Project report for SSCR-Potatoes

***Project title*:**

Agronomic methods for surface cultivation of potato and assessing the impact on yield, quality, soil biophysical properties and in-field biodiversity.

Applicant(s):

Gill Banks, Cathy Hawes

Background to the project

Commercial potato cultivation has high equipment, labour and energy costs (around £500-600 ha^{-1}) and cultivation typically involves moving a very large mass of soil (~3000 tonnes ha^{-1}) each growing season. Therefore, soil structure is degraded over large areas by aggressive powered cultivation, leading to erosion, pollution and loss of soil biota: (earthworm populations were found to take 3 years to recover after potato cultivation at the CSC).

There is little existing research in no-till potato production and this project would therefore build upon knowledge gained from 2 years of small-scale trials at JHI. In 2018 a polytunnel experiment using surface cultivation mulched with barley straw showed potential as an economically viable alternative to current commercial practice, without the negative impacts on soil health and fertility. Although there were less tubers, weed density and common scab incidence were lower, tubers were cleaner and soil structure was unaffected. A field plot experiment in 2019 developed this work to include “living mulches” which were shown to potentially reduce the need for added mineral nitrogen fertilizer. Together, these trials have demonstrated the potential for surface cultivation in commercial production and funds are therefore sought to test the system at a field scale.

3 varieties of potatoes were grown under each of the four treatments a) ridges (control) b) on the surface of the soil under straw c) on the surface of the soil under mix 1 (60% legume and 40% rye grass) and d) on the surface of the soil under mix 2 (60% rye grass: 40 % legume). Here 0% N means

Aims and objectives

Aim: To determine optimal methods for surface cultivation of potatoes to disease incidence and weed pressure, and optimise nutrient supply, soil health and biodiversity with minimal tuber greening. This will be done using a large-scale field experiment, testing the responses of a range of salad and ware potato varieties to different kinds of living and cut mulches and nutrient supplies. The project focuses on three main objectives: 1. Effect of different cultivation methods on growth and development, yield, and product quality; 2. Impact of surface cultivation on soil health and biodiversity; 3. Best practical methods for crop harvesting.

Research results

1. Effect of different cultivation methods on growth and development, yield, and product quality. A two-sample t-test showed that there was a significant impact between the four different cultivation treatments (mulches (mix 1, mix 2), straw and ridges and yield (kg) of potatoes and addition of nitrogen on the final yield, *Figure 1* ($P = 0.01; n = 36$). Potato variety had no impact on yields obtained in the final yield (*Figure 2*; $P = 0.43$; $n = 36$) all three varieties of potato showed greater yields under the ridges (*Figure 1; Figure 2*). Although addition of mineral nitrogen at the field rate (100% N) produced the highest yields there was no significant difference between the two mixes (Mix 1 and Mix 2), (*Figure 3*; $P = 0.76$; $n = 36$).

2. Impact of surface cultivation on soil health and biodiversity – percentage greenness or presence or absence of disease. Note: measurements for disease were taken from a sub-sample of potato plants under each type of cultivation and nitrogen regimes.

Greenness Index: Greenness was estimated by the percentage of greenness on each of the potatoes. There was a highly significant difference between cultivation treatments (*Figure 3*; $P = < 0.001; n = 18$). The percentage mean showed that straw had the least amount of greening with a percentage mean of *3.06*; Mix 2 had the highest percentage mean of *8.38* whilst Mix 1 and the ridges had similar percentage means of *6.53* and *6.91* respectively.

Common scab was found to be highest in the ridge treatment and was highly statistically significant ($P = > 0.001$; $n = 18$) which was also borne out by the moisture and temperature readings in the soil.

Slug damage was found to be significant ($P = 0.02$) across all the cultivations with straw having the highest mean of *0.31*, and ridges having the lowest mean of *0.12*.

Visually there were high numbers of pollinators such as bees and hoverflies and natural enemies of aphids were seen on the flowering mixes although counts were not undertaken due to time constraints.

