experimental plots at Long Ashton and North Wyke (Drewsteignton) and to discuss results to date and the programme for next year.
2. Long Ashton site visit.
   The Committee met at Long Ashton and we viewed the plots there.
   (i) The first experiment that we visited (LARS no. 99.612) is investigating the use of white clover: cereal bi-cropping as an alternative to using a red clover/ley to build fertility for organic arable cropping. There are four rotations (stockless arable, typical arable, replace ley/clover with continuous bi-crop). A spring barley crop had been grown in each rotation and grain yield with either continuous wheat or alternatively crops of wheat and oats (4 Aug 99) averaged a creditable 2.69 t/ha @ 15%mc across all four treatments; there were no significant differences between treatments. Dry matter yields of forage at a cut taken on 2nd September had averaged 3.57 t DM/ha. All of the plots appeared vigorous and weed free. Those that were to be bi-cropped had been direct drilled with winter wheat the day before our visit.
   (ii) We then visited a second experiment (LARS no. 00.611) investigating a range of white clover:cereal bi-crop treatments and a number of strategies for growing bi-crops with wide and narrow cereal row spacings, ± weeds and ± clover suppression. Treatments and results to date are as below:

Treatment	**Establishment of crop (harvest year)**			**Silage yield 13.7.99 t/ha DM**	**Grain yield 4.8.99 t/ha 15%**	**After cut silage 2.9.99 t/ha DM**
	Sp. Barley 1999	W.Wheat 2000	W.Wheat 2001			
A No clover "clean"	Plough	Plough	Plough	5.10	2.6	0.47
B No clover "weed" bi-crop	Plough	direct drill	direct drill	5.88	3.2	0.40
C Clover bi-crop 12.5cm rows	Plough	direct drill	direct drill	6.62	2.7	2.82
D Clover bi-crop 25cm rows	Plough	direct drill	direct drill	6.65	3.1	3.58
E Clover bi-crop 25cm rows + suppression of clover in April	Plough	direct drill	direct drill	6.72	2.5	3.20
			LSD (5%)	1.402	0.94	N/A

Yield differences for grain and first silage cut did not differ significantly between treatments, but after cut forage yields did differ - those with clover (CDE) giving significantly higher yields. We then visited experiments relating to maize:clover understorey work which are not part of this Committees responsibility, but were of considerable interest to us.

As ever, all of the plots and experiments at Long Ashton appear well managed and cared for.

3. North Wyke (Drewsteignton) site visit
The Committee left Long Ashton and met up again at the North Wyke (Drewsteignton) site where there is only one experiment - the same as described at (ii) above.

Treatment	**Establishment of crop (harvest year)**			**Whole crop silage (t/ha DM)** (29/7/99)	**Grain yield (t/ha 15%)** (1/9/99)
	Sp. Barley 1999	W.Wheat 2000	W.Wheat 2001		
A No clover "clean"	Plough	Plough	Plough	5.3	2.58 (A and B)
B No clover "weed" bi-crop	Plough	direct drill	direct drill	5.5	
C Clover bi-crop 12.5cm rows	Plough	direct drill	direct drill	5.6	
D Clover bi-crop 25cm rows	Plough	direct drill	direct drill	6.1	2.49 (C, D and E)
E Clover bi-crop 25cm rows + suppression of clover in April	Plough	direct drill	direct drill	5.6	

Plots at Drewsteington were due to be 'topped' and drilled a day or two after our visit. The experiment looked well managed, but there was clearly already a grass weed (Agrostis) problem building-up in some plots.

4. Report of Wakelyns experiment
The Committee went via some other related work on arable undersowing and maize:clover understorey experiments at North Wyke to a round table discussion. MW reported progress at Wakelyns.

There are effectively two experiments at Wakelyns, although the randomised layout should allow comparison between the two:

(i) Wakelyns drill experiment:
5 clover treatments x 2 varieties (mixture vs pure) x 4 reps = 40 plots
The pure variety plots are sown with each of the three varieties planted randomly among the three cropping strips (Hereward, Shamrock and Malacca). This combination of varieties and the mixture are also being grown in a variety trial on the same farm.

