



Grower Summary

CP 107b

Growing Resilient Efficient
And Thriving” GREAT Soils

Final 2018

Disclaimer

While the Agriculture and Horticulture Development Board seeks to ensure that the information contained within this document is accurate at the time of printing, no warranty is given in respect thereof and, to the maximum extent permitted by law the Agriculture and Horticulture Development Board accepts no liability for loss, damage or injury howsoever caused (including that caused by negligence) or suffered directly or indirectly in relation to information and opinions contained in or omitted from this document.

©Agriculture and Horticulture Development Board 2017. No part of this publication may be reproduced in any material form (including by photocopy or storage in any medium by electronic mean) or any copy or adaptation stored, published or distributed (by physical, electronic or other means) without prior permission in writing of the Agriculture and Horticulture Development Board, other than by reproduction in an unmodified form for the sole purpose of use as an information resource when the Agriculture and Horticulture Development Board or AHDB Horticulture is clearly acknowledged as the source, or in accordance with the provisions of the Copyright, Designs and Patents Act 1988. All rights reserved.

The results and conclusions in this report may be based on an investigation conducted over one year. Therefore, care must be taken with the interpretation of the results.

Use of pesticides

Only officially approved pesticides may be used in the UK. Approvals are normally granted only in relation to individual products and for specified uses. It is an offence to use non-approved products or to use approved products in a manner that does not comply with the statutory conditions of use, except where the crop or situation is the subject of an off-label extension of use.

Before using all pesticides check the approval status and conditions of use.

Read the label before use: use pesticides safely.

Further information

If you would like a copy of the full report, please email the AHDB Horticulture office (hort.info.@ahdb.org.uk), quoting your AHDB Horticulture number, alternatively contact AHDB Horticulture at the address below.

AHDB Horticulture,
AHDB
Stoneleigh Park
Kenilworth
Warwickshire
CV8 2TL

Tel – 0247 669 2051

AHDB Horticulture is a Division of the Agriculture and Horticulture Development Board.

Project title: "Growing Resilient Efficient And Thriving" GREAT Soils

Project number: CP 107b

Project leader: Ben Raskin, Soil Association

Report: Final report, March 2018

Previous report: Annual report, March 2017

Key staff: Liz Bowles - Project Director
Ben Raskin - Project Leader WP 4 and involvement in WP 1,2,3
Simone Osborn – Project Manager
Anja Vieweger – Project Leader WP1,2
Bruce Pearce – Scientific Supervisor
Audrey Litterick – Project Leader WP3
Martin Wood – Technical involvement WP3,4

Location of project: UK wide – with project leaders based in Bristol

Industry Representative: James Brown
Pollybell
Holmes Farm, Wroot Road, Epworth, Doncaster

Date project commenced: 01 April 2015

Date project completed (or expected completion date): 31 March 2018

GROWER SUMMARY

Headlines

- Simple soil health assessment methods can be used by growers to assess the health of soils. The methods have been demonstrated in this project and are detailed in this report.
- Small measures to improve soil health in commercial horticulture production systems can have benefits in the short term. Longer-term plans for soil improvement should be considered by land-owners and those using rented land.
- Collaboration on measures to improve soil health is key, particularly among growers sharing the same land for crop rotations.

Background

AHDB Horticulture project CP 107b began against a backdrop of widespread acknowledgment by scientists and an increasing number of farmers and growers of problems with the state of UK soils. In the early part of 2018 (the final year of this project) the importance of improving the health of soils rose up the political agenda. The UK Government's recently-released 25 Year Environment Plan¹ contains 57 references to soil. Before that, in December 2017 a group of 32 scientists published a letter in *The Times* newspaper calling for soil organic carbon content to be adopted as the indicator of soil quality in agri-environment schemes.²

Many growers understand that some current farming practices can lead to soil degradation, including compaction, declining soil organic matter content, nutrient leaching and erosion. Growers often understand the importance of soil health, but when faced with difficult commercial demands, they are not always able to keep up to date with the latest research and best practice.

This project worked with growers to improve the health of soils by assessing and field-testing current grower-known methods of soil testing. It inspired and empowered growers to improve their soil by sharing up to date research and latest best practice via training and outreach events, and also by integrating soils knowledge, methods and tools into accessible practical information in AHDB Horticulture GREATsoils factsheets.