Soil measurements were taken on one occasion during July, August and September 2021 on or around the same date and at a similar time of day for the soil moisture, soil temperature and soil electroconductivity (EC) measurements. July showed that the ridges were the hottest, driest, and had the lowest EC across all the cultivation treatments at the time when the measurements were taken (*Figure 4, Figure 5 and Figure 6*). Straw showed the opposite result, but all results were highly significant ($P = <0.001; n = 36$).

In August the ridged cultivation continued to have a higher temperature and percentage moisture mean with differences that were highly significant ($P = <0.001; n = 36$), although the difference in the EC was not significant ($P = 0.07; n = 36$). The temperature continued to decrease in September, (*Figure 5*) and at this time the differences between the 4 cultivation treatments became smaller, although the percentage moisture was highly significant (*Figure 4*; $P = <0.001; n = 36$). There were no differences between the 2 mulches (Mix 1 and Mix 2) apart from August when the EC was significant (*Figure 6*; $P = 0.05$).

Worms: The total number of worms (both juveniles and adults) were highly significant across all cultivations with ridges having the lowest mean (1.25) and Mix 2 had the highest mean (10.33), Mix 1 had a mean of 7.92 and straw a mean of 4.08 worms. Nitrogen at (100%) field rate had no effect on worm numbers ($P = 0.62$; $n =24$). There was no significant difference between the two mulches (Mix 1 and Mix 2), $P = 0.38$; $n = 12$). The variety of potatoes had no effect on the worm numbers ($P = 0.45; n = 16$).

Outcomes

This project demonstrated that although total yield was less under surface cultivation conditions compared to standard ridging, there were positive impacts on soil quality, including worm numbers as an indicator of soil health, and tuber greening, less aphids and more pollinators on the living mulches. Of the 3 surface cultivation options, straw produced the best performance relative to green mulch mixes.

These results have demonstrated the potential for alternative, more sustainable options for potato cultivation, contributing to SC1's focus on crop production methods that protect the environment, and to "identify sustainable production systems". It delivers to the challenge "Can we grow more food in a socially and environmentally acceptable way?" The results complement those gained from RESAS WPs (RD2.3.8 Alternative approaches to sustainable land management and 2.3.9 Integrated Management Systems) and Underpinning Capacity CSC long-term platform where the impacts of stacking management interventions to achieve multiple benefits are tested on all key elements of arable production systems. At the CSC platform, the disturbance caused by soil cultivation has been shown to cause a degradation of soil properties. Although this negative impact is less in the integrated system compared to standard practice and the baseline appears to improve in a stepwise fashion over the course of multiple rotations, greater benefits to soil biophysical properties would be achieved by eliminating the need for soil inversion. This project has demonstrated that options to achieve this are possible, at least at a small scale, and paves the way for further work to develop practical management strategies at a commercially realistic field scale.

Next steps *(e.g. Information on further funding etc – 100 words max):*

The results can be used to apply for future grant applications, such as Innovate UK competitions or Syngenta as there are still questions to be answered, including ways to mechanise some of the processes and improving the trial design – for example some of the potatoes ended up growing within the mulches rather than the mulches being cut and put on top of the potato tubers. Other questions need to be explored – for example would covering up potatoes more thoroughly by cutting mulches regularly further increase yield. Mulches appeared to protect potato plants from some skin diseases such as common scab when compared to the potatoes that were grown in ridges and this would need further investigation. The agronomy would have potentially made a difference if, for example the mixes had been sown several months before the potatoes.

