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THE AUSTRALIAN AGRONOMIST MAGAZINE

Crops: Light environment modifications could maximise productivity

Plant tissue engineering improves drought and salinity tolerance

Space to grow, or grow in space -how vertical farms could be ready to take-off

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PLANT TISSUE ENGINEERING IMPROVES DROUGHT AND SALINITY TOLERANCE

AFTER SEVERAL YEARS OF EXPERIMENTATION, SCIENTISTS HAVE ENGINEERED THALE CRESS, OR ARABIDOPSIS THALIANA, TO BEHAVE LIKE A SUCCULENT, IMPROVING WATER-USE EFFICIENCY, SALINITY TOLERANCE AND REDUCING THE EFFECTS OF DROUGHT.

The tissue succulence engineering method devised for this small flowering plant can be used in other plants to improve drought and salinity tolerance with the goal of moving this approach into food and bioenergy crops.

"Water-storing tissue is one of the most successful adaptations in plants that enables them to survive long periods of drought. This anatomical trait will become more important as global temperatures rise, increasing the magnitude and duration of drought events during the 21st century," said University of Nevada, Reno Biochemistry and Molecular Biology Professor John Cushman, co-author of a new scientific paper on plant tissue succulence published in the Plant Journal.

The work will be combined with another of Cushman's projects: engineering another trait called crassulacean acid metabolism (CAM), a water-conserving mode of photosynthesis that can be applied to plants to improve water-use efficiency.

Arabidopsis thaliana, Thale Cress, engineered to behave like a succulent, improving water-use efficiency, salinity tolerance and reducing the effects of drought. Leaf anatomy changes to be helpful in crassulacean acid metabolism (CAM) plant engineering work. Photo credit: University of Nevada, Reno

"The two adaptations work hand-in-hand," Cushman, of the University's College of Agriculture, Biotechnology & Natural Resources, said. "Our overall goal is to engineer CAM, but in order to do this efficiently we needed to engineer a leaf anatomy that had larger cells to store malic acid that accumulates in the plant at night. An added bonus was that these larger cells also served to store water to overcome drought and to dilute salt and other ions taken up by the plant, making them more salt tolerant."

When a plant takes up carbon dioxide, it takes it through its pores on the leaf, called stomata. They open their stomata so carbon dioxide goes in, and then it gets fixed into sugars and all other compounds that support most of life on earth. But, when stomata open, not only does carbon dioxide come in, but also water vapour goes out, and because plants transpire to cool themselves, they lose enormous amounts of water."

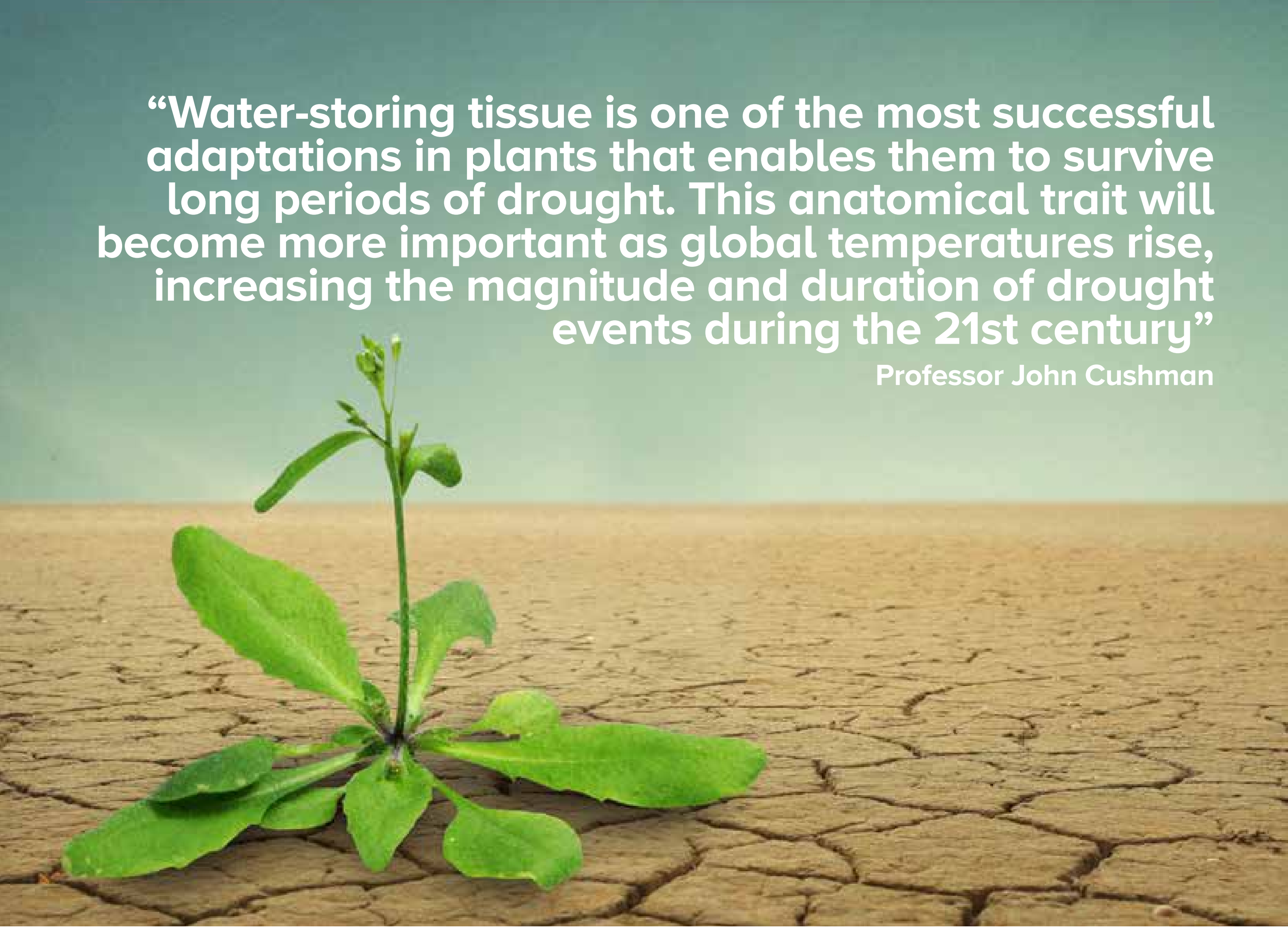
Cushman's team of scientists created genetically modified A. thaliana with increased cell size resulting in larger plants with increased leaf thickness, more water-storage capacity, and fewer and less open stomatal pores to limit water loss from the leaf due to the overexpression of a gene, known as VvCEB1 to scientists. The gene is involved in the cell expansion phase of berry development in wine grapes.

The resulting tissue succulence serves two purposes.

"Larger cells have larger vacuoles to store malate at night, which serves as the carbon source for carbon dioxide release and refixation, by what's called Rubisco enzyme action, during the day

“Water-storing tissue is one of the most successful adaptations in plants that enables them to survive long periods of drought. This anatomical trait will become more important as global temperatures rise, increasing the magnitude and duration of drought events during the 21st century”

Professor John Cushman



behind closed stomatal pores, thereby limiting photorespiration and water loss" Cushman said. "And, the succulent tissue traps the carbon dioxide that is released during the day from the decarboxylation of malate so that it can be refixed more efficiently by Rubisco.

One of the major benefits of VvCEB1 gene overexpression was the observed improvements in whole-plant instantaneous and integrated water-use efficiency, which increased up to 2.6-fold and 2.3-fold, respectively. Water-use efficiency is the ratio of carbon fixed or biomass produced to the rate of transpiration or water loss by the plant. These improvements were correlated with the degree of leaf thickness and tissue succulence, as well as lower stomatal pore density and reduced pore openings.

"We tried a number of candidate genes, but we only observed this remarkable phenotype with the VvCEB1 gene," Cushman said. "We typically will survey between 10 to 30 independent transgenic lines, and then these are grown for two to three generations before detailed testing."

Arabidopsis thaliana is a powerful model for the study of growth and development processes in plants. It is a small weed-like plant that has a short generation time of about six weeks and grows well under laboratory conditions where it produces large amounts of seeds.

Engineered tissue succulence is expected to provide an effective strategy for improving water?use efficiency, drought avoidance or attenuation, salinity tolerance and for optimising performance of CAM.

CAM plants are very smart, keeping their stomata closed during the day, and only opening them at night when evapotranspiration is low because it is cooler and the sun is not shining, Cushman explained. The significance of CAM is found in its unique ability to conserve water. Where most plants would take in carbon dioxide during the day, CAM plants do so at night.

"Essentially, CAM plants are five to six times more water-use efficient, whereas most plants are very water inefficient," he said. "The tissue succulence associated with CAM and other adaptive traits like thicker cuticles and the accumulation of epicuticular waxes, means that they can reduce leaf heating during the day by reflecting some of the light hitting the leaf. Many desert-adapted CAM plants also have a greater ability to tolerate high temperatures."

With demand for agricultural products expected to increase by as much as 70% to serve a growing human population, which is predicted to reach about 9.6 billion by 2050, Cushman and his team are pursuing these biotechnology solutions to address potential future food and bioenergy shortages.

"We plan to move both tissue succulence and CAM engineering into crop plants. This current work is proof-of-concept," Cushman said.

Journal Reference:

Sung Don Lim, Jesse A. Mayer, Won Cheol Yim, John C. Cushman. Plant tissue succulence engineering improves water- use efficiency, water- deficit stress attenuation and salinity tolerance in Arabidopsis. The Plant Journal, 2020; DOI: 10.1111/tpj.14783

NEWLY IDENTIFIED GENE REDUCES POLLEN NUMBER OF PLANTS

Already in the 19th century Charles Darwin recognised that the number of male gametes - pollen for plants, sperm for animals - is highly variable among individuals and species. At first sight a high number of male gametes seems beneficial for the competition among males to produce more offspring. However, many domesticated species have a reduced number of male gametes. In theory it might be advantageous to reduce the cost of producing male gametes, for example when the rate of self-fertilisation or inbreeding is high and fewer male gametes are necessary for successful reproduction.

Genome analysis of self-fertilising plant

"So far there has been little evidence to support this idea, because the production of male gametes is a complex trait affected by many genes with small effects and its molecular basis remained unknown", says Kentaro Shimizu, Professor for Evolutionary Biology and Environmental Studies at the University of Zurich (UZH). An international study under his lead now provides such evidence and demonstrates that a reduction in pollen number is not necessarily deleterious but rather advantageous in a self-fertilising species.

For their investigation the researchers used the well-characterised model plant Arabidopsis thaliana that is mainly self-fertilising and has a reduced number of pollen grains compared to its relatives in the wild. They counted the pollen number of 144 plants with distinct genetic background and found variations from 2,000 to 8,000 pollen grains per flower. They then compared the entire genetic information of these variants, looking for differences between plants with higher and lower pollen numbers.

RDP1 gene controls pollen production

This computational analysis, a so-called genome-wide association study, revealed one gene that affects the number of pollen each plant produces, which was subsequently named REDUCED POLLEN NUMBER1 (RDP1) gene. Using the novel genome editing technology CRISPR-Cas9 the researchers created several mutant variants of the RDP1 gene, both in plants with high and low pollen number. They crossed the mutated plants with each other and counted the pollen the hybrid offspring produced. "These experiments confirmed the subtle but significant effect of the RDP1 gene", says co-author Misako Yamazaki, a technical staff of the Shimizu group. A comparison with other organisms revealed that the gene encodes a factor that promotes the building of ribosomes, the cellular factories for protein production.

Less pollen confers higher fitness

Next, the team investigated if the reduction in pollen number is positively selected for and did not happen incidentally. For this they used a statistical method to gain insight into the evolution of the RDP1 gene within model plants with different pollen production. The results showed that the trait for reduced pollen number has indeed been under positive selection.

Furthermore, the research team studied the evolution of the many genomic regions associated with pollen number. The selection on pollen number was very strong - in comparison to previous studies of more than 100 traits such as disease-resistance and environmental responses. This supports the importance of pollen number for reproductive success.

Optimising fertilisation in agriculture

"The evidence supports the theoretical prediction that reduced investment in male gametes is advantageous. This is not only important for evolutionary biology but also for the practice of plant breeding and domestication in general", explains Shimizu. "Many crop plants have a reduced number of pollen due to domestication. Lowering the cost of producing pollen may increase crop yield. On the other hand, too few pollen grains might be an obstacle to breeding and seed production. Our study opens the way for molecular breeding of the optimal pollen number."

The plant species Arabidopsis thaliana is used as a model organism in research all over the world. Photo credit: Misako Yamazaki

Matured anthers of Arabidopsis thaliana: Compared to the wild type (left), the rdp1 mutant (right) contains only half of the pollen grains (in magenta). Photo credit: Hiroyuki Kakui

Journal Reference:

Tsuchimatsu, T., Kakui, H., Yamazaki, M. et al. Adaptive reduction of male gamete number in the selfing plant Arabidopsis thaliana. Nat Commun 11, 2885 (2020). https://doi.org/10.1038/s41467-020-16679-7

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Brassica Vegetables (Broccoli, Brussel Sprouts, Cabbage, Cauliflower)	Downy Mildew *(Peronospora spp)* White Blister *(Albugo spp)*
Cucurbit Vegetables (Cucumber, Melons, Pumpkin, Squash, Zucchini)	Powdery Mildew *(Sphaerotheca spp)*
Fruiting Vegetables (Capsicum, Eggplant, Peppers, Tomato)	Powdery Mildew *(Leveillula spp)*
Potatoes (Seed) (Dipping & Spraying)	Powdery Scab *(Spongospora subterranea)* Rhizoctonia Rot *(Black Scab)* *(Rhizoctonia solani)*
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SMALL SEE-THROUGH CONTAINER IMPROVES PLANT MICROGRAFTING

A type of plant grafting needing a tremendous amount of precision and skill has now been made faster and easier thanks to a simple transparent container. Researchers at Nagoya University have developed a micrografting device that guides seedling growth and facilitates the grafting of the embryonic shoots of one plant onto the tiny stalks of another. The new device shows potential for facilitating research into plant signalling. The details were published in The Plant Journal. The concept can be expanded to crop grafting to develop more resilient crop varieties. The system has already been developed and applied in tomato grafting by GRA&GREEN Inc., a start-up venture company from Nagoya University.