¹ <https://www.gov.uk/government/publications/25-year-environment-plan>

² https://twitter.com/john_quinton/status/936227707486130177

Summary



Figure 1: Simon Day of Worth Farms, GREATsoils Field Lab participant

Improving the health of soils is fundamental to the agronomic, financial and environmental sustainability of horticultural enterprises. To improve soil health, fertility and function growers need clear methods and criteria to allow for simple, quick assessments and measurements.

This project set out to -

- evaluate soil assessment methods for growers;
- improve growers' confidence in 'reading the signs';
- offer opportunities to practice assessment methods with colleagues and advisors;
- disseminate the methods and approaches to a wide range of levy payers, growers, advisors and stakeholders;
- develop methods and approaches for practical soil health analysis and evaluation to enable confident choice of management options.

To do this the project team used a range of approaches including -

- grower consultation events;

- field trials to assess the efficacy of soil health testing methods in different growing systems;
- field labs to try out soil health improvement methods in practice;
- grower workshops to engage with growers around the country on the project and share knowledge and;
- a knowledge exchange programme which included
 - advisor/agronomist workshops,
 - project publicity via contractor attendance at horticultural events,
 - live online webinars and
 - publication of new AHDB factsheets .

The project -

- demonstrated that growers are keen to improve soil health. Seven hundred and fifty-five growers, farmers, and advisors attended 56 live events.
- promoted soil health within the wider horticultural agenda, with articles in major publications, and events and presentations and talks given at various fora.
- highlighted to growers that small measures to improve soil health are worth the effort eg using short-term green manures within a season.
- engaged with growers in England, Scotland and Wales at all scales of production, and from almost every sector in horticulture.
- identified as a key challenge the management of soil health in shared rotations where land is rented, and have established a way forward on this via a Field Lab working with three businesses collaborating to improve the soil health of shared field.
- built networks/connections, particularly through the Field Labs and Field Trials, that will continue beyond the project and provide long-term benefits to soil health and growers' businesses.
- identified growers who are innovative; these growers shared their knowledge and experiences to peers in the presence of the research team who also provided technical support to the growers.
- identified sets of the most useful and practical tools for soil testing for the different horticulture production systems - field vegetables, protected leafy vegetables and top fruit, see Table 1.
- facilitated constructive exchange of information between organic and conventional growers; focusing on shared challenges and how to address them.

Table 1. Usefulness of each soil assessment test in a particular growing system as rated by growers during the project. The results represent qualitative feedback from around 20 growers per system including the growers hosting the different Field Trials.

• Method	Field vegetables	Top fruit systems	Protected crops
Visual Soil Assessment (VSA)			
Earthworm Counts			
Soil Health Laboratory Test			
Simple Infiltration rates			
Simple Compaction Test			

The main activities carried out in the project are summarised below.

Grower Trials

Review of existing methods of soil assessment

The soil assessment approaches that are available to UK growers were reviewed. The different methods were identified and categorised in a literature review and were then evaluated and rated by the growers to establish their usefulness and relevance in practice. This resulted in a two-paged summary GREATsoils [‘Soil assessment methods’ factsheet which is available on the AHDB website.](#)

Field Trials

To assist growers to identify which soil assessment methods are most useful for them, methods and approaches were field-tested with six host farms in England and Scotland which had different growing systems. These were supplemented by a programme of open days to bring the findings to a wider audience.

In each case the growers selected the soil health tests that they wished to compare from a suite of possible options which had been chosen by growers at public consultations.

Alongside the soil health tests each of the farms also chose to test a soil health improvement method, for example introducing short-term green manures, or observing the impact of different planting times on cover crops and soil structure.

A ‘Rating soil assessment methods’ factsheet with system-specific recommendations was produced from the field tests: <https://ahdb.org.uk/knowledge-library/greatsoils-rating-soil-assessment-methods>.

Field Labs

Four grower-led Field Labs were conducted specifically for the GREATsoils programme and run in collaboration with the Innovative Farmers programme³. The Field Labs offered growers an opportunity to bring forward specific ideas or issues around soil health for investigating as a group.

The methodology and achievements and outcomes from each are summarised in the main report, included in the Appendices and were recorded on the Innovative Farmers portal which can be accessed for free.