Appendix 1 ***Potato Surface Cultivation Experiment 2021 - Summary Graphs***

TOTAL HARVEST YIELD

Figure 1: Nitrogen addition, average yield, and cultivation treatment

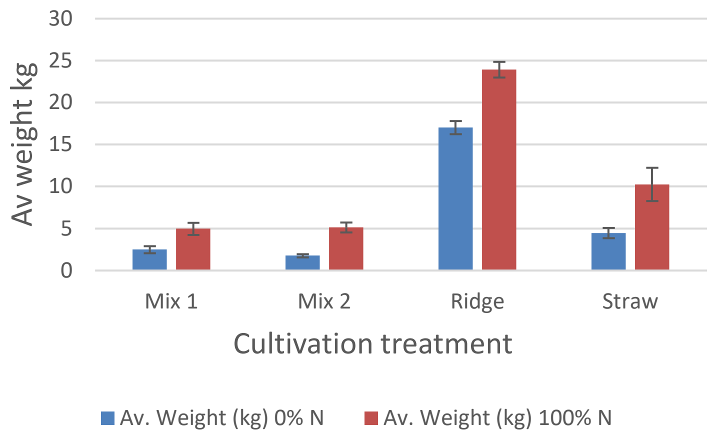
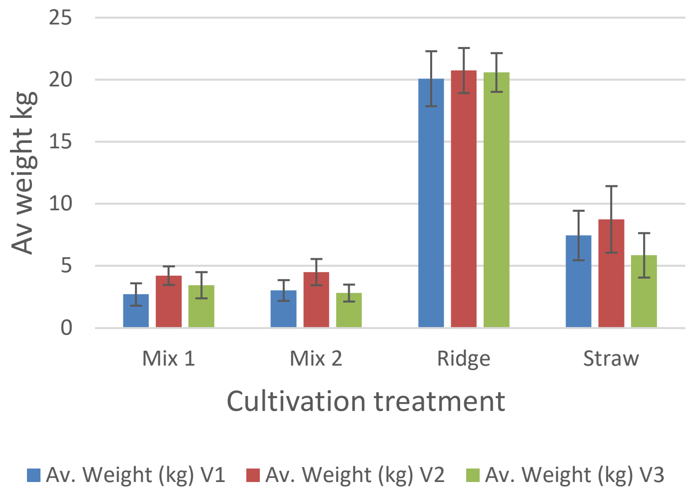
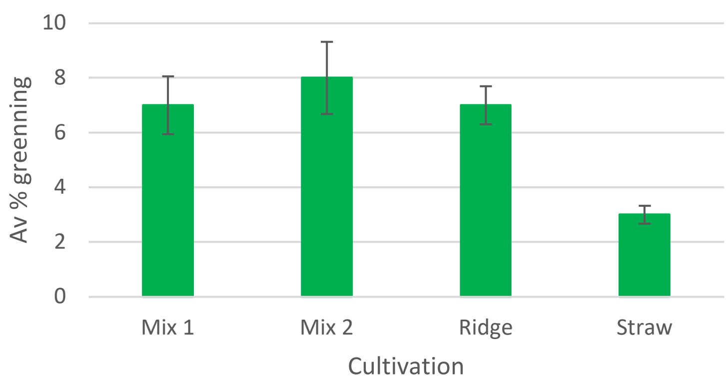


