EUROPEAN INNOVATION PARTNERSHIP PROJECT:
MAXIMISING ORGANIC PRODUCTION SYSTEMS (MOPS)

GREEN MANURES:
INTERIM REPORT 4
(JUNE 2020)

MAXIMIZING ORGANIC PRODUCTION SYSTEMS

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The European Agricultural Fund for Rural Development: **Europe investing in rural areas**

Landsberger mix green manure March 2020

OBJECTIVES: Part of the MOPS project involves a 3-year trial of short-term winter and summer green manure crops under Irish conditions. The same trial will be carried out over three seasons on the same field on the same farm in Old Ross, Co. Wexford, to determine the robustness of any effects. Each of the two green manure trials (summer and winter) consists of three green manure mixes and an unsown control, in which the natural weed population is allowed to establish and be incorporated. The mixes used in the summer and winter green manures and the experimental design were described in Interim Report 1.

SUMMARY
(June 2018 – November 2019)

In the summer green manure:

- Biomass: buckwheat/phacelia>rye/phacelia>clover/ryegrass>control
- Annual weed control: buckwheat/phacelia>rye/phacelia>clover/ryegrass>control
- Perennial weed control: rye/phacelia~buckwheat/phacelia>clover/ryegrass>control
- Beneficial insects: clover/ryegrass>rye/phacelia>control>buckwheat/phacelia
- Soil bacterial diversity: clover/ryegrass>rye/phacelia>control>buckwheat/phacelia
- Soil nutrient levels: rye/phacelia>buckwheat/phacelia~clover/ryegrass>control

- Soil organic carbon:
  buckwheat/phacelia>rye/phacelia>clover/ryegrass~control
- Cash crop development:
  buckwheat/phacelia>rye/phacelia~clover/ryegrass>control
- Onion yield:
  clover/ryegrass>rye/phacelia>buckwheat/phacelia>control

In the winter green manure:

- Biomass: Wild Atlantic mix*>rye/vetch>Landsberger**>control
- Perennial weed control:
  rye/vetch> Wild Atlantic>Landsberger>control
- Beneficial insects:
  Landsberger>Wild Atlantic~control>rye/vetch
- Soil nutrient levels:
  Landsberger~Wild Atlantic~rye/vetch>control
- Soil organic carbon:
  Wild Atlantic> rye/vetch>Landsberger>control
- Broccoli yield: Wild Atlantic>rye/vetch>Landsberger>control
- Lettuce yield: Wild Atlantic>Landsberger>control>rye/vetch

***Wild Atlantic mix** = oats/rye/vetch/clovers*
*** Landsberger** = ryegrass/clovers*
➢ = significantly greater; ~ = not significantly different

Overall, these short-term green manures (two months for summer green manure, six months for winter green manure) have achieved consistent beneficial effects over the first two years of the study, associated with better weed control, more beneficial insects, more and greater diversity of soil bacteria, greater soil carbon content and earlier-developing cash crops than in the control. The short green manure growing season may explain the inability to detect increased soil N in the legume-based summer or winter green manures. Of the nine green manure-cash crop combinations evaluated in 2019, eight produced significantly higher yields than in the control and higher cost-benefit analysis (after subtraction of additional costs) than the control, with extra profits in the range €38-106 per 50 m2 (onion), €16-53 (lettuce) and €28-46 (broccoli). The only exception was for the lettuce-rye/vetch winter green manure combination, where the yield was 23% lower and returns were €86 per 50 m2 lower than in the control.

4.A. SUMMER GREEN MANURE TRIAL (2019/20)

This trial was carried out as described in earlier Interim Reports, to test the robustness of any effects. Two additional experiments were carried out: a). to determine whether the increased numbers and diversity of soil bacteria detected under summer green manures were maintained after incorporation of the green manure; and b). to investigate the cause of the sub-control yield of red oakleaf lettuce after the rye/vetch green manure.

4.A.3. RESULTS AND DISCUSSION

4.A.3.1. Frequency of beneficial insects

The numbers of ground beetles present in the summer green manure plots in 2019 were consistent with the 2018 data again higher than in the control plots, with a negative relationship between green manure height and ground beetle density, the tall buckwheat/phacelia plots supporting similar numbers to the control plots, and the short clover/ryegrass plots supporting the highest frequency (Fig. A1).