The four Field Lab groups were:

1. Improving soil health across a shared rotation; Lincolnshire

Growers renting land within a rotation can often find it hard to justify investing in soil health measures as they might not reap the immediate benefit of the measures. This Field Lab brought together vegetable growers Jepco with two other businesses Loveden Estates and Worth Farm with whom they share land. The overall aim of the three partners was to improve soil organic matter and soil health in an arable / horticulture rotation and to deliver initial evidence for other farmers and growers that a joint strategic and long-term soil management approach is crucial for a long-term and sustainable improvement of soil health and soil fertility. The method adopted was for each business to bring mutually agreed cover crops into their rotation and to meet periodically to discuss progress. The field lab was successful with the group finding it useful to work together. A well-attended public meeting showed real interest in the approach. Year one showed some initial business benefits from use of the green manures which are summarised in the financial section below. The findings are summarised in the [‘Short-term green manures for intensively cultivated horticultural soils’ factsheet which is available on the AHDB website.](#)

2. The impact of whole digestate on soil health in field-grown vegetable crops on the Moray Coast; Moray Firth, Scotland

With many consultants and Anaerobic Digestate companies promoting the benefits of digestates as soil improvers, this field lab set out to set up to determine whether the application of separated liquid digestate made from farm-produced energy crops had any short-term impacts on aspects of the health of soils in Moray coast vegetable rotations.

There was no evidence from this short trial that digestate applied at 15 m³/ha on three occasions (October 2016 / March 2017 / August 2017) had any deleterious effects on soil structure, microbial respiration soil earthworm populations. Neither did the digestate have any beneficial effects on these parameters. There may be benefit in repeating the tests every 2 years annually for a period of at least 10 years in order to further study the impact of

³ <http://innovativefarmers.org/>

digestate on soil properties, because it is well known that soil properties can take a very long time to change in a significant way.

3. Green Manures to Increase Nitrogen Availability; Lancashire

This field lab aimed to understand more about how three green manure mixtures, with varying proportions of leguminous species, could optimise nitrogen (N) availability to a following brassica crop. The trial compared the three green manure mixes against a no treatment control, and a normal farm practice control which received a synthetic N fertiliser. N availability was measured by taking soil samples pre-incorporation and 4, 10 and 20 weeks after incorporation of the green manure, the last sample being close to harvest. At the same time, the team measured N uptake by analysing the plant tissues of the green manures just prior to incorporation and of the crop plants 10 and 20 weeks after incorporation.

Initial results indicate that using green manures could, in round figures, enable a 50% reduction in N fertiliser application. The year 2017 was unusually dry between April and July, and the team estimated that in a more typical year (where higher rainfall might cause of N through leaching from the plots with no green manures) this could be higher.

Additional benefits from the green manures are also important, including improvements in soil fertility, reducing soil erosion, weed suppression and enhancing biodiversity.

4. Amendments for soil health in top fruit; Southern England and West Wales

In this Field Lab, a group of fruit growers looked at how various soil amendments (woodchip, biochar, green waste compost, and mycorrhizae) affect soil health outcomes including soil structure, weed control, soil pH, water retention and drainage. They were also interested in tree establishment, fruit quality, storability and yield.

There were no firm conclusions from this field lab; but this had been expected to be the case following a years work on soil health in perennial crops. The tree fruit trials are continuing beyond the life of the GREATsoils project, with extra funding from other projects.

Some initial findings from some growers in this group are that -

- Mulches have higher levels of potash than surrounding areas.
- Weed control is better in wood chip mulches than in compost mulches
- Compost has higher potassium (K) and trace elements.
- Soil conditions appeared wetter under Holly mulch than under Alder or Compost.

Eastbrook farm in Wiltshire had done some extension growth measurements and observed differences in treatments but these appeared to be due to variety rather than to the different treatments.

Tolhurst Organics on the Berkshire/Oxfordshire border observed -

- large quantities of mushrooms on ramial woodchip plots;
- ramial wood rotting on the surface turned black and mycelium growth was present on surface;
- very large number of worms present on ramial plots;
- that woodchip compost mostly decomposed to soil;
- evidence of slightly stronger growth on woodchip compost as opposed to ramial wood;
- similar root nodulation of clovers on both plots.