Plant grafting is a centuries-old technique that involves attaching the growth of the upper part of one plant, called the scion, onto the lower part of another, called the rootstock. In more recent years, some plant experts have started using micrografting: transferring a very tiny part of a newly forming shoot onto the rootstock of a very young plant. Plant experts use this technique because it facilitates studies on the signalling system that controls plant growth and development. The problem is that this technique needs personnel who can skilfully and precisely do this under a microscope.

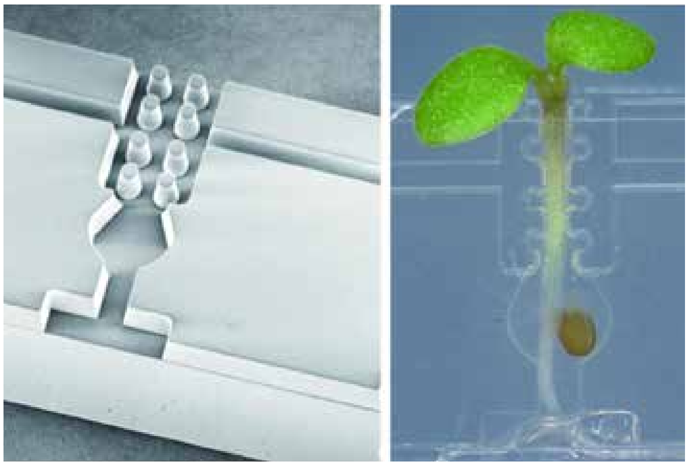
"We developed a silicon-based chip to improve the ease-of-use, efficiency, and success rate of micrografting, even for untrained users," says Nagoya University bioscientist Michitaka Notaguchi.

The device, made from a silicon elastomer called polydimethylsiloxane, is 3.6mm wide by 17mm long and contains four identical units. Each unit is formed of a small pocket in which the plant seed is placed, a lower pathway for root growth, and an upper pathway that guides shoot growth. A horizontal slot passes through the top parts of the four units. It is used to insert a tiny blade that cuts off the scions of the developing plants. Scions from other plants are then placed into the upper pathways for grafting onto the rootstocks.

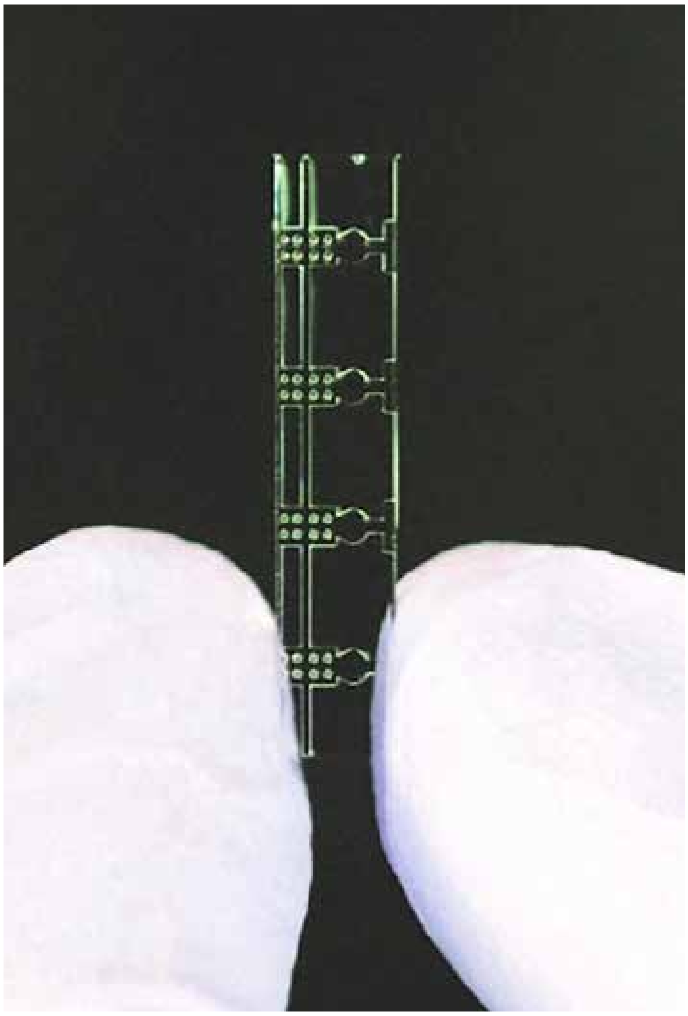
The device makes grafting much easier by facilitating the precise and delicate contact between the new scions and the original rootstocks. The researchers achieved a 48-88% grafting success rate using the device. Grafting was most successful when performed at 27°C and when the agar medium used to support seed sprouting contained 0.5% sucrose.

They then used the device to understand how the compound nicotianamine transports iron across different parts of a plant. In separate devices, they grew normal Arabidopsis plants, which are commonly used in plant research, and a mutant Arabidopsis that lacks nicotianamine. They then grafted normal Arabidopsis scions onto mutant rootstocks and vice versa. Their tests showed nicotianamine originating from the shoot or root can move to other areas and mobilize iron necessary for plant growth and development.

The team next aims to further develop their device to make it suitable for grafting other types of plants with different seed sizes. "Developing supportive devices for grafting experiments will help activate research in this area," says Notaguchi.



Each unit in the device is designed to control and support plant growth, cutting, and grafting.
Photo credit: The Plant Journal



The transparent device is tiny and allows the growth of four separate seedlings.
Photo credit: The Plant Journal

Journal Reference:

Hiroki Tsutsui, Naoki Yanagisawa, Yaichi Kawakatsu, Shuka Ikematsu, Yu Sawai, Ryo Tabata, Hideyuki Arata, Tetsuya Higashiyama, Michitaka Notaguchi. Micrografting device for testing systemic signaling in Arabidopsis. The Plant Journal, 2020; DOI: 10.1111/tpj.14768

THREATS TO GLOBAL FOOD SECURITY FROM EMERGING FUNGAL CROP PATHOGENS

Amongst the world's most challenging problems is the need to feed an ever-growing global population sustainably.

Securing the food supply is of paramount importance, and more attention must be given to the threat from fungal pathogens competing with us for our own crops.

We need to raise awareness of this fact across all of society - from politicians to the general public.

Research at the University of Exeter has a strong emphasis on understanding fungal plant disease and in developing new ways to protect our crops.

In an article, published in Nature Food, led by Professor Sarah Gurr and Dr Helen Fones (UKRI Fellow), a consortium of world-leading Exeter-based fungal researchers has merged their expertise to highlight the threat of fungal disease for our food security.

Professor Gurr said "Over the past centuries, crop diseases have led to the starvation of the people, the ruination of economies and the downfall of governments.

"Today, the threat to plants of fungal infection outstrips that posed by bacterial and viral diseases combined.

"Indeed, fungal and oomycete diseases have been increasing in severity and scale since the mid 20th Century and now pose a very serious threat to global food security.

"We face a future blighted by known adversaries, by new variants of old foes and by new diseases.

"Modern agricultural intensification practices have heightened this challenge.

"Moreover, climate change compounds the saga as we see altered disease demographics - pathogens are on the move, as shown so elegantly by Professor Dan Bebber and PhD student Tom Chaloner (co-authors)."

Dr Helen Fones said "Our review looks to the future; summarising our main challenges and knowledge gaps, and highlighting the research needed to face the threat of emerging crop pathogens.

"We consider this challenge in terms of both the crops essential for providing calories and those commodities that fuel global trade and the global economy that we rely upon.

"We show that in this increasingly interconnected world we must be prepared, with more robust agricultural systems, to weather pathogen outbreaks that might impact food production either in individual countries or around the globe.

"From writing the article to its publication, COVID-19 has arisen and demonstrated how deeply affected we can all be by outbreaks of new pathogens.

"This reminds us that we need to make agriculture less reliant on fungicides which are also used to treat fungal infections in humans, as this can lead to resistance moving from agricultural to clinical settings (as highlighted in an article in Science in 2018, authored by Sarah Gurr, with Mat Fisher from Imperial College).

"Here, we discuss the need for new fungicides, especially ones that have complex modes of action, and are harder for the pathogen to develop resistance to."

But not all is "doom and gloom" as illustrated in recent work, led by co-author Professor Gero Steinberg.

In a recent publication in the journal Nature Communications, Exeter scientists described the development of a new fungicide, which holds the potential to help protect our food crops against fungal pathogens.

Professor Steinberg said "The challenge of fungal crop disease is enormous.

"With the help of the BBSRC and the University of Exeter, Sarah Gurr's and my research group are following a dual strategy: to raise awareness, illustrated by this article in Nature Food, and also to develop new 'weapons' in our fight to secure global food security."

Dr Will Kay (co-author) with Prof Sarah Gurr, establishing banana plants for the group's work at Exeter on Panama disease. Photo credit: University of Exeter

Journal Reference:

Fones, H.N., Bebber, D.P., Chaloner, T.M. et al. Threats to global food security from emerging fungal and oomycete crop pathogens. Nat Food (2020). https://doi.org/10.1038/s43016-020-0075-0

REWIRING PLANT REPRODUCTION FOR HIGHER SEED YIELDS

Exploiting quirks in plant reproduction could boost yields in two staple crops, sorghum and cowpea, for crop farming communities in sub-Saharan Africa (SA).

That's the endgame of Hy-Gain, a multi-million dollar international collaborative research project led by University of Queensland's Professor Anna Koltunow, with support from the Bill & Melinda Gates Foundation.

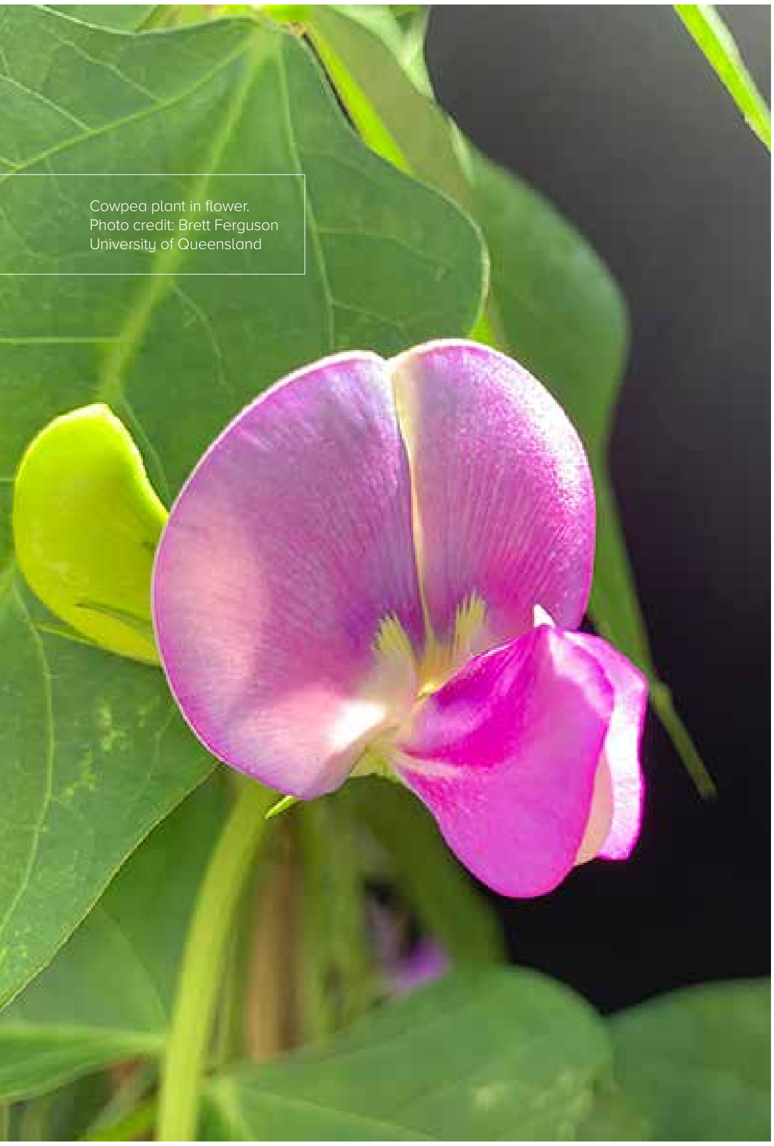
"Hy-Gain aims to empower smallholder farmers to save and sow high yielding sorghum and cowpea hybrid seed," Professor Anna Koltunow said.

Hybrids - the offspring of in-bred, genetically-divergent parents - can be exceptionally tough and produce significantly higher yield gains.

But these traits are not preserved in any of the seeds the hybrid plant produces because they form via sexual seed formation; a pathway, requiring meiosis and fertilisation.

Professor Koltunow said sexual reproduction naturally separated genetic traits in seeds formed in flowers of the hybrid.

"The key to preserving the seed yield gains of hybrids from one generation to the next lies with one of the quirkiest aspects of plant reproductive biology: 'apomixis' - a naturally occurring asexual seed formation pathway in plants," she said.