(ii) Direct drill experiment:
5 clover treatments x 4 reps = 20 plots
The mixture of Hereward, Shamrock and Malacca is used throughout. Each plot is divided into two sub-plots which will be used to generate more accurate yield estimates at harvest. The bed layout is achieved by blocking off appropriate coulters.

MW reported that the experiments at Wakelyns had all established well.

5. Discussion session and Conclusions
All of the plots and experiments were well established and 'on course'. We discussed the strategy that we should adopt regarding slurry application (50-60 N available N/ha) next year. GD and ROC would arrange to discuss this further with Dr Brian Pain at North Wyke.

Action: ROC and GD

We thanked MW for supplying cereal seed for autumn 1999 sowings.

We agreed to meet next at Wakelyns, probably in June 2000, but ROC would call in when in the area, probably early spring 2000.

Action: ROC

ROC said he would find a 'volunteer' to sample earthworms at all sites in spring 2000.

Action : ROC

R O Clements
15.11.99

Distribution

R O Clements(IGER, North Wyke)
T M Martyn "
G Donaldson (IACR, Long Ashton)
S Dixon "
R Unwin (FRCA)
M Wolfe (Elm Farm/Wakelyns)
R J Wilkins (North Wyke)
P A Costigan (MAFF, London)

Notes on a pre-meeting visit to Terrington EHF, 8th June 2000 and Steering Committee Meeting, held at Wakelyn's Farm, Fressingfield, 9th June 2000

OF 0173 Clover:cereal bi-cropping for organic farms
8th June Terrington EHF

Introduction

Dr Bill Cormack the senior scientist in charge of the organic farming research work at Terrington, was kind enough to take Guy Donaldson, Sheila Dixon and myself on a tour of relevant work. This also gave us an opportunity to discuss points of particular relevance to the clover:cereal bi-cropping work.

Tour and discussion

One of the areas we discussed was the need to obtain and apply N for the clover:cereal bi-cropping work - an input of *c*. 60 kg N/ha is needed in spring, to both boost N levels and to suppress the clover. This was initially done at LARS by the application of slurry, but organic slurry was difficult to obtain and transport. The slurry applied at LARS also, on analysis proved to have a low N content and was more akin to dirty water than slurry. At North Wyke (Drewsteignton) and subsequently at LARS, we have used Lawes N fertilizer for organic farming, (kindly obtained by GD). A better solution suggested by WC may be to use organic poultry manure of which there is a large excess in the UK. WC commented that under "organic rules" it is permissible to apply up to 170 kg N/ha each year.

The first experimental area we viewed was barley undersown with white clover. The clover had been drilled in successfully a month after the barley was sown and was growing satisfactorily. There had however been no opportunity for weed control and a few thistles had appeared which would need hand roguing (a standard practice over a large area at Terrington, where creeping thistle is an endemic and increasing problem).

An experiment to investigate the possibility of controlling thistles in a white clover crop by using different cutting frequencies was in hand.

Slugs were also a problem in some areas at Terrington, for which there seemed no easy solution. A calabrese crop would probably be prone to bird damage and to a range of insect pests. The crop had been covered by a mesh to prevent these pests from alighting, but was costly (£1000/ha per year) and only a high value crop such as calabrese could justify this level of expenditure.

A potato variety with good pest and disease resistance (cv. Santé) was being grown, but this variety has an undistinguished flavour and is not universally liked.

A large area (*c*. 1.5 ha) of winter wheat cv. Hereward was being grown and despite a few small patches of irregular height looked very good. There were some creeping thistles, but these were being hand-rogued. Growing the crop in wider rows (say 25 v 12.5 cm) would assist greatly with the hand-roguing operation and was being considered for future years.