Figure 2: Potato variety, yield, and cultivation



INCIDENCE OF DISEASE

Figure 3: Average greening by cultivation



SOIL HEALTH

Figure 4: Soil Moisture

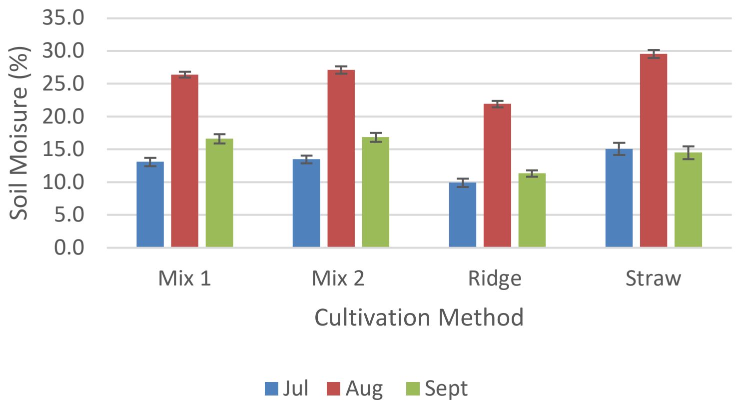


Figure 5: Mean soil temperature °C

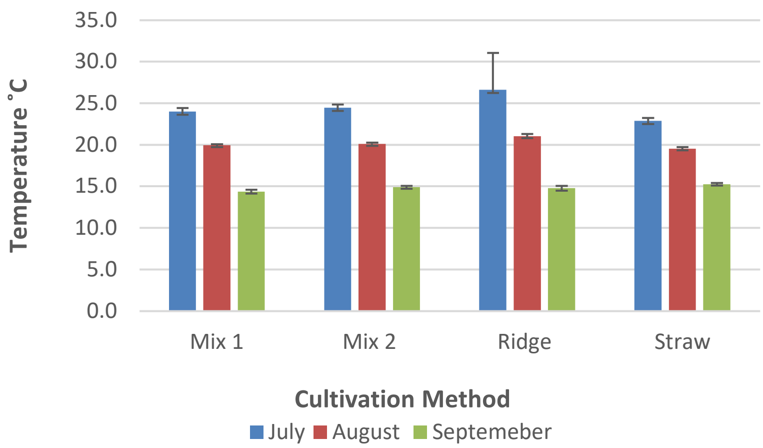
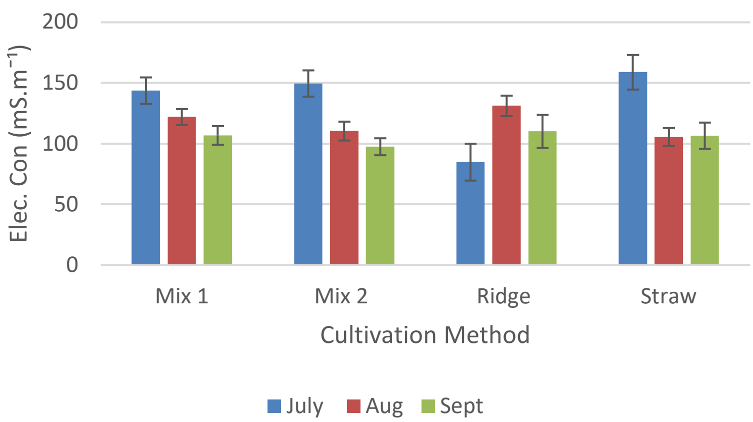
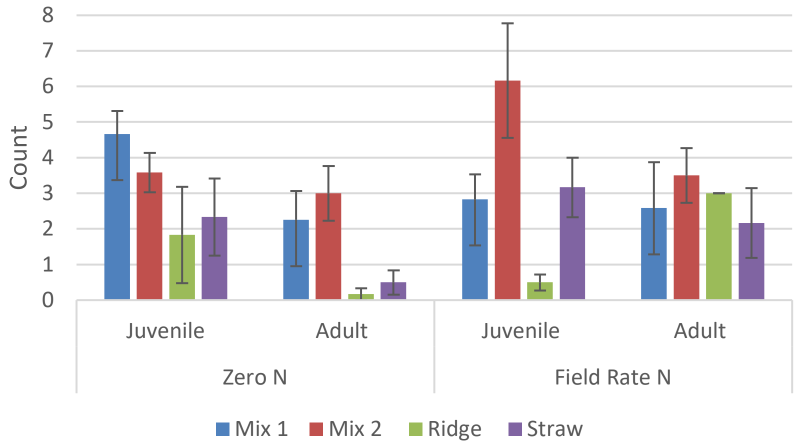


Figure 6: Mean electrical conductivity ($mS.m^{-1}$)



WORMS

Figure 7: Mean of juvenile and adult worm counts


Count
8
7
6
5
4
3
2
1
0
Juvenile
Adult
Juvenile
Adult
Zero N
Field Rate N
Mix 1
Mix 2
Ridge
Straw