Knowledge Exchange

Soil health testing tool kit

Over the course of the project a library of resources for growers wishing to better understand and take action to improve their soil health was built. These add to and build on the existing resources available from the AHDB. Resources from this project includes the following:

AHDB Horticulture GREATsoils factsheets -

- [Soil assessment methods](#)
- [Rating soil assessment methods](#)
- [Compost is good news for soil health](#)
- [A fresh look at soil testing for carrot production](#)
- [Engineering the landscape to secure asparagus production](#)
- [Biological tests for soil health](#)
- [Which nutrient management system to use?](#)
- [Short-term green manures for intensively cultivated horticultural soils](#)
- [Soil pH how to measure and manage it based on an understanding of soil texture](#)
- [Soil structure and infiltration](#)
- [Soil health and water supply](#)

- [Green manures improve soil health in apple orchards](#)
- [Testing soil health](#)

GREATsoils Youtube films

GREATsoils: Salad grower Simon Gardner of G's Global, Cambridgeshire on low till cover crops for soil

GREATsoils: Improving soil health in orchards with James Smith, Loddington Farm, Kent

GREATsoils: Why managing soils is important with kale grower Chris Molyneux, Molyneux Kale Company, Lancashire

The following video clips are also available on the AHDB website

- Worm count
- Infiltration test
- Spade test
- Respiration test
- Compaction test

GREATsoils online webinars

All webinars can be accessed from the AHDB website.

- Soil Health and the bottom line
- Soil health and what to measure
- Managing soil health using organic manures
- Short term green manure strategies for intensive growers -
- Soil health for horticulture (project summary)

Field Lab reports

Final field lab reports are available in the appendices -

- Improving soil health and organic matter using cover crops in a shared rotation
- The impact of whole digestate on soil health in field-grown vegetable crops on the Moray Coast
- Green manures to increase N availability
- Amendments for soil health in top fruit

Other knowledge exchange activities

The project team delivered events for 755 attendees, including 14 field trial events, 14 field lab meetings, 23 soil health grower workshops; 5 presentations reaching over 50 horticultural advisors. Details are given in the appendices. In addition, the project delivered five online live webinars which are also available as recordings; and 8 YouTube videos. The impact of the project has been increased by a strong media presence, appearing in over 30 articles, and the project team were present at 35 conferences and sector events.

Grower workshops

A highlight of the project has been the series of grower workshops held over the past two years. There have been 23 events at host farms across the UK. The events covered field vegetables, protected leafy growing, ornamental nursery stock, protected cut flowers, top fruit and soft fruit.

The workshops provided up-to-date information on best practice for soil health testing, both from a theoretical and practical perspective, and also offered practical steps to address soil health issues. At workshops participants were invited to share their knowledge and experience, while also learning from expert guest speakers, and taking part in farm walks, looking at soil health in practice.

Advisor workshops

Advisors work with growers on a regular basis and so workshops were designed to update them on the main findings and outputs of the project in the last quarter of the project.

Attendance at our workshops surpassed our targets and positive feedback was received.

Media and outreach

Media: Media interest both from trade and mainstream media has been strong throughout the project, demonstrating that soil health is topical for the food production industry.

Highlights in Year 3 have been 'Field Lab studies soil health across the rotation' in the *Farmers Guardian*, 'DIY soil testing' in *Tillage Magazine*, 'On farm trials look at methods of improving orchard soil-health' in the *Fruit Grower*, and 'Soil health – What should the doctor order?' in *Soil Use and Management*. Project articles also featured in the AHDB Horticulture Grower Magazine.

Overall the project has featured in 30 major articles, and the team has published 7 original blog posts.

Outreach: The project team have met growers and advisors at 35 conferences and sector events over the course of the project and built a network of growers via sign-ups at events, website, newsletters, and twitter. By the end of the project the network had 690 members as

well as 1475 followers on Twitter. The team has kept this network informed of upcoming events and the latest project publications via the broadcast email, the 'GREATsoils bulletin'.

Summing up success of programme and legacy

Overall the project delivered on all its key objectives. Growers engaged with the programme of workshops, trials, and resources, while the wider sector has helped to amplify that work through the media and outreach elements of the project. The project will have a significant legacy, not just through the concrete outputs of AHDB factsheets, films, and webinars but through ongoing groups, trials and conversations that growers and advisors will continue to have. The project has helped to raise the profile of soil health in the growing industry and improved grower skills and confidence in assessing and improving soils' health.