Steering Committee Meeting, Wakelyns 9th June 2000

Present Bob Clements (IGER, North Wyke)
Guy Donaldson (IACR, Long Ashton)
Sheila Dixon (" ")
Martin Wolfe (EFRC, Wakelyns)
Roger Unwin (FRCA)

The Group was also joined by Bill Cormack (Terrington EHF) who was kind enough to give up his morning to be with us.

1. Report from North Wyke

Bob Clements reported that direct-drilled plots in the trial at North Wyke (Drewsteignton) had become weedy - as hinted at during our previous meeting. The major problem was with grass weeds- no doubt a legacy of the previous crop which was an old permanent pasture. Attempts to remove the weeds using a Parmiter harrow comb hoe in March had not been successful as the weeds were then well established. Probably it would be feasible to take a silage cut at the soft dough stage (early July?) but cereal grain yields would be low. The ploughed areas (cf. direct drilled) stood-out as being substantially more weed free.

2. Report from Long Ashton

Guy Donaldson said that the twin trial of the "North Wyke" experiment alluded to above was also becoming weedy in the no clover, direct drilling plot. The rotational experiment at LARS had been apparently weed free up until March but there were some grass weeds appearing now.

3. Tour of Experiments at Wakelyns

(i) Martin Wolfe took us on a tour of experiments at Wakelyns, beginning with those relating to OF 0173. In the first set of experiments that we viewed, the plots had been planted with the Wakelyns strip drill, allowing the clover:cereal bi-crop to be hoed (Rollstar) at different stages of crop development. Plots hoed in the autumn were largely weed free compared with those hoed later. 'Control' plots, which had not been hoed were extremely weedy, with relatively few crop plants present. In the treatment where inter-row areas were being mown, there were relatively high weed populations. Clover populations in the autumn-hoed plots were low, but may be sufficient to regenerate in the autumn. In the other hoed plots, clover populations were high, mainly from plants that had survived within the cereal strips. In the mowed plots, the high clover population was distributed across the whole plot. In the control plots, grass weeds were competing successfully against the clover.

In the second set of treatments, sown with the Moore's Unidrill directly into the clover sward, grass weed competition was severe in all treatments because of the difficulty of applying any form of mechanical weed control to the closely-spaced rows. The overall weed levels were clearly higher than in the first set of plots sown with the Wakelyns drill.

Interestingly the wheat plants in all treatments were disease free. For this reason it was not possible to see any difference between plots planted with separate single rows of the three varieties (Hereward, Malacca, Shamrock) and those sown with a mixture.

Generally, across several treatments and both experiments, weed levels were so high that even attempting a silage cut would be of dubious value, particularly in the direct-drilled plots. The Committee agreed that the most sensible way forward would be to mulch the direct-drilled treatments, plough and make a fresh start. However, the plots planted with the Wakelyns strip drill were in significantly better condition and could be retained for grain harvest. Martin suggested, on the basis of other work in progress that oats should be grown to follow the wheat as the denser crop canopy that develops would be better at suppressing weeds. We saw evidence of this later on our tour of other trials. For the experiment overall, this would mean that, in 2001, there would be a comparison of winter oats following wheat in the Wakelyns drill plots, with winter oats following, in effect, a ploughed in ley and new clover bi-crop in the abandoned direct-drill plots.

The rotation experiment with bi-cropping (Potatoes-onions-parsnips-beans-swedes-oats), was in the early stages of establishment following delays during the wet spring. Some problems were being experienced with soil condition and beds that were insufficiently level. Nevertheless, the potatoes and parsnips were well-established.

(ii) We then toured other experiments at Wakelyns. One of them (also MAFF funded) was a rotational experiment growing seven different crops with clover or vetch or nil as comparisons. This work is being expanded in a new experiment (WA funded) to assess the potential of growing a larger range of crop/varieties with a clover inter-crop. A critical factor in the success of growing crops in this way was the nature of the previous crop and the weed burden it left behind.

Martin also showed us a field trial of potatoes in grown in mixtures, with appropriate control plots, to combat blight. This work would be expanded in a new EU programme. We also saw two cereal variety trials (NIAB and EFRC) and were able to see for ourselves the weed-suppressing effect of winter oats.