Cowpea plant in flower.
Photo credit: Brett Ferguson
University of Queensland

"If a high quality hybrid seed is equipped with genetic switches to allow it to produce a plant with new seeds asexually, that is without meiosis and fertilisation, the resulting seeds would produce plants that are identical clones of the hybrid parent.

"This would allow hybrid seed to be retained and re-sown on-farm for a number of generations, with the farmer able to realise yield gains and pocket the cost of purchasing hybrid seed each year."

The Hy-Gain project, which involves six research organisations and a multinational seed company, follows a prior five-year project led by Professor Koltunow, also funded in part by the Bill & Melinda Gates Foundation.

Professor Koltunow said one of the most striking aspects identified in the previous research was the relatively small number of changes required to switch from the sexual to an asexual mode of seed formation.

"In Hy-Gain, we are developing plant prototypes to test if we can lock in those valuable hybrid characteristics over generations when the hybrid seed is planted, flowers, and produces more seed," she said.

"The goal is to deliver African-adapted sorghum and cowpea varieties with improved yield and resilience traits, targeted to specific regions.

"The Hy-Gain team is aiming for forward delivery of a very useful technology that can be readily, and cheaply, used in breeding.

"In-country cowpea and sorghum breeders need to be able to make decisions on varieties to develop in their regions, as they are connected with their farming communities."

Professor Koltunow said, if successful, the Hy-Gain technology was a potential "game-changer" for farmers everywhere, including within Australia's sorghum breeding program.

"This technology could enable much more effective plant breeding and seed production at a time when the grains industry is dealing with the challenge of maintaining yields under increasingly hotter and drier growing conditions," Professor Koltunow said.

The University of Queensland team includes world-leading sorghum researchers Professor David Jordan, Dr Emma Mace and Professor Ian Godwin from the Queensland Alliance for Agriculture and Food Innovation - a UQ research institute supported by industry and the Queensland Government, and Associate Professor Brett Ferguson from UQ's School of Agriculture and Food Sciences who has expertise in legumes.

Strong linkage to the Department of Agriculture and Fisheries, Queensland with its sorghum and legume breeding programs and facilities, provides significant opportunity for future crop testing.

This project is funded in part by the Bill & Melinda Gates Foundation with further support from The University of Queensland and the Department of Agriculture and Fisheries, Queensland.

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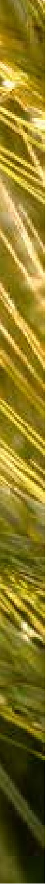


CROPS: LIGHT ENVIRONMENT MODIFICATIONS COULD MAXIMISE PRODUCTIVITY

THE CROPS WE GROW IN THE FIELD OFTEN FORM DENSE CANOPIES WITH MANY OVERLAPPING LEAVES, SUCH THAT YOUNG "SUN LEAVES" AT THE TOP OF THE CANOPY ARE EXPOSED TO FULL SUNLIGHT WITH OLDER "SHADE LEAVES" AT THE BOTTOM. IN ORDER TO MAXIMISE PHOTOSYNTHESIS, RESOURCE-USE EFFICIENCY, AND YIELD, SUN LEAVES TYPICALLY MAXIMISE PHOTOSYNTHETIC EFFICIENCY AT HIGH LIGHT, WHILE SHADE LEAVES MAXIMISE EFFICIENCY AT LOW LIGHT.

"However, in some of our most important crops, a maladaptation causes a loss of photosynthetic efficiency in leaves at the bottom of the canopy, which limits the plants' ability to photosynthesise and produce yields," said Charles Pignon, a former postdoctoral researcher at the University of Illinois. "In order to address this problem, it's important to know whether this is caused by leaves being older or exposed to a different light environment at the bottom of the canopy."

This question was answered in a recent study published in Frontiers in Plant Science, where researchers from the University of Illinois and the University of Oxford worked with maize and the bioenergy crop Miscanthus to find that the decline in the efficiency of leaves at the bottom of the canopy was not due to their age but to their altered light environment.

This work was conducted through the Illinois Summer Fellows (ISF) program. Launched in 2018, ISF allows undergraduate students to conduct plant science research alongside highly skilled scientists at Illinois. 2018 Fellows Robert Collison and Emma Raven worked with Pignon and Stephen Long, the Stanley O. Ikenberry Chair Professor of Plant Biology and Crop Sciences at Illinois, to confirm and better understand results from previous studies for Water Efficient Sorghum Technologies (WEST), a research project that aimed to develop bioenergy crops that produce more biomass with less water.

Photosynthesis is the natural process that plants use to convert sunlight into energy. Plants usually fall under the two main types of photosynthesis - C3 and C4. The difference between these types is that C4 plants have a mechanism that concentrates carbon dioxide inside their leaves, allowing them to photosynthesise more efficiently. However, most plants, trees, and crops operate using the less efficient C3 photosynthesis.

Both sun and shade leaves contribute to photosynthetic carbon assimilation, producing the sugars that feed the plant and fuel yield. Therefore, lower canopy photosynthesis is an important process that affects the yield of the whole plant, with an estimated 50 percent of total canopy carbon gain contributed by shade leaves.

Previous studies of C3 plants have shown that shaded leaves are typically more efficient than sun leaves at low light intensities, meaning shaded leaves adapt to their low light environment. However, a previous study by Pignon and Long showed that this is not the case for all plants. The canopies of maize and Miscanthus, C4 crops that usually photosynthesise more efficiently than C3 crops, had shade leaves that were less photosynthetically efficient, suggesting a maladaptation in these important crops.

"Shade leaves receive very little light, so they usually become very efficient with low light use," said Pignon, now a plant physiologist at Benson Hill in St. Louis. "Essentially, they make the most of what little light they do receive. However, in the C4 crops we studied, shade leaves in these crops not only receive very little light, but they also use it less efficiently. It's a very costly maladaptation in crops that are otherwise highly productive - hence our calling it an Achilles' heel."

With six to eight layers of leaves in our modern maize crop stands, most leaves are shaded and can account for half of the plant's growth during the critical phase of grain filling.

"In the previous study, researchers estimated that this maladaptation was causing a loss of 10 percent in potential canopy photosynthesis gain," said Raven, who recently graduated

> **"In some of our most important crops, a maladaptation causes a loss of photosynthetic efficiency in leaves at the bottom of the canopy, which limits the plants' ability to photosynthesise and produce yields"**
> **Charles Pignon**

from Oxford with plans to pursue her doctorate. "There are essentially two potential reasons: the age of the leaves or the light conditions, so we investigated which factor was causing this inefficiency."

Collison and Raven, co-first authors of this newly published paper, collected data and analysed the maximum quantum yield of photosynthesis - the maximum efficiency with which light is used to assimilate carbon - in leaves of the same chronological age but different light environments to discover the crops' Achilles' heel. This was achieved by comparing leaves of the same age in the centre of plots of these species versus those on the sunlight southern edge of these plots. From this, they showed that the poor photosynthetic efficiency of these crops' lower leaves is caused by altered light conditions and not age.

"Maize and Miscanthus are both closely related to sugarcane and sorghum, so other C4 crops could potentially have this loss in photosynthetic efficiency caused by the light environment," explained Collison, who has also graduated from Oxford and may pursue graduate studies. "By finding the cause of this loss in efficiency, we can begin to look at potential solutions to this problem, modifying plants to improve their productivity."

Illinois Summer Fellows Program

The ISF program has cultivated an environment where the Fellows have the independence needed to develop as scientists while knowing that they have the support and encouragement of their supervisors. Fellows are paired with a scientist supervisor to assist them with a specific element of a project aimed to increase crops' photosynthetic and/or water-use efficiency. The program aims to provide a rewarding experience that helps students develop as scientists, and ultimately, to consider pursuing careers in plant biology.

"The opportunity to travel to another country and conduct meaningful research in a real-world field environment alongside mentors in their field is invaluable," said Long, who launched and directs the ISF program at the Carl R. Woese Institute for Genomic Biology. "At the end of their time at Illinois, our Fellows have expressed that this experience allowed them to contribute to the world and take back valuable skills they can apply in their future endeavours as innovators in the field of agriculture and beyond."

Collison reflects on his time at Illinois as an experience that not many students, especially so early in their career, get to take part in. "The chance to do any research so early in your career as a scientist is really exciting," he said. "Everyone we met- including our supervisors and other scientists - was always willing to help us."

Raven also shared her insights on the value of doing research at Illinois and what differences there may be in other academic or work settings. "When you are attending lectures or practical classes, you never quite get that feeling of true ownership of your own projects because you just follow whatever your professor tells you to do," Raven said. "But having ownership of this paper at Illinois is gratifying. It is also exciting to be a part of something that is bigger than us and will ultimately help farmers in other countries to grow food more sustainably."

The ISF program is supported by Oxford University in England and the Realising Increased Photosynthetic Efficiency (RIPE), an international research project led by Illinois that is engineering crops to be more productive by improving photosynthesis. It is supported by the Bill & Melinda Gates Foundation, the U.S. Foundation for Food and Agriculture Research (FFAR), and the U.K. Government's Department for International Development (DFID).

Water Efficient Sorghum Technologies (WEST) is a research project that is developing bioenergy crops that require less water per acre, ensuring a sustainable source of biofuel. The project is supported by the Advanced Research Projects Agency-Energy and led by the University of Illinois in partnership with Cornell University, University of Nebraska-Lincoln, University of Wisconsin-Madison, and the USDA Agricultural Research Service.

Realising Increased Photosynthetic Efficiency (RIPE) aims to improve photosynthesis to equip farmers worldwide with higher-yielding crops to ensure everyone has enough food to lead a healthy, productive life. This international research project is sponsored by the Bill & Melinda Gates Foundation, the U.S. Foundation for Food and Agriculture Research, and the U.K. Government's Department for International Development.

Journal Reference:

Robert F. Collison, Emma C. Raven, Charles P. Pignon, Stephen P. Long. Light, Not Age, Underlies the Maladaptation of Maize and Miscanthus Photosynthesis to Self-Shading. Frontiers in Plant Science, 2020; 11 DOI: 10.3389/fpls.2020.00783

UNIVERSITY OF QUEENSLAND RESEARCHERS SOLVE A 50-YEAR-OLD ENZYME MYSTERY

Advanced herbicides and treatments for infection may result from the unravelling of a 50-year-old mystery by University of Queensland researchers.

The research team, led by UQ's Professor Luke Guddat, revealed the complete three-dimensional structure of an enzyme, providing the first step in the biosynthesis of three essential amino acids - leucine, valine and isoleucine.

"This is a major scientific advance, which has been pursued globally by chemists for half a century," Professor Guddat said.

"This information provides new insights into an important enzyme - acetohydroxyacid synthase - a target for more than 50 commercial herbicides.

"It's also a potential target for new drugs to treat infections such as tuberculosis and invasive Candida infections."

Using advanced techniques such as cryo-electron microscopy and X-ray crystallography, the team deciphered the structure of the plant and fungal versions of the enzyme.

"We identified how this highly complex structure is assembled, which is the highly unusual shape of a Maltese Cross," Professor Guddat said. "Coincidently, the Maltese Cross also features as a part of UQ's logo."

Professor Guddat said the discovery could have big implications for global agriculture.

"Sulfometuron is a herbicide that targets this enzyme, and was widely used in the 1990s for wheat crop protection throughout Australia," he said. "But today it is completely ineffective due to the development of resistance.

"With this new insight, we will be able to make changes to existing herbicides, restoring options for future herbicide application."

Professor Guddat said the enzyme was only found in plants and microbes, not in humans.

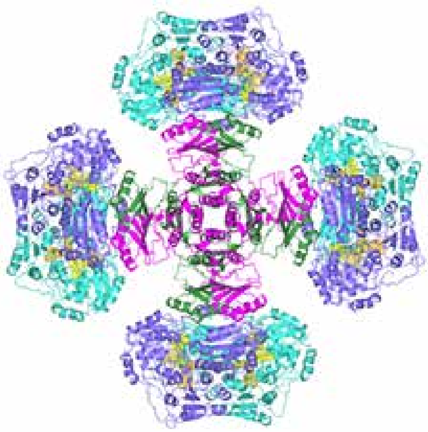
"For this reason, the herbicides and drugs that it targets are likely to be safe and non-toxic to all mammals," he said.

"And another surprising finding of the research was the role that the molecule known as ATP plays in the regulation of the enzyme.

"Normally ATP plays a role in providing energy to all living cells," Professor Guddat said. "However, here it is acting like a piece of glue to hold the structure together."

"They're fascinating findings for us, and we're excited for new opportunities for targeted design of next-gen herbicides and antimicrobial agents."

The majority of the study was undertaken by Dr Thierry Lonhienne and UQ PhD candidate, Yu Shang Low, who worked closely with the ShanghaiTech University, China to obtain the cryo-EM images for the plant enzyme.



Journal Reference:

Lonhienne, T., Low, Y.S., Garcia, M.D. et al. Structures of fungal and plant acetohydroxyacid synthases. Nature (2020). https://doi.org/10.1038/s41586-020-2514-3

HOW GLOBAL RESPONSES TO COVID-19 COULD THREATEN GLOBAL FOOD SECURITY

The ongoing COVID-19 pandemic has forced nations worldwide to implement unprecedented social measures to stem the rapid spread of the virus. In a Policy Forum, David Laborde and colleagues discuss how the economic fallout from these efforts and impacts on food supply chains worldwide puts global food security at risk. Laborde et al. argue that these new threats need to be acknowledged and addressed by governments worldwide to prevent the COVID-19 health crisis from becoming a global food crisis as well. According to the authors, COVID-19's most direct impacts on food security stem from the economic damage associated with the extreme measures designed to contain the virus, which has caused many around the world to lose their incomes and ability to buy food - particularly for the world's most poverty-stricken populations. What's more, disruptions to agricultural supply, production, and distribution of foods due to labour shortages, widespread industry closures, and restrictions on the movement of people and goods have placed further strain on the global food system. To address these emerging threats to global food security, Laborde et al. suggest that governments of both rich and poor nations should first focus on ways to provide income support to protect food access for their most vulnerable citizens. Novel strategies to enact safe social distancing in ways that facilitate food production and trade and allow for the movement of food-sector workers could also minimize disruptions to food systems and prevent looming food shortages as the COVID-19 pandemic progresses.