Financial Benefits

Is there money in soil health?

Drawing accurate financial conclusions from soil health improvements is not easy, particularly in the short-term. There is also significant variation in the potential financial benefits depending on soil type and crops grown. The motivation for most growers is not short-term gain but long-term investment in the resilience of their soils and business.

However, financial incentive helps to convince growers to spend time and money on assessing and improving soil health. Anecdotal evidence was collected throughout the project to build a picture of how improving soil health also improves the profitability as illustrated by two examples.

JEPCO – short-term green manures

In 2017, JEPCO took part in a GREATsoils Field Lab, part-sponsored by Innovative Farmers (www.innovativefarmers.org). Part of the trial looked at the impact on agronomy of growing wholehead lettuce crops following an overwintered green manure (King's Italian ryegrass mix).

The grower felt that cultivations were easier and that JEPCO had used less diesel, particularly with its triple bed tiller, where around 10 litres per hour were saved. They also found that water infiltration into the soil was improved where the lettuce crops had followed green manures. For example, in late Summer 2017, following a wet spell when around 75mm of rain fell in just over 24 hours, the grower noticed that water disappeared off the beds a lot quicker where the lettuce had followed a green manure crop.

There was a 7.9 per cent increase in lettuce head weights where the crop was grown following the overwintering green manure. It is important to note that only a small trial area was planted and the trial was not replicated. The increased weights were down to both bigger heads and improved integrity of leaf structure. The grower felt that the improved leaf structure would potentially give a longer shelf life and that since the crop was more consistent in size and shape, harvesting was easier, which was likely to further reduce costs. The grower admitted that the incorporation of the cover crop was challenging. However, he felt that there were clear indications of benefits to both soils and cash crops from growing the cover crop. The findings are documented in the GREATsoils factsheet '[Short-term green manures for intensively cultivated horticultural soils](#)'.

Molyneux Farm – Nitrogen availability following green manures

This GREATsoils field lab aimed to compare how different green manures affect the availability of nitrogen (N) and key nutrients to a following spring green crop. N availability was measured via soil analysis and also tissue analysis of the green manure and crop plants.

Initial cost-benefit analysis from the one year trial showed that the cost per kg of nitrogen supplied by the green manure and the synthetic nitrogen were broadly similar. For the N treatment it was estimated at £0.12 £/kg, which was the same as the green manure 'Mix', a penny higher than the 'legume' and a penny lower than the 'non legume' (Table 2). Despite such small differences, with large volumes of product coming off the field, 1 pence per kg can add up to a large amount of money.

Treatment	Cost of Field operations (£/ha)	Cost of treatment (£/ha)	Total Cost December (£/ha)	Cost per kg N added £/ha	Cost per kg N uptake £/ha (using NUE)	Cost per unit output crop Yield (£/kg)
Control	223	0	223	0	0	0.15
Green manure - legume	212.4	89.8	302.2	1.16	2.09	0.11
Green manure - non legume	212.4	109.7	322.1	1.99	2.64	0.13
Green manure - mix	212.4	106.45	318.85	1.26	2.23	0.12
nitrogen	264	98	362	0.73	1.25	0.12

Table 2: Cost benefit analysis of Green Manures to Increase N availability field lab

Additional benefits from the green manures such as reduction in soil erosion, weed suppression and enhancing biodiversity are not included in the analysis, but would have a benefit to the soil and crop if green manures were included as a permanent part of the growing system.

The general conclusion of the project is that there are many methods of increasing soil health that will bring financial benefits and resilience to growing systems, but that finding the most cost-effect strategy for any particular business takes time and experimentation.

Action Points

1. Simple and practical soil assessment tools can be very useful to growers who aim to evaluate the health of their soils, who wish to monitor changes in soils over time (e.g. structure, fertility etc.), or who aim to assess the effects of certain soil management strategies and activities. Most of the soil assessment methods and tools do not need specialist knowledge or equipment.
2. Doing an infiltration test is a useful way to quickly assess compaction and soil structure. It is easy to do and generates results that are easy to translate into soil management strategies.
3. Earthworm counting has some use in field cropping, although growers need to ensure that this is done at the right time of year and in appropriate soil conditions.
4. Fruit growers can use the Visual Soil Assessment tool developed by Eblex/Dairy co (there is no specific horticultural one available).
5. For all systems the simple compaction test, using a blunt knife, soil probe or corer was a useful tool for soil structure and compaction assessment. Growers found it very fast, cheap and easy to use to locate areas of compaction and the more frequently they used the method the more able they became in estimating the depth of the compacted layer.
6. Laboratory-based soil biology tests (e.g. respiration, DNA fingerprinting) are developing rapidly and they are likely to have potential in the future. Protected cropping growers saw more potential in these tests than other crop growers.
7. Assessing soil health is a not a short-term activity; growers should be prepared to monitor improvements over the long-term.