We thanked Martin and his wife Ann for their hospitality.

We agreed to have our next Steering Committee Meeting at Long Ashton in late October/early November 2000. ROC would arrange for this in due course.

R O Clements
12th June 2000

Distribution

R O Clements(IGER, North Wyke)
T M Martyn "
G Donaldson (IACR, Long Ashton)
S Dixon "
R Unwin (FRCA)
M Wolfe (Elm Farm/Wakelyns)

Steering Committee Meeting, Long Ashton, 6th November 2000
OF 0173 Clover:cereal bi-cropping for organic farms

Present: R O Clements (IGER, North Wyke)
T M Martyn (" " ")
G Donaldson (IACR, Long Ashton)
S Dixon (" " ")
M Wolfe (EFRC, Wakelyns)

Apologies: R Unwin (FRCA, Gloucester)

1. Tour of plots Long Ashton (GD)

GD and SD took us on a tour of their two experiments at Long Ashton.

(i) We first visited an experiment (LARS no 00.611) investigating a range of clover:cereal bi-crop treatments which encompasses strategies for growing bi-crops with wide and narrow cereal row spacings. Treatments and results to date are given below (para 2 (i)). A striking feature of the plots was their general vigour. The white clover is growing well, but there are many grass (ryegrass) weeds present in unploughed areas that are proving difficult to overcome. The plots were due to be mown and direct-drilled with winter wheat as soon as soil conditions allow.

(ii) The second experiment we visited (LARS no 99.612) is investigating the use of white clover:cereal bi-cropping as an alternative to using a red clover/ley to build fertility for organic arable cropping. There are four rotations (stockless arable, typical arable, replace ley/clover, continuous bi-crop). Red clover plots had been vigorous and generally smothered all weeds. However, grass weeds had been troublesome on pure white clover plots although they at present looked reasonably free from weeds. The white clover plots would be direct-drilled as soon as conditions allow.

2. Discussion of Long Ashton Results (year 2000) GD

(i) **LARS 00.611** (see table below)
Cereal Plant population - There had been satisfactory cereal establishment on all treatments; ploughing and narrow row drilling into clover gave highest % establishment.
Wheat whole crop silage - Results were as expected, bi-crop yields comparable with "conventional" treatment A, but weeds (low DM) appear to be constraining yield of treatment B.
Wheat grain yield - Yield significantly depressed by weeds in B, and clover bi-crop C-E; harrowing in E seemed to do more damage (through wheeling?) than good. May need to do this earlier and more often in 2001. Although 1.4 t/ha bi-crop yield is not impressive, grain produced was worth £280/ha + cereal:IACS payment compared with set-aside payment of £217/ha, and still benefiting from build up of fertility. Plots were split for ± N application, applied as 50 kg N/ha Laws organic fertilizer. The addition of this fertilizer had no effect on either silage or grain yield, perhaps because the application timing was too late in the season, for what is probably a slow release product.

Results summary for Long Ashton (year 2000) Experiment 00.611

Treatment			Cereal plant population plants/m^2 24/3/00	Whole-crop silage yield t/ha DM 17/7/00		Grain yield† t/ha @ 15% 11/8/00		% ryegrass †† seed in harvested sample 11/8/00	
				0N	50 kg N/ha	0N	50 kg N/ha	0N	50 kg N/ha
A	No clover "clean" ploughed	12.5cm drill row	412	7.54	7.54	4.16	4.51	2.6	2.2
B	No clover "weed" (d.drilled)	"	344	6.66	6.66	0.61	0.62	9.5	1.2
C	Clover bi-crop	"	422	7.63	7.01	1.36	1.73	6.6	6.0
D	Clover bi-crop	25 cm drill row	318	7.36	6.61	1.49	1.39	6.2	6.1
E	Clover bi-crop + suppression of white clover	"	300	7.43	6.81	1.29	1.19	8.2	6.3
	S.e.d (16df)			1.52	1.52	0.415	0.415	1.7	1.7