Journal Reference:

David Laborde, Will Martin, Johan Swinnen, Rob Vos. COVID-19 risks to global food security. 2020; https://doi.org/10.1126/science.abc4765

POST-PANDEMIC BRAVE NEW WORLD OF AGRICULTURE

Robots working in abattoirs, sky-high vertical farms, more gene-edited foods in our supermarkets and automated farming systems could all help guarantee food supply in the next pandemic.

University of Queensland Professor Robert Henry said the technologies had all been in various stages of planning prior to COVID-19, but food producers would now be moving much faster to prepare for the next pandemic.

"Food processing facilities like meat works have had to close due to a staff member being infected with the coronavirus, and all food processing industries where you have workers in small confined spaces are similarly at risk," Professor Henry said.

Professor Henry, who is the Director of the Queensland Alliance for Agriculture and Food Innovation (QAAFI), said roboticised abattoirs and automated harvesting and production facilities would also reduce the risk of transmission of pathogens among workers but also the spread of viruses via the food itself.

"COVID does not seem to be transmissible from an infected human touching food but a future pandemic virus might be transmitted this way, so automating the food supply chain reduces this risk.

"It also minimises reliance on human workers that are not available due to migration restrictions and border closures."

Professor Henry said protected cropping, including vertical farms - or growing food in vertically stacked layers similar to a skyscraper building - would optimise plant growth and enable control over climate variations, chemical inputs and water resources.

"There will have to be policies that drive consumer acceptance of gene edited foods, which some consumers consider as GMOs.

"Advanced technologies need to be adopted globally, in each region, to deliver local food production capability that could provide secure sources of food in future pandemics.

"We will need to design crops to suit automated systems - for example for fruit to grow in places where it can be harvested robotically."

Professor Henry said the ongoing COVID-19 pandemic made it difficult to fully assess the impact on agriculture and food supply.

He said despite growing stocks of foods such as cereals, it was estimated the number of people facing a food crisis will grow from 135 million to 265 million by the end of 2020.

"It may seem to those of us in Western countries that the only impact on food supply has been a rush on pasta and rice in the supermarket and home-baking but the loss of income caused by the pandemic has hit some countries in Africa hard.

'We are in a situation where we have food surpluses while there has been a doubling in the number of people who can't afford to eat - and the situation is likely to get worse." Professor Henry said increased investment in agricultural research and development would support enhanced food security.

Robert Henry is a Professor of Innovation at the University of Queensland, Australia, and Director of the Queensland Alliance for Agriculture and Food Innovation (QAAFI). Photo credit: QAAFI

Journal Reference:

Robert Henry, Innovations in Agriculture and Food Supply in Response to the COVID-19 Pandemic, Molecular Plant (2020). DOI: 10.1016/j.molp.2020.07.011

CRUCIAL ADVICE FOR FARMERS ON RESISTANCE MANAGEMENT NOW AVAILABLE ONLINE

CropLife Australia has released its updated Resistance Management Strategies for fungicides, herbicides and insecticides, featuring a newly developed strategy for fall armyworm.

Chief Executive Officer of CropLife Australia, Mr Matthew Cossey, said, “Food crops compete with tens of thousands of weeds, plant-eating insects, viruses, fungi and more - all with the ability to devastate farming operations. Farmers must adopt agricultural practices that control pests, while reducing their environmental impact and limiting resistance issues.

“Having an integrated pest management system and an effective resistance management strategy for chemical crop protection products is crucial to the long-term viability and profitability of Australian farming.”

With the devastating pest, the fall armyworm, now in Australia, the Australian Pesticides and Veterinary Medicines Authority (APVMA) has approved a number of emergency use permits to provide protection options for a range of crops.

Mr Cossey continued, “Fall armyworm has been devastating for many overseas farming sectors. This is a pest that now poses a serious threat to Australian crops.

“The Australian Pesticides and Veterinary Medicines Authority has responded by approving a number of emergency permits for farmers to utilise should they encounter fall armyworm on their crops.

“The plant science industry is focussed on providing growers with as many solutions as possible to manage pest incursions - including fall armyworm.

“That’s why we have prepared a fall armyworm strategy as part of our 2020 Resistance Management Strategies. These strategies ensure important crop protection products remain effective tools for farmers.

“Growers encountering fall armyworm should utilise the emergency permits approved by the APVMA in line with their integrated pest management strategy.”

The Resistance Management Strategies for fungicides, herbicides and insecticides have been reviewed by scientific technical review committees in consultation with relevant national and international experts.

Mr Cossey concluded, “As part of our stewardship initiatives, CropLife and our members are committed to making resistance management advice freely available. The more farmers adopting this best-practice information, the more sustainable the use of crucial crop protection products for Australia’s farming sector.”

The 2020 Resistance Management Strategies are available at croplife.org.au/resistance-management

CROP PATHOGENS 'REMARKABLY ADAPTABLE'

Pathogens that attack agricultural crops show remarkable adaptability to new climates and new plant hosts, new research shows.

Researchers at the Department of Biosciences, University of Exeter studied the temperature preferences and host plant diversity of hundreds of fungi and oomycetes that attack our crops.

The researchers found that plant pathogens can specialise on particular temperatures or host plants, or have wide temperature or host ranges.

Lead author Professor Dan Bebber, a member of Exeter's Global Systems Institute, said "Traditionally, scientists have considered species to be specialists or generalists.

"Generalists are sometimes called 'Jack of all trades, master of none'. Our analyses show that many plant pathogens are 'Jack of some trades, master of others'."

Tom Chaloner, an SWBIO DTP PhD student, said "We have collated the largest dataset on plant pathogen temperature responses, and made this available for the scientific community.

"Our data allow us to test some of the most fundamental questions in ecology and evolution.

"For example, we found that temperature preferences are narrower when pathogens are growing within plants, demonstrating the difference between the so-called fundamental niche and the realised niche."

The researchers used recently-developed statistical methods to investigate the co-evolution between pathogens and their hosts, showing that pathogens can readily evolve to attack new host plants.

"In an era of growing global population size, climate change and emerging threats to crop production and food security, our findings will be key to understanding where and when pathogens could strike next," said co-author Professor Sarah Gurr.

Bananas in Java, Indonesia, infected by the fungal pathogen Fusarium oxysporum f.sp. cubense, causal agent of Fusarium Wilt. Photo credit: Clare Thatcher

Journal Reference:

Thomas M. Chaloner, Sarah J. Gurr, Daniel P. Bebber. Geometry and evolution of the ecological niche in plant-associated microbes. Nature Communications, 2020; 11 (1) DOI: 10.1038/s41467-020-16778-5

USING MULTIOMICS IN AN AGRICULTURAL FIELD, SCIENTISTS DISCOVER THAT ORGANIC NITROGEN PLAYS A KEY ROLE

Researchers from a collaboration led by the RIKEN BioResource Science Centre in Japan have analysed agricultural systems using a multiomics approach, and successfully digitalised the complex interactions between plants, microbes and soil in an agricultural field. Using the new approach, they made the surprising finding that organic nitrogen plays a key role in promoting plant growth. The study, published in the Proceedings of the American Academy of Sciences, could pave the way toward more sustainable agricultural practices.

In 1840, the German scientist Justus von Liebig proposed that plants required the input of minerals-particularly nitrogen-to grow properly. Then, in the early 20th century, the development of the Haber-Bosch process made it possible to produce large amounts of nitrogen-based fertilisers, revolutionising agriculture. However, there has been a price. Fertilisers typically use inorganic nitrogen, which leaches through the soil into water, leading to contamination.

As a response to this, various ways are being explored to promote plant growth without harmful fertilisers. One is a method called "soil solarisation," which involves putting plastic sheets over a field to trap the heat of the sun. This raises the temperature of the soil and is believed to help prevent weeds and parasites that hamper the growth of plants. However, the mechanism that promotes plant growth is not fully understood.

To figure out why solarisation works, the RIKEN-led team set up an experiment where they used a multitude of "omics" methods-looking at the metabolome (an examination of various metabolites), ionome (looking at the distribution of elements), microbiome (a comprehensive survey of microbial profile), and phenome (an examination of plant phenotypes)-to examine an experimental agricultural field. The field, which was used to grow Japanese mustard spinach (Brassica rapa Var. perviridis), was split into sections where solarisation was used and a non-solarised one. These sections were further split into areas that were given either compost or chemical fertiliser.

The results confirmed previous studies, showing that the solarised area had fewer weeds and increased the weight of the plant shoots. The plants themselves had similar characteristics such as sugar content and leaf shape regardless of whether they were grown in the solarised area or not, leading the researchers to surmise that the difference was related to nutrition in the soil. Surprisingly, when the researchers did an analysis of compounds and elements in the soil, they found that there was no difference in inorganic nitrogen concentration between the solarised field and non-solarised one. The network analysis using digitalised information of agricultural field by multiomics led them to the suspicion that somehow sources of organic nitrogen, such as amino acids, were fueling the growth. They also found differences in bacteria that grow on the roots of plants, known as the rhizosphere, which are important in making nitrogen available to plants.

Though they were able to determine the importance of organic nitrogen, it is still unclear in what form this happens. To test further, they planted seeds in a germ-free environment, and sound that the growth was still maintained, implying that the plants were taking up organic nitrogen directly. They also found that certain forms of organic nitrogen, namely choline and alanine, encouraged growth even at very low concentrations, implying that they also act as biologically active compounds that promote growth.

According to Yasunori Ichihashi, the corresponding author of the study, "Digitalizing agroecosystems using multiomics is a very powerful tool for extracting key information in order to enhance crop production. Our findings imply that contrary to the long-held belief that mineral nutrition was most important for plant growth, organic nitrogen can also contribute to plant nutrition. This could pave the way to decreased use of chemical fertilisers in future crop production, helping to attain one of the important Sustainable Development Goals."

Journal Reference:

Ichibashi et al. (2020). Multi-omics analysis on an agroecosystem reveals the significant role of organic nitrogen to increase agricultural crop yield. Proc Natl Acad Sci U S A. doi: 10.1073/pnas.1917259117

PLANT CELL GATEKEEPERS' DIVERSITY COULD BE KEY TO BETTER CROPS

Scientists have shed new light on how the network of gatekeepers that controls the traffic in and out of plant cells works, which researchers believe is key to develop food crops with bigger yields and greater ability to cope with extreme environments.

Everything that a plant needs to grow first needs to pass through its cells' membranes, which are guarded by a sieve of microscopic pores called aquaporins.

"Aquaporins (AQPs) are ancient channel proteins that are found in most organisms, from bacteria to humans. In plants, they are vital for numerous plant processes including, water transport, growth and development, stress responses, root nutrient uptake, and photosynthesis," says former PhD student Annamaria De Rosa from the ARC Centre of Excellence for Translational Photosynthesis (CoETP) at The Australian National University (ANU).

"We know that if we are able to manipulate aquaporins, it will open numerous useful applications for agriculture, including improving crop productivity, but first we need to know more about their diversity, evolutionary history and the many functional roles they have inside the plant," Ms De Rosa says.

Their research published mid June in the Journal BMC Plant Biology, did just that. They identified all the different types of aquaporins found in tobacco (Nicotiana tabacum), a model plant species closely related to major economic crops such as tomato, potato, eggplant and capsicum.

"We described 76 types of these microscopic hour-glass shape channels based on their gene structures, protein composition, location in the plant cell and in the different organs of the plant and their evolutionary origin. These results are extremely important as they will help us to transfer basic research to applied agriculture," says Ms De Rosa, whose PhD project focused on aquaporins.

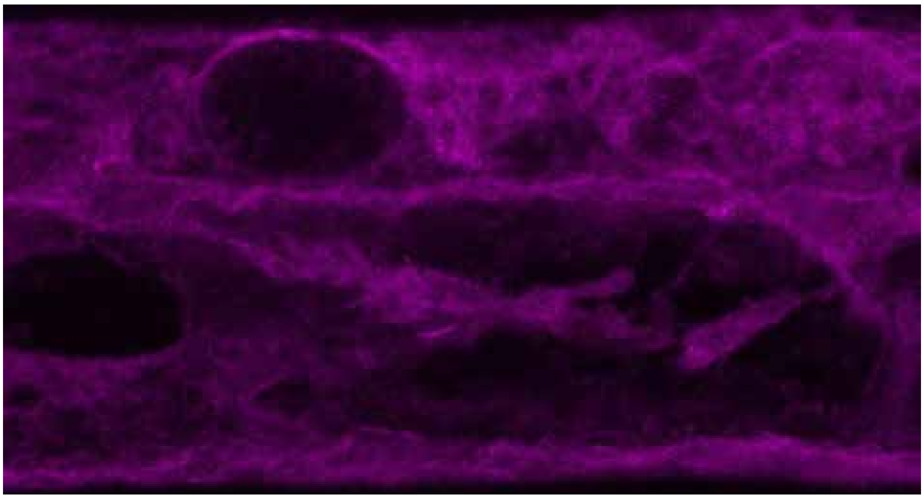
"The Centre (CoETP) is really interested in understanding aquaporins because we believe they are a key player in energy conversion through photosynthesis and also control how a plant uses water. That is why we think we can use aquaporins to enhance plant performance and crop resilience to environmental changes," says lead researcher Dr Michael Groszmann from the Research School of Biology and the CoETP at ANU.