Action points on improving soil health

1. Much of the learning from this project came from growers exchanging knowledge and experiences. Growers should be encouraged to talk to their neighbours, colleagues and other growers in different parts of the country about soil health.
2. There is likely to be a green manure/cover that will improve soil health in any particular growing system. Trialling different green manures and different sowing dates is important.
3. When improving soil health consider also the uncropped areas, improving the health of access routes or marginal areas will have an impact on the general soil health within the cropped area.

Soil Health Testing - Findings

- Routine analysis is essential. Do it well prior to every high value crop going in. Collect basic soil health information which affects crop yield and quality.
- Spend the time sampling properly – the results are only as useful as the quality of the sample itself.
- Choose your method (and ideally your soils laboratory too) and stick to them. It is important that variation in results is real, and not due to differences in methods or labs used.
- Look at what's possible for your soil by assessing soil health in the field margins.
- Soil physical assessments are very useful, whether documented or not.
- Learn how to quickly assess whether soils are functioning as well as they could, given the crop, system and weather.
- Question why soils are in the condition that they are.
- Records should be kept to build up pictures of what is “normal” for particular fields in a particular rotation. The impact of management changes can then be measured against earlier results.

Methods:

Visual Soil Assessment - Conduct regular test digs. Look for evidence of good soil colours, healthy soil smells, good rooting, visible pore spaces and good structure versus mottling, anaerobic smells, compaction, limited rooting, deformed or horizontal roots, platyness and drainage problems. It was found that the Healthy Grassland Assessment Tool⁴ can be a useful tool to score the VSA. Results were however found to be subjective and based on the interpretation of the tester - to build a picture over time they should be conducted by the same person. Growing systems where the soil had been “bed-formed” (for example for some root and field vegetables) using VSA did not prove useful as all visible soil structure was absent.

Earthworm counts - can be a useful indicator for soil fertility, health and organic matter, but can also be very time consuming. Results should be interpreted with care (since soil moisture affects the results so much). AHDB has published a factsheet on how to count earthworms and produced a counting earthworms record template; both of which are available on the GREATsoils website. In intensive growing systems earthworms may not be present. Also when heavy tillage machinery and tools are used, earthworm populations can decrease very quickly.

Soil Health Laboratory Tests - These are relatively newly developed laboratory tests, often providing an overall soil health index or score based on chemical soil health indicators (P, K, Mg, pH, total soil organic matter), physical indicators (texture) and biological indicators (respiration), with certain soil management recommendations derived from the results. Such laboratory tests were seen by the growers in the trials as potentially very useful in the future, once more information is available about soil biology indicators, and once useful testing procedures/protocols are developed for routine soil biology testing and monitoring over time. Soil respiration measurements - Can be a useful blunt instrument to measure soil health, but it is not clear yet how results should be interpreted in terms of being able to recommend management options. Useful to test pre, during and post-crop in order to build a picture of what is normal for particular fields.

Simple Compaction Test – Although measuring compaction is very subjective with the result being the tester’s interpretation of the resistance felt in probing the ground, it is quick and easy to perform. The test can be conducted with a compaction probe, but some growers prefer a blunt knife. With experience some growers stated that they were able to measure the depth of the compacted layer. This test was popular across all horticultural growing systems.

⁴ The Healthy Grassland Assessment Tool was developed by EBLEX-DairyCo. Now AHDB Beef & Lamb and AHDB Dairy

Simple Infiltration Rates - The test was seen by growers as a useful tool for assessing soil structure and compaction. Growers in all systems liked the test as it is easy to do and generates self-explanatory results. Depending on the soil type, structure or moisture content, it can take a long time to wait for 800ml of water to infiltrate into soil through a piece of drain pipe at several spots in a field which can result in growers losing patience.