† cleaned grain †† as a contaminant of wheat grain

18/10/99 All plots drilled with cv. Shamrock winter wheat @ 235 kg/ha (500 seeds/m^2)
30/03/00 Plots in Trt E harrow-combed
17/04/00 + N half of each plot, 550 kg/ha Laws 9% granular N (50 kg N)

(ii) **LARS 99.612** (see table below)
Forage yield during season - The red clover fertility building phase of rotations 1 & 2 produced c. 22 t/ha of dry matter from 3 cuts during the season, the white clover/wheat bi-crop 3 & 4 produced c. 8 t/ha from 2 cuts.
Grain yield of bi-crop - No grain yields of wheat (3 & 4) were taken, due to the wheat lodging and the high incidence of grass weeds. The grass weeds were not apparent until later in the season - too late for weed harrowing. Timely harrow-combing will be employed in spring 2001. Treatment 4 will be sown to winter oats this autumn, which will allow comparison of oats superior competitive effect with winter wheat (3).
+50 kg N - No significant effect on yield of the bi-crop treatments 3 & 4. (Slurry that was applied belatedly on 13 April had low N when analysed, thus the Laws granular fertilizer N was applied to try and make up the N level late in the season.)

Experimental treatment (Expt 99.612)

Rotation year	1	2	3	4
	Stockless arable	Typical arable	Replace ley/clover	Continuous bi-crop
1999	Spring barley + red clover	Spring barley + ley/red clover	Spring barley + white clover	Spring barley + white clover
2000	Red clover (mulched)	Ley/red clover (conserved)	Winter wheat + white clover	Winter wheat + white clover
2001	Red clover (mulched)	Ley/red clover (conserved)	Winter wheat + white clover	Winter oats + white clover

18/10/99 Trts 3 & 4 drilled to Shamrock winter wheat @ 235 kg/ha (500 seeds/m^2)
5/4/00 All plots sampled for residual N
13/4/00 Trts 3 & 4 + N half plot, cow slurry (0.046%N) applied @ 46,000 l/ha, [1.71 NH_4, N + 0.71 P + 4.52 K kg/ha]
5/5/00 Trts 3 & 4 + N half plot, 550 kg/ha Laws 9% granular N (50 kg N)

Results summary for Long Ashton (year 2000) Experiment 99.612

Treatment	Available N in soil kg/N ha	Whole crop forage yields (t/ha DM)					
	5/4/00	17/5/00	27/6/00	25/7/00		22/9/00	
				0N	50 kg N/ha	0N	50 kg N/ha
1. Stockless arable	153	6.67	Mulched	-	-	3.78	4.35
2. Typical arable	153	Mulched	11.16	-	-	4.43	3.93
3. Replace ley/clover	49	-	-	5.74	5.95	2.32	2.20
4. Continuous bi-crop	49	-	-	5.88	6.26	2.29	2.32
Sed				0.535	0.535		

3. Work at North Wyke (Drewsteignton) ROC/TMM

A twin experiment to 00.611 at LARS is being carried out at North Wyke (Drewsteignton). Treatments and general approach are identical.
29/10/99 All plots drilled @ 244 kg ha (519 seeds/m^2).
13/4/00 Plots in Treatment E harrowcombed.
3/5/00 + N half to each plot 986 kg ha Laws 9% granular N (89 kg N).

Clover stolon length had been assessed on bi-crop plot on 2 May 00. There were no significant differences between treatments, but the average of 5.22 stolon/m^2 is low compared to that present in a vigorous clover/ryegrass sward.
Wheat shoot counts were made on 2 May 00 and were higher in the ploughed treatment than elsewhere. Nos of wheat shoots in bi-cropped areas were disappointingly low.
Wheat whole-crop silage yields were lower on bi-cropped plots than for those that had been ploughed. Weed invasion of bi-cropped areas was great, with only, on average, 20.4% of the harvested material being cereal - the remaining *c.* 80% was weed. However, even on ploughed, non bi-crop areas almost 30% of the harvested material was weeds. Application of 50 kg N/ha of Laws fertilizer had had no effect on yield as at LARS.