Aquaporins are found everywhere in the plant, from the roots to flowers, transporting very different molecules in each location, at an astonishing 100 million molecules per second. The configuration of an aquaporin channel determines the substrate it transports and therefore its function, from the transport of water and nutrients from roots to shoots, to stress signalling or seed development.

"We focused on tobacco because it is a fast-growing model species that allows us to scale from the lab to the field, allowing us to evaluate performance in real-world scenarios. Tobacco is closely related to several important commercial crops, which means we can easily transfer the knowledge we obtain in tobacco to species like tomato and potato. Tobacco itself has own commercial applications and there is a renewed interest in the biofuel and plant-based pharmaceutical sectors," he says.

"This research is extremely exciting because the diversity of aquaporins in terms of their function and the substrates they transport, mean they have many potential applications for crop improvement ranging from improved salt tolerance, more efficient fertiliser use, improved drought tolerance, and even more effective response to disease infection. They are currently being used in water filtration systems and our results could help to expand these applications. The future of aquaporins is full of possibilities," says Dr Groszmann.

This research has been funded by the Australian Research Council (ARC) Centre of Excellence for Translational Photosynthesis (CoETP), led by the Australian National University, which aims to improve the process of photosynthesis to increase the production of major food crops such as sorghum, wheat and rice.



Tagging aquaporins with fluorescent protein shows their location in the cell membrane. These gatekeepers help move substances in and out of the cell. Photo credit: Annamaria De Rosa, CoETP

Annamaria De Rosa, former PhD student, ARC CoE for Translational Photosynthesis in the lab, studying diversity of aquaporins. Photo credit: Dr Tory Clarke, CoETP

Journal Reference:

Annamaria De Rosa, Alexander Watson-Lazowski, John R. Evans, Michael Groszmann. Genome-wide identification and characterisation of Aquaporins in Nicotiana tabacum and their relationships with other Solanaceae species. BMC Plant Biology, 2020; 20 (1) DOI: 10.1186/s12870-020-02412-5

NEWLY DISCOVERED PLANT GENE COULD BOOST PHOSPHORUS INTAKE

Researchers from the University of Copenhagen have discovered an important gene in plants that could help agricultural crops collaborate better with underground fungi - providing them with wider root networks and helping them to absorb phosphorus. The discovery has the potential to increase agricultural efficiency and benefit the environment.

It is estimated that about 70 percent of phosphorus fertiliser used in Danish agriculture accumulates in soil, whereas only 30 percent of it reaches plants.

Quid pro quo - that's how one might describe the "food community" that the majority of plants have with mycorrhizal fungi. Plants allow fungi to live among their roots, while feeding them fat and sugar. And in return, fungi use their far-reaching hypha (filamentous branches) to capture vital soil nutrients for plants, including the important mineral phosphorus.

Now, researchers at the University of Copenhagen's Department of Plant and Environmental Sciences have discovered an extraordinary plant gene, the CLE53 gene, which regulates cooperation between fungi and plants. The gene is central to a mechanism that controls how receptive plants are to working with mycorrhizal fungi. Down the road, this newfound knowledge could serve to deliver better harvests and reduced fertiliser use.

"Similar genes are found in all plants - including agricultural crops. So, by mutating or turning off the CLE53 gene in a crop plant, it is more likely for a plant to become symbiotically involved with a fungus. In doing so, it becomes possible to reduce the need for phosphorus fertilisers, as plants improve at absorbing preexistent phosphorus from soil," explains Assistant Professor Thomas Christian de Bang of the Department of Plant and Environmental Sciences.

The research has been published in the Journal of Experimental Botany

Seventy percent of phosphorus fertilisation does not reach plants

Phosphorus is vital for all plants. However, the problem with phosphorus use in agriculture is that more of it is applied for fertilisation than can be absorbed by crops. It is estimated that about 70 percent of phosphorus fertiliser used in Danish agriculture accumulates in soil, whereas only 30 percent of it reaches plants. With rain, there is an ever present risk that some of the accumulated phosphorus will be discharged into streams, lakes and the sea.

Paradoxically, researchers have observed that when phosphorus levels in soil are high, plants are less likely to collaborate with fungi, meaning that they become worse at absorbing nutrients.

"Through a range of experiments, we have demonstrated that a plant does not produce the CLE53 gene if it lacks phosphorus. However, when the phosphorus levels in a plant are high, or if the plant is already symbiotically involved with a fungus, then the level of CLE53 increases. Our study demonstrates that CLE53 has a negative effect on a plant's ability to enter into symbiosis with a fungus, and thereby absorb phosphorus most effectively," says Thomas Christian de Bang.

Requires CRISPR approval

The genomic editing of plants is legal in a number of non-EU countries - e.g., China, the US, Switzerland and the UK. However, within the EU, there is no general acceptance of gene-editing methods, such as CRISPR, to alter plants and foodstuffs.

Therefore, the researchers' discovery has, for the time being, a poorer chance of being used in Denmark and the rest of the EU.

"One can use the technology in other parts of the world, and getting started would be relatively straightforward. My guess is that within five years, plants will be tested and refined in such a way that they become more symbiotically involved with fungi and absorb more phosphorus. Here in Denmark and throughout the EU, an acceptance is required for gene editing and an amended approach to approval procedures for these types of plants," says Thomas Christian de Bang.

Facts:

90% of all plants engage in symbiotic relationships with mycorrhizal fungi, which popularly said, extend the root networks of plants, thus helping them to obtain enough phosphorus, water and other nutrients.

In order to benefit from the ability of mycorrhizal fungi to extract phosphorus from soil, a plant must feed it with fat and sugar. To avoid spending too much energy on the sponge, if for example, it is experiencing high phosphorus levels or has already been colonised by a fungus, the plant may switch off symbiosis.

It is estimated that Danish farms fertilise with roughly 30 kilos of phosphorus per hectare of land.

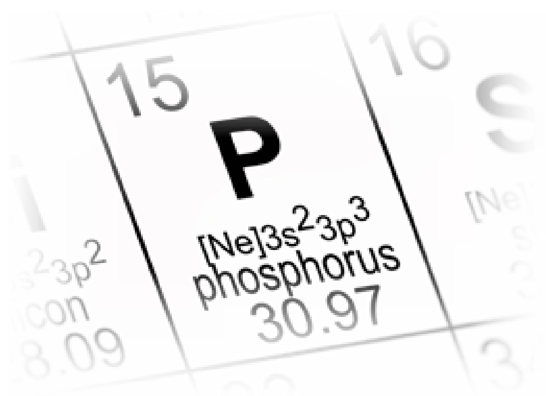
Of this, roughly 30 percent makes its way to crops, while the remaining 70 percent binds to soil.

With rain, some of this accumulated phosphorus is flushed away via surface runoff, into nearby streams, lakes and the sea. This increases algae growth and can kill both plants and wildlife.

Phosphorus is a finite natural resource, one that is expected to eventually be depleted.

The research is funded by the Novo Nordisk Foundation and the University of Copenhagen

Previous research has shown that a similar mechanism exists for symbiosis between legumes and rhizobium bacteria. This involved a CLE gene as well, albeit a different one than the researchers have now discovered.



Journal Reference:

Thomas C de Bang, Patrick X Zhao, Xinbin Dai, Kirankumar S Mysore, Jiangqi Wen, Gonzalo Sancho Blanco, Katrine Gram Landerslev, Clarissa Boschiero, Magda Karlo. The CLE53-SUNN genetic pathway negatively regulates arbuscular mycorrhiza root colonization in Medicago truncatula. Journal of Experimental Botany, 2020; DOI: 10.1093/jxb/eraa193

CROP RESIDUE DECISIONS AFFECT SOIL LIFE

In some ways, farming is like cooking. Cooking would be much easier if we could leave the kitchen after eating and not come back until we make the next meal. But someone needs to put away the leftovers, do the dishes, and clean up the table.

Similarly, there's work to do in farm fields after harvest and before planting the next spring.

After harvest in the fall, farmers take the harvested crops to market or store them on their farm. They don't take the whole plant from the field, though.

The leftover parts of the plant, like the stalk and leaves from corn, remain in the field. This debris is called crop residue.

Using no-till and prescribed fire management are two potential ways to manage crop residue. Both practices help keep organic matter and nitrogen in the soil. However, research was needed to understand how these two practices can affect long-term soil health.

Lisa Fultz and her team want to help farmers determine the best way to manage their residue between growing seasons. To do this, her team decided to learn more about how no-till and prescribed fire management affect nutrients and microbes in the soil. Fultz is a researcher at Louisiana State University AgCenter.

No-till is a practice where farmers plant directly into the crop debris from the previous year. Prescribed fires are used to purposely burn off the previous crop debris with controlled fire.

"Both of these practices have minimal physical disturbance to the soil," says Fultz.

Both of these practices also come with drawbacks. No-till can cause poor conditions for crop growth like low spring temperatures and increased moisture, which promotes disease. Prescribed fire can leave bare soil vulnerable to erosion.

The team focused the research on wheat and soybean rotations and continuous corn production systems. "These are common practices not only in the mid-south, but across many areas of the world," explains Fultz.

"Wheat and corn production leave behind residue," she says. "Common practices, like conventional tillage, are highly disruptive. The need to identify viable conservation practices is growing in importance."

Crop residue and its degradation by soil microbes is an important part of the carbon cycle. Plants store carbon during the growing season, then microbes use the plant residue for food. The carbon then gets stored in the soil in a chemically stable form.

"Fresh, green material in no-till fields is easy to breakdown and provides rich nutrients for soil microbes," says Fultz. "Ash from burned residue is more chemically stable, but it doesn't provide a nutrient source for microbes."

The team found that impacts from crop management practices, like crop rotation or fertilisation, outweighed the influence of prescribed fire for residue management. Researchers found some decreases in microbial activity after yearly prescribed burns.

Findings show prescribed fire had some possible short-term benefits for soil nutrient availability, but timing is crucial. Prescribed burning of wheat residue provided an increase of nitrogen for about 7 days. These benefits should be weighed against other possible impacts, like carbon dioxide production and crop yield.

We still need to learn the long-term influence of prescribed fire on the soil biological community," says Fultz. "While short-term impacts were measured, the long-term influence on soil nutrients, biological cycles and soil health are not known."

No two farm management systems are the same, and their success is defined by the user. Scientists continue to examine possible scenarios to provide accurate and sustainable recommendations to farmers.

"I have always been interested in soil conservation and the potential it has to impact many facets of life," says Fultz. "By improving soil health, we can improve air and water quality, store carbon, and provide stable resources for food production."

Controlled burns can be used to remove crop residue from farm fields between growing seasons. Photo credit: Rachel Schutte

Some farmers leave crop residue in the field after harvest and plant directly into it in the spring. This is called no-till. Photo credit: Rachel Schutte

Josh Lofton and students monitor prescribed fire progress in wheat stubble. Photo credit: Beatrix Haggard

Journal Reference:

Autumn Acree, Lisa M. Fultz, Josh Lofton, Beatrix Haggard. Soil biochemical and microbial response to wheat and corn stubble residue management in Louisiana. Agrosystems, Geosciences & Environment, 2020; 3 (1) DOI: 10.1002/agg2.20004

ARE COVER CROPS NEGATIVELY IMPACTING ROW CROPS?

Winter cover crops benefit soil health and can suppress weeds in subsequent row crops but may also lead to lower yields. Some farmers and agronomists speculate that allelopathic chemicals released by cover crops may be the cause for some of the observed yield reductions, but cause-and-effect relationships are rarely established. We know that allelopathic cover crops inhibit weed seed germination and early growth, but do they also impact row crops?

In an article recently published in Agricultural & Environmental Letters, a publication of the American Society of Agronomy, Crop Science Society of America and Soil Science Society of America, researchers reviewed literature documenting effects of allelopathic winter cover crops on four row crops. Studies that used known allelochemicals in the lab or measured allelochemicals in the field were included.

Only seven studies met the criteria for inclusion and six of them were lab studies. Corn and wheat germination and root length were sometimes impacted by allelopathic chemicals from cereal rye and other cover crops, but soybean was unaffected. One field study reported reduced cotton performance due to allelopathic cover crops.

We could not establish clear cause-and-effect relationships for row crops grown in the field due to the limited number of studies. However, with the increase in cover crop acreage and constantly evolving management practices, research to identify risk factors for allelopathic impacts and how to avoid them is needed.

One example of evolving cover crop management is growing corn in cereal rye that was terminated after corn planting ("planting green"). Picture taken June 17, 2020 at the Eastern Nebraska Research and Extension Center near Mead, Nebraska. Photo credit: Katja Koehler-Cole

Journal Reference:

Koehler-Cole, K, Everhart, SE, Gu, Y, et al. Is allelopathy from winter cover crops affecting row crops? Agric Environ Lett. 2020; 5:e20015. https://doi.org/10.1002/ael2.20015

SPACE TO GROW, OR GROW IN SPACE - HOW VERTICAL FARMS COULD BE READY TO TAKE-OFF

VERTICAL FARMS WITH THEIR SOIL-FREE, COMPUTER-CONTROLLED ENVIRONMENTS MAY SOUND LIKE SCI-FI. BUT THERE IS A GROWING ENVIRONMENTAL AND ECONOMIC CASE FOR THEM, ACCORDING TO NEW RESEARCH LAYING OUT RADICAL WAYS OF PUTTING FOOD ON OUR PLATES.