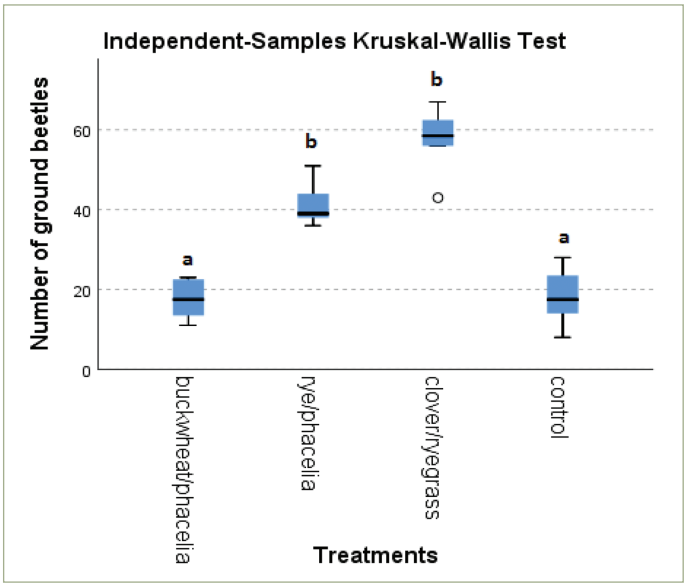

Figure A1. Numbers of ground beetles in summer green manure and control plots. Any two samples with a shared letter are not significantly different (P>0.05).

4.A.3.2. Effects of summer green manure on soil bacteria before/after incorporation

The 2019 investigation expanded on the 2018 trial, under the different green manures; the samples were frozen until being analysed in 2020. The bacteria in the different soil samples were analysed for the numbers of bacteria (AWCD) and the number of different types of bacteria (Richness, Shannon Index). In the 2018 trial, the clover/ryegrass green manure supported the highest bacterial population. In the 2019 trial, again the clover/ryegrass supported the largest population, but the buckwheat/phacelia green manure supported the most diverse population, as measured by Richness (Table A1).

A second evaluation was then carried out in 2019, four weeks after incorporation of the green manures; this is the first such published analysis as to whether the effects of green manures were maintained after the green manures were dug in. Incorporation resulted in an increase in the size of the soil bacterial population (presumably as a result of increased organic matter) in all plots (including the control plots, which contained weeds) bar the clover/ryegrass green manure plot, which exhibited a significant decrease in the size of the soil bacterial population (Table A1).

This unusual behaviour of the clover/ryegrass plot may be because legumes, such as clovers, attract N-fixing bacteria – following incorporation, production of these chemical signals would fade away, resulting in elimination of the N-fixing bacteria. After incorporation, the green manures had little significant effect on the numbers and diversity of the soil bacterial population, although the buckwheat/phacelia green manure had the greatest beneficial effect.

Table A1. Effect of green manures (before and after incorporation) on soil bacterial population numbers (AWCD) and diversity (Richness, Shannon Index) from Biolog-ECO plates.

Parameter	Incorporation	Buckwheat/ phacelia	Rye/ phacelia	Clover/ ryegrass	Control
AWCD	-	0.92bc	0.71b	1.03c	0.58a
	+	1.15d	1.03c	0.86bc	1.11c
Richness	-	25b	20a	22a	21a
	+	30c	27bc	24b	27bc
Shannon index	-	1.36ab	1.26a	1.30a	1.28a
	+	1.42b	1.38b	1.35ab	1.36ab

AWCD: average well colour development; - incorporation = before incorporation; + incorporation = after incorporation. For a given parameter, any two samples with a shared letter are not significantly different (P>0.05).

Principal Component Analysis (PCA) was then carried out to compare the functions of the different bacterial populations under the different green manures and before/after incorporation. Despite the apparent similarities under the different green manures after incorporation (Table A1), PCA revealed that differences remained in the ability of the bacterial populations under different green manures to metabolise different organic compounds in the soil (Fig. A2).