Results summary for North Wyke (year 2000) Experiment No. NW 290

Treatment			Clover stolon length 2/5/00	Wheat shoot counts shoots/m^2 2/5/00	Whole crop silage, harvested 20/7/00					
					DMY t/ha	% DM	% contribution to DM			
							Wheat	Clover	Grass	BLW
A	No clover "clean" ploughed	12.5cm drill row	-	581	10.14	45.0	71.8	-	27.8	0.4
B	No clover "weed" (d.drilled)	"	-	251	8.00	39.5	11.8	-	85.0	3.2
C	Clover bi-crop	"	3.77	202	9.22	41.2	22.1	1.5	74.5	1.8
D	Clover bi-crop	25 cm drill row	6.21	163	7.74	39.6	16.6	2.8	78.7	2.0
E	Clover bi-crop + suppression of white clover	"	5.68	196	7.56	37.8	22.7	4.6	69.8	3.0
	LSD 5%		NS	88.3	1.398	2.31	9.65	2.36	9.41	NS

No assessment for grain yield was taken as most of the plots were too badly infested with grass weeds, and all plots suffered Badger damage post-silage harvest.

Because of the overwhelming invasion by grass weeds and the low incidence of clover it was decided that the trial area should be ploughed and clover re-established. Clover was sown on 24 August 00 at the original rate and mixture.

The clover re-established well, but grass weeds and some broad leaved weeds are already becoming a significant problem. The Committee agreed that drilling with a winter cereal without taking drastic action would result in a massive weed invasion and loss of the crop. The best course of action seemed to be to plough the area when conditions permit and re-start i.e. sow clover under a barley nurse crop in spring 2001.

4. Work at EFRC (Wakelyns) MW

Results summary 2000

One objective of the bi-crop trial in 2000 was to compare the effectiveness of the Wakelyns strip drill (20cm cereal strips alternating with 30cm clover strips), with the standard Moore Uni-drill direct drill. By the time of the Steering Committee meeting in early June, the direct drilled plots were severely affected by grass weeds and as a consequence, were mulched on the 10 June. The strip drilled plots were maintained to grain harvest on 25 August.

Main treatments and cereal grain yields (all plots sown with Wakelyns strip drill)

1. Control (no intervention with clover growth): 0.99 t grain/ha (@ 15% m.c.)
2. Strip mowing only: 1.17
3. Late intervention with Rollstar cultivator plus strip mowing: 1.09
4. Early intervention with Rollstar cultivator plus strip mowing: 1.40
5. Clover rotavated at drilling time followed by Rollstar and strip mowing: 3.12 (mean yield of complete mixture and adjacent row mixture)

The difference between treatment 5 and the remainder was significant at P less than 1%; no other differences were significant.

Sub-plot treatments

Wheat cvs. Hereward, Malacca, Shamrock sown as:
Adjacent (randomised) variety strips: 1.47 t/ha
Complete variety mixture: 1.64 t/ha

The complete mixture gave 12% higher yield, but this was not significantly different from the yield of the three varieties grown in adjacent strips.

General

The yield of treatment 5 (3.17 t/ha yield at complete variety mixture only) compared reasonably with 3.90 t/ha for the same mixture averaged over 5 EFRC sites in 2000. In the Wakelyns EFRC cereals trial (strip drill, no clover), the mixture gave 4.39 t/ha, which represented an 8% yield increase over the mean of the components. However, this was in a more fertile and less weedy field than the bi-crop trial.

Two important features of the mixture in the bi-crop trial were:

c) It was free from all diseases except for a moderate infection of Septoria tritici.
d) The 1000 grain weight was relatively high (46g) compared with that of the same mixture and its components in the EFRC trial (respectively, 36 and 35g).

Clearly, there is a problem with organic bi-cropping at the moment because of competition from the clover and, more particularly, grass weeds, against the cereal because of the difficulty of finding appropriate cultural or mechanical control of clover and weeds.