The interdisciplinary study combining biology and engineering sets down steps towards accelerating the growth of this branch of precision agriculture, including the use of aeroponics which uses nutrient-enriched aerosols in place of soil.

Carried out by the John Innes Centre, the University of Bristol and the aeroponic technology provider LettUs Grow, the study identifies future research areas needed to accelerate the sustainable growth of vertical farming using aeroponic systems.

Dr Antony Dodd, a group leader at the John Innes Centre and senior author of the study, says: "By bringing fundamental biological insights into the context of the physics of growing plants in an aerosol, we can help the vertical farming business become more productive more quickly, while producing healthier food with less environmental impact."

Jack Farmer, Chief Scientific Officer at LettUs Grow and one of the authors of the study, adds: "Climate change is only going to increase the demand for this technology. Projected changes in regional weather patterns and water availability are likely to impact agricultural productivity soon. Vertical farming offers the ability to grow high value nutritious crops in a climate resilient manner all year round, proving a reliable income stream for growers."

Vertical farming is a type of indoor agriculture where crops are cultivated in stacked systems with water, lighting and nutrient sources carefully controlled.

It is part of a rapidly growing sector supported by artificial intelligence in which machines are taught to manage day to day horticultural tasks. The industry is set to grow annually by 21% by 2025 according to one commercial forecast (Grand View Research, 2019).

Green benefits include better use of space because vertical farms can be sited in urban locations, fewer food miles, isolation from pathogens, reduction in soil degradation and nutrient and water recapturing and recycling.

Vertical farms also allow product consistency, price stabilisation, and cultivation at latitudes incompatible with certain crops such as the desert or arctic.

"Vertical systems allow us to extend the latitude range on which crops can be grown on the planet, from the deserts of Dubai to the 4-hour winter days of Iceland. In fact, if you were growing crops on Mars you would need to use this kind of technology because there is no soil," says Dr Dodd.

The study, which appears in the journal New Phytologist, lays out seven steps - strategic areas of future research needed to underpin increased productivity and sustainability of aeroponic vertical farms.

These seek to understand:

- Why aeroponic cultivation can be more productive than hydroponic or soil cultivation.
- The relationship between aeroponic cultivation and 24-hour circadian rhythms of plants.
- Root development of a range of crops in aeroponic conditions.
- The relationship between aerosol droplet size and deposition and plant performance.
- How we can establish frameworks for comparing vertical farming technologies for a range of crops.
- How aeroponic methods affect microbial interactions with plant roots.

The nature of recycling of root exudates (fluids secreted by the roots of plants) within the nutrient solutions of closed aeroponic systems.

The report argues that a driver of technological innovation in vertical farms is minimising operation costs whilst maximising productivity - and that investment in fundamental biological research has a significant role.

Dr Dodd's research area covers circadian rhythms - biological clocks which align plant physiology and molecular processes to the day to day cycle of light and dark. He recently completed a year-long Royal Society Industry Fellowship with LettUs Grow.

This involved combining Dr Dodd's expertise in circadian rhythms and plant physiology with the work of LettUs Grow's team of biologists and engineers to design optimal aeroponic cultivation regimens. This is a key area of investigation as these molecular internal timers will perform differently in vertical farms.

Aeroponic platforms are often used to grow high value crops such as salads, pak choi, herbs, small brassica crops, pea shoots and bean shoots. LettUs Grow are also working on growth regimens for fruiting and rooting crops such as strawberries and carrots, as well as aeroponic propagation of trees for both fruit and forestry.

John Innes Centre researchers have bred a line of broccoli adapted to grow indoors for a major supermarket and one of the aims of research will be to test how we can genetically tune more crops to grow in the controlled space of vertical farms.

Bethany Eldridge, a researcher at the University of Bristol studying root-environment interactions and first author of the study adds "Given that 80% of agricultural land worldwide is reported to have moderate or severe erosion, the ability to grow crops in a soilless system with minimal fertilisers and pesticides is advantageous because it provides an opportunity to grow crops in areas facing soil erosion or other environmental issues such as algal blooms in local water bodies that may have been driven by traditional, soil-based, agriculture."

Lilly Manzoni, Head of Research and Development at LettUs Grow and one the authors of the study says, "This paper is unique because it is broader than a typical plant research paper, it combines the expertise of engineers, aerosol scientists, plant biologists and horticulturalists. The wonderful thing about controlled environment agriculture and aeroponics is that it is truly interdisciplinary."

The study Getting to the Roots of Aeroponic Indoor Farming appeared in the New Phytologist journal.

“Vertical systems allow us to extend the latitude range on which crops can be grown on the planet, from the deserts of Dubai to the 4-hour winter days of Iceland. In fact, if you were growing crops on Mars you would need to use this kind of technology because there is no soil”
Dr Antony Dodd

Vertical Farming - economic and environmental benefits. Photo credit: LettUs Grow

Journal Reference:

Bethany M. Eldridge, Lillian R. Manzoni, Calum A. Graham, Billy Rodgers, Jack R. Farmer, Antony N. Dodd. Getting to the roots of aeroponic indoor farming. New Phytologist, 2020; DOI: 10.1111/nph.16780

FUNGAL PATHOGEN DISABLES PLANT DEFENCE MECHANISM

Cabbage plants defend themselves against herbivores and pathogens by deploying a defensive mechanism called the mustard oil bomb: when the plant tissue is damaged, toxic isothiocyanates are formed and can effectively fend off attackers. Researchers at the Max Planck Institute for Chemical Ecology and the University of Pretoria have now been able to show in a new study that this defence is also effective to some extent against the widespread and detrimental fungus Sclerotinia sclerotiorum. However, the pathogen uses at least two different detoxification mechanisms that enable the fungus to successfully spread on plants defended in this way. The metabolic products thus formed are non-toxic to the fungus, allowing it to grow on these plants.

Sclerotinia sclerotiorum is a devastating fungal pathogen that can infect more than 400 different plant species. The main symptom of the disease called Sclerotinia wilt or white mould is wilting. Visible are also the white, cotton-like fungal spores that overgrow plant leaves and stalks. In agriculture, rapeseed cultivation is particularly at risk. The plant disease can affect other members of the cabbage family, and also potatoes, legumes and strawberries.

Scientists at the Max Planck Institute for Chemical Ecology in Jena have long been studying the glucosinolates and isothiocyanates that constitute the special defence mechanism of cabbage family plants, which include rapeseed, radishes and mustard.

"We wanted to find out how successful plant pathogens overcome the plant defence and colonise these plants. We therefore asked ourselves whether widespread fungal pathogens have strategies to adapt to the chemical defences of plants of the cabbage family," Jingyuan Chen, the first author of the study, explains.

The researchers were able to show experimentally that the defence based on glucosinolates is actually effective against fungal attacks. However, they also discovered two different strategies of the white mould fungus to detoxify the defensive substances: The first is a general detoxification pathway that binds glutathione to the isothiocyanate toxins. This type of detoxification of organic poisons is quite common in insects and even mammals. The second and far more effective way to render the isothiocyanates harmless is to hydrolyse them, i.e. to cleave them enzymatically with a water molecule. The researchers wanted to identify the enzymes and corresponding genes underlying this detoxification mechanism. Genes that enable the successful detoxification of these substances had already been described in bacteria. They are called Sax genes after experiments with the model plant Arabidopsis thaliana: Survival in Arabidopsis eXtracts.

"We based our search on the known bacterial SaxA proteins to select candidate genes for further investigations. We then tested whether these genes are actually expressed in greater quantities in fungi exposed to the toxins, and whether the resulting protein can render the toxins harmless," explains Daniel Vassão, one of the study leaders. Using high-resolution analytical methods, the scientists were able to identify and quantify the metabolites produced by the fungus during detoxification. They also used mutants of the fungus in which the SaxA-encoding gene had been knocked out for comparison. This revealed that the Sax protein of the white mould fungus is active against a range of isothiocyanates, allowing it to colonise different plants of the cabbage family.

Mutants lacking the gene for this detoxification pathway were dramatically reduced in their capacity to tolerate isothiocyanates. "However, it was surprising to see that these mutants up-regulated their general pathway of detoxification, although this did not compensate for the mutation," says Jingyuan Chen. Glutathione conjugation cannot detoxify isothiocyanates nearly as effectively as hydrolysis can. Although it seems to be metabolically more expensive for the fungus, this general pathway is always present as it helps the fungus to detoxify a huge variety of poisons. "It is possible that this general pathway protects the fungus initially, while the machinery required for the more specialised pathway is assembled after an initial exposure to the toxin and can take over later in the infection," says Daniel Vassão.

In further experiments, the researchers want to investigate whether other fungi that successfully infect plants of the cabbage family also detoxify isothiocyanates via the same pathway, and whether unrelated fungal species are also able to degrade these toxins. "Then we will know whether this widespread detoxification is due to repeated evolution in fungi colonising mustards, or is a feature which has been conserved over time and is therefore found in many fungal lines," Jonathan Gershenzon, director of the Department of Biochemistry where the research was conducted, concludes.

Infection of an Arabidopsis thaliana plant by the fungus Sclerotinia sclerotiorum. This fungus, which causes white mold disease, can colonize Arabidopsis in spite of the chemical defenses present using two detoxification pathways to deactivate the plant toxins. Photo credit: Anna Schroll

Growth of the fungus Sclerotinia sclerotiorum on an agar plate, showing different developmental stages. Photo credit: Anna Schroll

Journal Reference:

Chen, J., Ullah, C., Reichelt, M., Beran, F., Yang, Z.-L., Gershenzon, J., Hammerbacher, A., Vassão, D. G. (2020). The phytopathogenic fungus Sclerotinia sclerotiorum detoxifies plant glucosinolate hydrolysis products via an isothiocyanate hydrolase. Nature Communication 11: 3090, DOI 10.1038/s41467-020-16921-2

UNIQUE CO-FORMULATION FUNGICIDE SET TO IMPROVE CEREAL DISEASE PROGRAMS

Western Australian producer Leigh Strange has adopted a new co-formulation fungicide to help improve cereal disease management, encouraged by its results and the fact it will help extend the life of other fungicide products.

The fourth generation on the family's 'Cotswold Farms' property near Bruce Rock in the WA wheatbelt, Leigh and his wife De operate a cropping and livestock enterprise.

Leigh said they employ a three-tiered approach to crop disease management, including use of a seed dressing followed by fungicide applications featuring multiple active ingredients.

Last year they applied the new broadspectrum fungicide, Topnotch, which combines high loadings of azoxystrobin (Group 11) and propiconazole (Group 3) in a unique suspo-emulsion (SE) formulation.

Developed by ADAMA, Topnotch provides highly effective control of all major foliar diseases in barley and wheat. In barley it helps combat leaf rust, powdery mildew, net form net blotch, spot form net blotch and scald, while in wheat it controls leaf rust, powdery mildew, septoria nodorum, septoria tritici, stripe rust, stem rust and yellow spot.

The combination of strobilurin and DMI modes of action ensures disease infections are targeted from the time of spore germination on the leaf surface through to mycelial development within leaves.

An ideal disease resistance management tool, the new Topnotch provides protectant and curative activity across key fungi life cycle stages to help maximise yield potentials.

ADAMA Portfolio Manager Matt Sherriff said with confirmed spot form net blotch resistance to single mode of action fungicide in southern areas of WA, co-formulated products like Topnotch would increasingly become a vital option in growers' disease management programs.

Typically, the most cost-effective time to apply the fungicide, at rates of 200-600 millilitres per hectare when conditions favour disease, is between stem elongation and full head emergence.

Leigh said despite the dry season last year, there were reasonable levels of disease in their wheat and barley crops.

"The Spartacus barley we grow that was on barley stubble had a little bit of spot form net blotch and net form net blotch in there," Leigh said.

"It wasn't too bad, but we thought we would spray it regardless to keep things under control.

"Even with a seed dressing upfront, there was still some disease pressure there, so we used Topnotch and were very happy with the results."

The fungicide is compatible with a wide range of herbicides, insecticides and foliar fertilisers for one-pass control, with extensive testing on multiple varieties across Australia ensuring its crop safety.

Leigh said they applied it in a mix with Flexi-N liquid nitrogen fertiliser with good results.

"We did two applications to get the disease under control in a timely fashion and to get the nitrogen on before rains."

"There was no more crop scorching than a normal propiconazole and Flexi-N mix."

He said the easy application and good control achieved highlighted the benefits of Topnotch for future disease management programs.

"It's really important to recognise going forward that by investing in products like this, it will hopefully extend the life of a few other products," Leigh said.

For further information on Topnotch fungicide, growers, advisers and agronomists can contact their local ADAMA representative.

Matt Sherriff, Adama, pictured with his "best friend" Brian, says with confirmed spot form net blotch resistance to single mode of action fungicide in southern areas of WA, co-formulated products like Topnotch will increasingly become a vital option in growers' disease management programs.

PLANT GROWTH PROMOTING MICROBES

BY UWE STROEHER, MICROBIOLOGIST AND R&D MANAGER

Plants naturally produce five major plant hormones (phytohormones) including auxins or indole-3-acetic acid (IAA), cytokinins, gibberellins, abscisic acid and the gaseous hormone, ethylene. It is a combination and balance of these hormones that regulate many aspects of plant growth, development and reproduction. The first three hormones are recognised as being plant growth promoting, whereas abscisic acid and ethylene are considered to be growth inhibitors due to their effect on plant abscission (the shedding away or cutting off of different parts of the plant) ***(Fig 1)***.