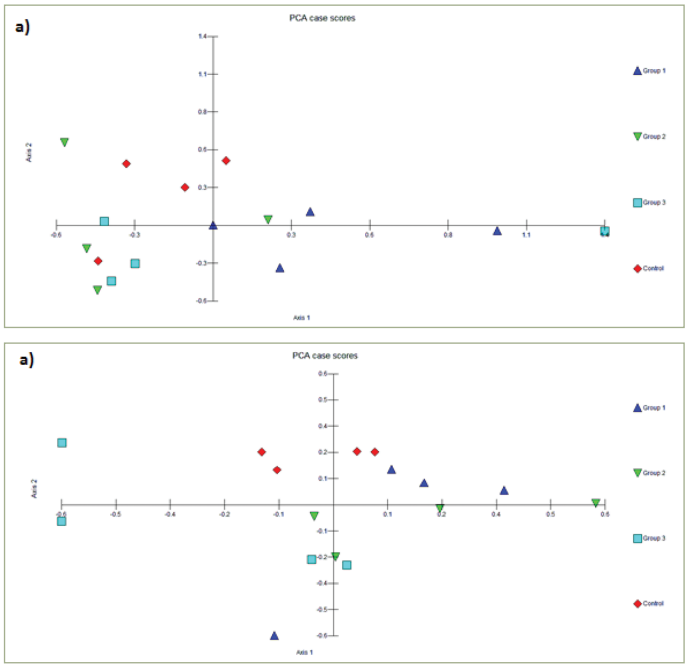

Fig. A2. Principal Component Analysis of Biolog-ECO data from the different green manure plots before (a) and after incorporation (b). Red: control; dark blue: buckwheat/phacelia; green: rye/phacelia; light blue: clover/ryegrass

The four examples of each green manure in Fig. A2 represent the four replicate plots. Although the replicates of the same green manure are scattered, trends are visible. Before incorporation (Fig. A2a), the dark blue symbols (buckwheat/phacelia) were widely separated from the red symbols (control), showing that the greater diversity in the green manure supported bacterial populations with different functions from the control plots. After incorporation (Fig. A2b), the differences were smaller but were retained, with the scatter of the buckwheat/phacelia green manure plots still being different from that of the control, with the distribution of the light blue symbols (clover/ryegrass) now being quite different from that of the control. These results indicate that, after incorporation, any effects of the green manure on soil bacteria was due to the functions rather than the numbers of the bacteria

4.A.3.3. Investigation of inhibitory effect on lettuce yield of rye/vetch winter green manure

The cash crop yield in each of the nine green manure-cash crop combinations in the 2019 harvests were significantly higher than those in the corresponding controls (Organic Matters Winter 2019), with the exception of red oakleaf lettuce following the winter green manure rye/vetch.

Lettuce showed inhibition, relative to the control, when planted after the rye/vetch winter green manure (60% grazing rye) but not after the Wild Atlantic winter green manure (30% grazing rye), indicating that the effect was concentration dependent. Furthermore, earlier studies had shown that rye-based green manures were effective at controlling perennial weeds such as docks (Interim Report 2), suggesting an allelopathic effect, in which plants like rye produce chemicals (from living roots or as they decompose) which inhibit the germination or growth of other plants; rye is known to produce allelochemicals when decomposing.

The reason for this effect was investigated in the current experimental period in growth room experiments, using soil collected from incorporated winter green manure plots. Of six crops tested, transplants of only lettuce (green or red oakleaf, butterhead) showed growth inhibition (relative to the transplants in control soil), with only the rye/vetch green manure proving inhibitory (Table A2). As a consequence, particular care needs to be taken when using high percentage rye (30–60%) as a component of a green manure, to avoid planting lettuce as the subsequent cash crop.

Table A2. Fresh weight of six-week-old plants (as % of control) growing in soil containing incorporated winter green manures.

Transplant	Wild Atlantic	Rye/vetch	Landsberger
Red oakleaf lettuce	122	78	118
Green oakleaf lettuce	126	73	130
Butterhead lettuce	119	69	128
Cabbage	126	127	120
Spring onion	117	120	131
Broad bean	124	132	134

4.A.3.4. Effect of summer green manure on cash crop development

Crop development was scored in the different plots in early March 2020. The results were similar to those from the 2019 results, with all green manures being associated with more rapid development of both cash crops, onion and cabbage (Table A3). For onion, the only significant effects of the green manures on onion development were the stimulatory effects of rye/phacelia and buckwheat/phacelia green manures, whereas all three green manures increased cabbage development.

Table A3. Effects of incorporated summer green manures on crop development (leaf number/plant) of onion and cabbage cash crops

	Rye/phacelia	Buckwheat/phacelia	Clover/ryegrass	Control
Onion	2.43b	2.33b	2.12a	2.10a
Cabbage	7.23b	7.40c	7.36c	6.85a

Any two samples within a row with a shared letter are not significantly different (P>0.05), using the Tukey test.

4.B. WINTER GREEN MANURE TRIAL (2019/20)

The green manures continue to grow and will be incorporated, and cash crops planted at appropriate times, travel restrictions permitting.

SUMMARY

- The effect of summer green manures on soil bacteria numbers disappears after incorporation
- Buckwheat/phacelia green manure supported a bacterial population with different functions before and after incorporation
- A summer green manure containing >30% rye controls perennial weeds but inhibits the growth of lettuce after incorporation.