However, one major effect noted in the EFRC and NIAB organic cereal trials was the difference between the yields of wheat and the other cereals. Wheat yields generally under organic conditions tended to be considerably lower than those obtained under non-organic regimes. On the other hand, the yields of oats and triticale were much higher: in some circumstances, they were as high as those achieved conventionally. There are several possible explanations including differences in the ability to scavenge for soil nutrients, differences in disease resistance and differences in weed competition. From MW's observations during the season, he was convinced that the major factor was weed competition: modern wheats are not competitive against other plants, whereas modern oats particularly, but also triticale varieties, are highly competitive.

This raises the question as to whether the organic bi-crop approach would be better aimed at oats and triticale rather than wheat production. To try to provide an indication of this, the bi-crop trials at Wakelyns for 2000/2001 have been planned as follows:

a) *Main winter trial:* direct drill trial area replaced by strip drill trial (trial drilled on 25 October) in which one hazel alley (150m x 10m) has been planted with winter wheat (Hereward, Malacca, Shamrock mixture as in 1999/2000) and a second, with a winter oat mixture (Solva, Kingfisher, Dunkeld, Millennium). Five treatments will be applied as previously, but more severely to try to shift the competitive balance more towards the cereal than the clover (or weeds).

b) *Subsidiary winter trial*: a small four replicate trial with the same wheat and oat mixtures was drilled 24 October in North Field by rotovating into an almost pure clover ley with few grass or other weeds.

c) *Main spring trial*: a strip drill trial will be planted into the two hazel alleys previously occupied by the 2000 strip drill trial. One alley will be planted with a spring wheat mixture and the other with a spring oat mixture.

d) *Subsidiary spring trial*: as for the winter trials, the same spring cereal mixtures will also be planted into pure clover in a small area next to the winter subsidiary trial.

5. Some recent publications

Clements, R.O., Martyn, T.M. and Donaldson, G. (2000) Clover:cereal bi-cropping. *IGER Leaflet,* 4 pp.

Clements, R.O., Martyn, T.M., Donaldson, G. and Wolfe, M. (2000) Clover:cereal bi-cropping for organic farms. *AAB Meeting, Farming Systems for the Millennium, Cambridge, 18-20 December 2000.*

Martyn, T, Clements, R.O., Donaldson, G. and Wolfe, M. (2000) Development of clover: cereal bi-cropping for organic farms. *BGS 6th Research Conference, Aberdeen, September 2000,* 83.

Wolfe, M.S., Clements, R.O. and Donaldson, G. (2000) Clover:cereal bi-cropping for organic farms. *IFOAM Meeting, Basle.*

6. General Discussion

The main points to emerge were that although the bi-crop system is well proven and developed for use in a non-organic system:

- Grass weeds, and to some extent broad leaved weeds, are a major problem in translating the bi-crop system to organic farming as herbicides cannot be used to control them. It should be noted though that the grass problem at LARS is a carry over from the grass/clover ley sown to build fertility during the organic conversion period. In a stockless arable system, pure clover stand would have been a better option, but one can only go on best advice given at the time. However,
  - growing oats (or triticale) which forms a tall and dense canopy instead of winter wheat which allows more light to penetrate may suppress weeds better (there is evidence of this from Wakelyns NIAB trials).
  - "strip drilling" (alternate 20 cm strips of cereal and 30 cm strips of clover) instead of bi-cropping may be a way of suppressing weeds where herbicides can not be used.
  - further work is required to develop other strategies to control especially grass weeds. These could include crop rotation, use of flame-gun, various mowing/defoliation strategies of bi-crop areas.

R O Clements
7th November 2000

Distribution

R O Clements(IGER, North Wyke)
T M Martyn "

G Donaldson (IACR, Long Ashton)
S Dixon "
R Unwin (FRCA)
M Wolfe (Elm Farm/Wakelyns)
S C Jarvis (North Wyke)
P A Costigan (MAFF, London)

Date of next meeting June/July at Wakelyns (ROC to arrange)

Please press enter