FIG. 1 : STRUCTURE OF THE MAJOR FIVE PHYTOHORMONES

However, plants are not the only organisms that produce these hormones. A range of soil microbes that either produce or influence these hormones are known as microbial phytohormones. In essence, the microbes in the soil and on the plant can influence plant growth and development. With a few exceptions, these microbes are generally bacteria, and so the term 'plant growth-promoting bacteria' (PGPB) has been coined. These PGPB not only produce phytohormones, but may also have other positive effects on plants such as pathogen suppression and nutrient acquisition. This article will focus on the essential role of the microbial-derived phytohormones.

As the world moves towards more sustainable agriculture, there has been a push to examine the use of biologicals to increase growth and yield. The current crop of biologicals on the market can be broadly divided into two classes - there are those that contain essentially active compounds i.e. phytohormones, and in some cases co-factors and nutrients for soil microbes and plants. The second class are those that use living microbes to introduce bacteria into the soil, which then grow and multiply, and release the phytohormones into the soil. Due to their versatility and in many cases longevity, there has been considerable interest in isolating and identifying these microbes.

The most widely studied of the bacterial phytohormones are auxins - in particular IAA. This is a small, readily diffusible molecule which bacteria produce, not as a phytohormone per se, but as a signalling molecule.

Whilst bacteria use IAA to communicate with each other, the role of IAA in plant development is far-reaching. It can stimulate tuber and seed germination and control vegetative growth, it is perhaps best known for its effect on root development.

As plants normally produce IAA at the tip or shoots, this hormone then needs to be translocated to the roots, where high levels of IAA leads to lateral root formation. It therefore makes sense to encourage bacteria in the soil which naturally produce IAA, leading to not only enhanced root formation, but improved early seedling development and survival.

Evidence has recently come to light that IAA can also play a role in the defence response of a plant by reducing its susceptibility to pathogens. Due to the fact that IAA is also a bacterial signalling molecule, many genera of bacteria produce this compound, such as Bacillus, Streptomyces, Pseudomonas and Azotobacter to name a few. Some of these, in particular the Bacillus and Streptomyces species are long lived and can survive in soils even in unfavourable conditions. This makes them ideal candidates for soil inoculants such as Neutrog's GOGO Juice.

The other major phytohormone involved in plant growth and development is cytokinin. At the correct levels this small molecule controls cell division in both roots and shoots. It is produced primarily in the roots of plants and then transported via the xylem to the rest of the plant. Production of cytokinins in the soil by bacteria allows plants to take up this hormone and translate it to the tips of the plant to enhance shoot development.

Besides their ability to enhance plant growth, evidence has also come to light that cytokinins produced by soil bacteria can improve the drought tolerance of some plants. As is the case for many hormones, the right levels can lead to increased growth, whereas excessive levels can cause damage. So although PGPB produce this hormone, it is at levels which enhance plant growth, but below concentrations which lead to plant growth inhibition. Alternatively, several plant pathogens produce high levels of cytokinins which then act in a growth inhibitory manner, making it easier for the pathogen to gain a foothold and damage the plant.

Another interesting global phytohormone is gibberellin or gibberellic acid (GA). It is involved in growth stimulation such as as stem elongation, seed germination, fruit set and even photosynthetic efficiency. GAs were first discovered in a fungi on rice plants where excess production of this phytohormone resulted in longer than normal internode lengths. The elongation of stems is one of the most notable effects of GA, and is seen most clearly in young stems. GA-producing microbes have seen only limited usage due to the difficulty in controlling the level of GA produced, however GAs have been used in commercial settings to increase flower buds and improve fruit production. It has also been applied to seedless grapes to increase bunch weight and size. Using gibberellin-producing bacteria to enhance plant growth is limited, as excessive amounts of this hormone can lead to damaging effects.

Although abscisic acid (ABA) is generally considered a plant growth inhibitory hormone, it plays a major role in how plants respond to stress. Sudden increases of ABA are known to be harmful to plants, however extensive evidence suggests that exogenous ABA coming from soil microbes can potentially reverse the effects of stress. As an example, inoculation of the soil with the ABA-producing bacteria Bacillus amyloliquefaciens has shown increased salinity tolerance in plants. It would appear that one role of ABA is to help plants maintain hydraulic conductivity of shoots and roots, thereby mitigating drought and salinity stress.

The phytohormone ethylene is generally considered an inhibitor of plant growth, and is produced in order to ripen fruit. It is also released from dying plant material and during periods of stress. It is in this stress setting where ethylene can create a series of events leading to plant death. Although microbes don't produce this phytohormone, they can influence its effect. What we know is that a large number of soil microbes produce an enzyme know as 1-aminocyclopropane-1-carboxylate (ACC) deaminase. This enzyme essentially converts a precursor of ethylene into another compound, thereby reducing the amount of ethylene a plant can produce. As such, PGPB that produce ACC deaminase reduce the levels of ethylene to below inhibitory levels, resulting in a reduction in damage to the plant due to a stressor. Furthermore, inoculation of seeds or roots with bacteria capable of producing ACC deaminase also promotes root elongation and shoot growth by reducing ethylene levels which may otherwise inhibit development.

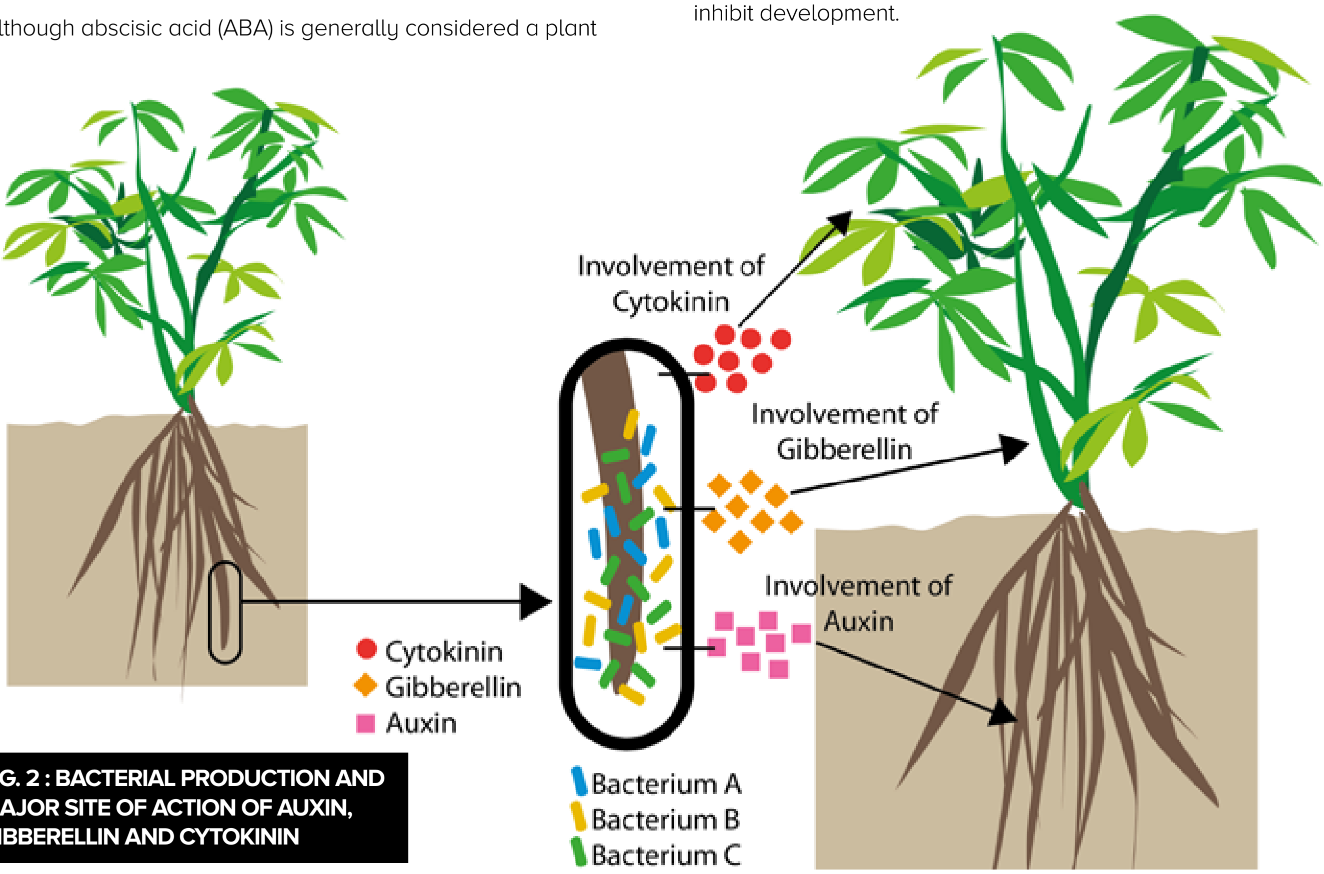


FIG. 2 : BACTERIAL PRODUCTION AND MAJOR SITE OF ACTION OF AUXIN, GIBBERELLIN AND CYTOKININ

These hormones work together in a coordinated manner to optimise plant development.

The question is how do we obtain the maximum benefit of these PGPB? For this we need to have soils with a wide and dynamic microbial population. This can best be achieved by the use of organic inputs (composts or mulches), which encourages diversity and can be further enhanced by inoculation with a probiotic such as GOGO Juice to colonise and populate the soil.

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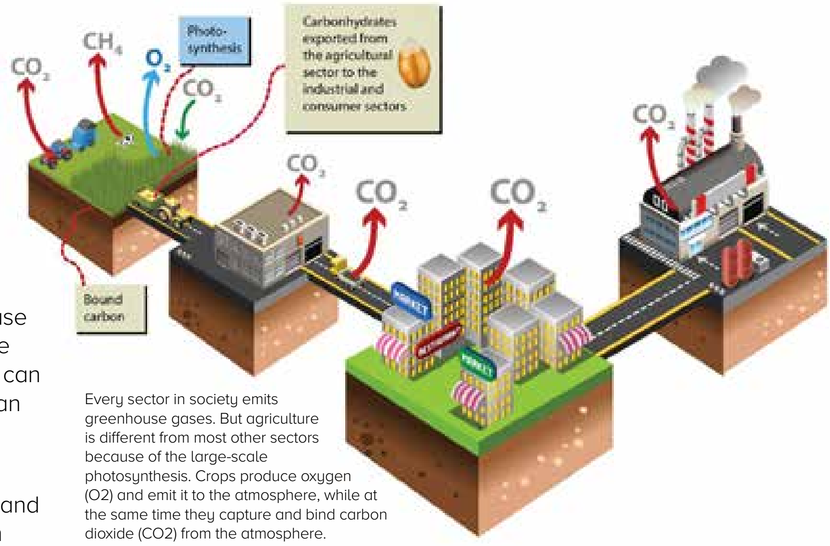
AGRICULTURE - A CLIMATE VILLAIN? MAYBE NOT!



Every sector in society emits greenhouse gases. But agriculture is different from most other sectors because of the large-scale photosynthesis. Crops produce oxygen (O2) and emit it to the atmosphere, while at the same time they capture and bind carbon dioxide (CO2) from the atmosphere.
Photo credit: Per Frankelius

The UN's Intergovernmental Panel on Climate Change (IPCC) claims that agriculture is one of the main sources of greenhouse gases, and is thus by many observers considered as a climate villain. This conclusion, however, is based on a paradigm that can be questioned, writes Per Frankelius, Linkoping University, in an article in Agronomy Journal.

The fundamental process in agriculture is large-scale photosynthesis, in which carbon dioxide is captured by crops and at the same time oxygen is produced. A fraction of the carbon is bound in the plant roots, while most of it is bound in the form of carbohydrates that are harvested and used in other sectors of society. This involves various form of cereal, oilseed crops, vegetables and grassland.

"The fact that the carbon is bound in the crops, which at the same time produce oxygen, just as growing forest does, is a positive effect that is not included in the IPCC calculations. These only consider the greenhouse gases that have a negative impact on the climate. This is also the case in The Greenhouse Gas Protocol, which is a well established standard for calculating the emission of greenhouse gases", says Per Frankelius, associate professor in business administration at Linköping University, who has recently written an article in the prestigious Agronomy Journal, published by the American Society of Agronomy.

"This view is based on a paradigm that has essentially never been questioned. Politicians and decision-makers must understand the complete range of the climate impact of agriculture, otherwise there is a risk that many decisions that influence long-term sustainability in a negative manner will be taken", says Per Frankelius.

The justification that crops are not included as a positive factor is probably that carbon dioxide is formed in the next step along the chain, when the crops are consumed by humans. "But that takes place in another sector: it's not part of agriculture", Per Frankelius points out.

Per Frankelius gives an example calculation in the article in Agronomy Journal:

Many different crops are cultivated as agricultural products, and all of them perform photosynthesis. One common crop is cereals, such as wheat, and in 2019, global production of cereals was 2.7 billion tonnes. This corresponds to approximately 1 billion tonnes of carbon, which in turn corresponds to 3.8 billion tonnes of carbon dioxide. The figure would be significantly higher if we included other crops such as oilseed crops and sugar beet.

"The total agricultural production has been estimated to be 9200 million tons by FAOSTAT. Different crops have different water content, but a good guess is that the total production corresponds to approximately 9100 million tonnes of carbon dioxide", adds Per Frankelius.

Agriculture produces also grasslands and grazing that bind carbon, and a further 2.7 billion tonnes of carbon is bound in the soil.

"So is agriculture one of the world's largest climate villains, or does the sector actually have a positive impact on climate?" asks Per Frankelius.

He does not question the fact that agriculture also produces a significant amount of negative greenhouse gases, and it is important to reduce this in a sustainable manner.

Per Frankelius, who is also process manager at Agtech 2030, an innovation platform at Linköping University, presents in the article no less than seven concrete measures that can both advance the sector and reduce emissions. The measures range from ensuring that fields are green throughout the year to the marketing of animal ecosystem services, the use of fossil-free mineral-based fertilisers, the spread of biochar, replacing diesel by fossil-free biodiesel, electricity, fuel cells or even steam to power engines, planting trees in rows along the edges of fields and placing solar panels there to follow the sun with a recently patented technology, and various ways to reduce soil compaction. He refers to concrete examples in all cases.

The conclusions Per Frankelius draws are unambiguous: in order to achieve long-term sustainability, all aspects of global agriculture must be developed, not wound down or given less advantageous economic conditions. One key to success is innovation.

Per Frankelius, senior researcher, Linkoping University. Photo credit: Per Frankelius/LiU

Journal Reference:

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RESEARCH REVEALS PLANT CONTROL WITH THE POWER OF LIGHT

University of East Anglia scientists have helped find a way to control different plant processes - such as when they grow - using nothing but coloured light. The development which was published in June in the journal Nature Methods, reveals how coloured light can be used to control biological processes in plants by switching different genes on and off.

The researchers hope that their findings could lead to advances in how plants grow, flower, and adapt to their environment, ultimately allowing increases in crop yields. The research was led by Heinrich Heine University and the Cluster of Excellence on Plant Sciences (CEPLAS) in Düsseldorf, in collaboration with colleagues at the University of Freiburg and UEA.

Dr Ben Miller, from UEA's School of Biological Sciences, said "Our team have been working on optogenetics - using light to precisely control biological processes - in plants.

"Using optogenetics in plants hadn't been possible before because plants naturally respond to light as they grow. Any genetic switches controlled by light would therefore be constantly active.

"But we have developed a special system which overcomes this problem and allows us to control different cellular processes in plants using light.

"We can now use a red light to cause gene expression at a precise moment, while an ambient white light can be used as an 'off switch' to reverse the process. This can be repeated any number of times.

"We can use this system to manipulate physiological responses in plants, for example their immune response, and perhaps their development, growth, hormone signalling and stress responses."

The project bridges two hot topics in biology - optogenetics and synthetic biology. The new tool called PULSE (Plant Usable Light-Switch Elements) is suitable for plants growing under normal day and night cycles.

Dr Miller said "In the future, this research might mean that we can modulate how plants grow, and respond and adapt to their environment, with light cues.

"For example, we have shown that plant immune responses can be switched on and off using our light-controlled system. If this system was used in crops, we could potentially improve plant defences to pathogens and have an impact by improving yields.

"Using light to control biological processes is far less invasive and more reversible than using chemicals or drugs, so this new system in plants is a really exciting new tool for us to answer fundamental questions in plant biology."

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HOW TO TACKLE CLIMATE CHANGE, FOOD SECURITY AND LAND DEGRADATION

How can some of world's biggest problems - climate change, food security and land degradation - be tackled simultaneously?

Some lesser-known options, such as integrated water management and increasing the organic content of soil, have fewer trade-offs than many well-known options, such as planting trees, according to a Rutgers-led study in the journal Global Change Biology.

"We argue that if we want to have an impact on multiple problems, we need to be smart about what options get us multiple benefits and which options come with potential trade-offs," said lead author Pamela McElwee, an associate professor in the Department of Human Ecology in the School of Environmental and Biological Sciences at Rutgers University-New Brunswick. "We found that many of the better-known solutions to climate mitigation and land degradation come with a lot of potentially significant trade-offs."

The idea of planting trees in vast areas to remove carbon dioxide from the air and reduce the impact of climate change, for example, has attracted a lot of attention, with some claiming it's the best "low-hanging fruit" approach to pursue, McElwee said. But large-scale tree planting could conflict directly with food security because both compete for available land. It could also diminish biodiversity, if fast-growing exotic trees replace native habitat.

Some potential options that don't get as much attention globally, but are quite promising with fewer trade-offs, include integrated water management, reducing post-harvest losses in agriculture, improving fire management, agroforestry (integrating trees and shrubs with croplands and pastures) and investing in disaster risk management, she said.

The study examined possible synergies and trade-offs with environmental and development goals. It was based on a massive literature review - essentially 1,400 individual literature reviews - conducted by scientists at many institutions. They compared 40 options to tackle the interrelated problems of climate change, food security and land degradation and looked for trade-offs or co-benefits with 18 categories of services provided by ecosystems, such as clean air and clean water, and the United Nations' 17 sustainable development goals. The work was done as part of an Intergovernmental Panel on Climate Change (IPCC) Special Report on Climate Change and Land released last year. Such reports offer only highlights, and this study includes all the details.

Several interventions show potentially significant negative impacts on sustainable development goals and ecosystem services. These include bioenergy (plant-based sources of energy such as wood fuels or ethanol) and bioenergy with carbon capture and storage, large-scale afforestation and some risk-sharing measures, such as commercial crop insurance.

The results show that a better understanding of the benefits and trade-offs of different policy approaches can help decision-makers choose the more effective - or at least the more benign - interventions.

"Policy officials can't always undertake the kind of work we did, so we hope our findings provide a useful shorthand for decision-makers," McElwee said. "We hope it helps them make the choices needed to improve future policy, such as strengthened pledges to tackle climate mitigation under the 2015 Paris Agreement. There are a lot of potential steps for reducing carbon emissions that aren't as well-known but should be on the table."

Journal Reference:

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TIMING KEY IN UNDERSTANDING PLANT MICROBIOMES

Oregon State University researchers have made a key advance in understanding how timing impacts the way microorganisms colonise plants, a step that could provide farmers an important tool to boost agricultural production.

The findings, published in the journal Current Biology, will help scientists better understand the plant microbiome, which consists of hundreds of thousands of microorganisms that live in and on plants and contribute to their health and productivity.

While scientists have studied microbes living in plants for decades, it has only been in the last 10 years or so that advances in DNA sequencing technology have it made it possible to characterise the unseen diversity of plant microbiomes with more precision. The surge in research involving the plant microbiome coincides with a spike in research involving the human microbiome and its role in human health and disease.

Understanding how plant microbiomes form is important because some microorganisms are beneficial and others are harmful to plants. Some factors shaping microbiome composition are predictable, like the relative humidity of the environment, or the thickness of the protective, waxy layer of cells on the leaf surface.

However, much of the variation in microbiome composition remains unexplained. The Oregon State research, led by Posy Busby, an assistant professor in the Department of Botany and Plant Pathology, and Devin Leopold, a postdoctoral fellow in her lab, unravels some of those mysteries.

In this study, Busby and Leopold explored one process that likely contributes to this unexplained variation: the order in which microorganisms colonise plants.

The research was unique in that they studied plants with different genetic backgrounds, in this case black cottonwood trees collected throughout the Cascade Range in the Pacific Northwest, and also exposed those plants to leaf rust, a disease-causing fungus.

They found that the order the microorganisms reached the plant had a significant impact on microbiome composition and how susceptible the plant was to disease. Additionally, the researchers found that this random variation in arrival order of microorganisms may be more important for highly disease-susceptible plants, which have not evolved their own effective defence strategies.

Farmers have a long history of applying beneficial microorganisms to crops. This research provides them with more information about which plant cultivars may be best suited for microbial biocontrol, and how to best time treatments to prevent disease in plants.

"Our hope is that our findings will translate into tools for combating plant disease that aren't limited to planting only disease-resistant cultivars," Busby said. "Because maintaining diversity in our crops is essential to the long-term sustainability of our agricultural systems."

This research was supported by the U.S. Department of Energy's Office of Biological and Environmental Research and the OSU Department of Botany and Plant Pathology in the College of Agricultural Sciences.

Journal Reference:

Devin R. Leopold, Posy E. Busby. Host Genotype and Colonist Arrival Order Jointly Govern Plant Microbiome Composition and Function. Current Biology, 2020; DOI: 10.1016/j.cub.2020.06.011

Posy Busby, an assistant professor at Oregon State University, with black cottonwood trees. Photo credit: Oregon State University

Black cottonwood trees with holes punched in the leaves. Holes are punched in leaves to collect tissue for the DNA extraction. Photo credit: Devin Leopold

Black cottonwood trees in a greenhouse at Oregon State University. Photo credit: Posy Busby

PHOTOSYNTHETIC HACKS CAN BOOST CROP YIELD, CONSERVE WATER

Plants are factories that manufacture yield from light and carbon dioxide - but parts of this complex process, called photosynthesis, are hindered by a lack of raw materials and machinery. To optimise production, scientists from the University of Essex have resolved two major photosynthetic bottlenecks to boost plant productivity by 27 percent in real-world field conditions, according to a new study published in Nature Plants. This is the third breakthrough for the research project Realising Increased Photosynthetic Efficiency (RIPE); however, this photosynthetic hack has also been shown to conserve water.

"Like a factory line, plants are only as fast as their slowest machines," said Patricia Lopez-Calcagno, a postdoctoral researcher at Essex, who led this work for the RIPE project. "We have identified some steps that are slower, and what we're doing is enabling these plants to build more machines to speed up these slower steps in photosynthesis."

The RIPE project is an international effort led by the University of Illinois to develop more productive crops by improving photosynthesis - the natural, sunlight-powered process that all plants use to fix carbon dioxide into sugars that fuel growth, development, and ultimately yield. RIPE is supported by the Bill & Melinda Gates Foundation, the U.S. Foundation for Food and Agriculture Research (FFAR), and the U.K. Government's Department for International Development (DFID).

A factory's productivity decreases when supplies, transportation channels, and reliable machinery are limited. To find out what limits photosynthesis, researchers have modelled each of the 170 steps of this process to identify how plants could manufacture sugars more efficiently.

In this study, the team increased crop growth by 27 percent by resolving two constraints: one in the first part of photosynthesis where plants transform light energy into chemical energy and one in the second part where carbon dioxide is fixed into sugars.

Inside two photosystems, sunlight is captured and turned into chemical energy that can be used for other processes in photosynthesis. A transport protein called plastocyanin moves electrons into the photosystem to fuel this process. But plastocyanin has a high affinity for its acceptor protein in the photosystem so it hangs around, failing to shuttle electrons back and forth efficiently.

The team addressed this first bottleneck by helping plastocyanin share the load with the addition of cytochrome c6 - a more efficient transport protein that has a similar function in algae. Plastocyanin requires copper and cytochrome requires iron to function. Depending on the availability of these nutrients, algae can choose between these two transport proteins.

At the same time, the team has improved a photosynthetic bottleneck in the Calvin-Benson Cycle - wherein carbon dioxide is fixed into sugars - by bulking up the amount of a key enzyme called SBPase, borrowing the additional cellular machinery from another plant species and cyanobacteria.

By adding "cellular forklifts" to shuttle electrons into the photosystems and "cellular machinery" for the Calvin Cycle, the team also improved the crop's water-use efficiency, or the ratio of biomass produced to water lost by the plant.

"In our field trials, we discovered that these plants are using less water to make more biomass," said principal investigator Christine Raines, a professor in the School of Life Sciences at Essex where she also serves as the Pro-Vice-Chancellor for Research. "The mechanism responsible for this additional improvement is not yet clear, but we are continuing to explore this to help us understand why and how this works."

These two improvements, when combined, have been shown to increase crop productivity by 52 percent in the greenhouse. More importantly, this study showed up to a 27 percent increase in crop growth in field trials, which is the true test of any crop improvement - demonstrating that these photosynthetic hacks can boost crop production in real-world growing conditions.

"This study provides the exciting opportunity to potentially combine three confirmed and independent methods of achieving 20 percent increases in crop productivity," said RIPE Director Stephen Long, Ikenberry Endowed University Chair of Crop Sciences and Plant Biology at the Carl R. Woese Institute for Genomic Biology at Illinois. "Our modelling suggests that stacking this breakthrough with two previous discoveries from the RIPE project could result in additive yield gains totalling as much as 50 to 60 percent in food crops."

RIPE's first discovery, published in Science, helped plants adapt to changing light conditions to increase yields by as much as 20 percent. The project's second breakthrough, also published in Science, created a shortcut in how plants deal with a glitch in photosynthesis to boost productivity by 20 to 40 percent.

Next, the team plans to translate these discoveries from tobacco - a model crop used in this study as a test-bed for genetic improvements because it is easy to engineer, grow, and test - to staple food crops such as cassava, cowpea, maize, soybean and rice that are needed to feed our growing population this century. The RIPE project and its sponsors are committed to ensuring Global Access and making the project's technologies available to the farmers who need them the most.

Realising Increased Photosynthetic Efficiency (RIPE) aims to improve photosynthesis to equip farmers worldwide with higher-yielding crops to ensure everyone has enough food to lead a healthy, productive life. This international research project is sponsored by the Bill & Melinda Gates Foundation, the U.S. Foundation for Food and Agriculture Research (FFAR), and the U.K. Government's Department for International Development (DFID).

RIPE is led by the University of Illinois in partnership with The Australian National University, Chinese Academy of Sciences, Commonwealth Scientific and Industrial Research Organisation, Lancaster University, Louisiana State University, University of California, Berkeley, University of Cambridge, University of Essex, and U.S. Department of Agriculture, Agricultural Research Service.

Journal Reference:

Patricia E. López-Calcagno, Kenny L. Brown, Andrew J. Simkin, Stuart J. Fisk, Silvere Vialet-Chabrand, Tracy Lawson, and Christine A. Raines. Stimulating photosynthetic processes increases productivity and water-use efficiency in the field. Nature Plants, 2020 DOI: 10.1038/s41477-020-0740-1

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PESTICIDES CAN PROTECT CROPS FROM HYDROPHOBIC POLLUTANTS

RESEARCHERS HAVE REVEALED THAT COMMERCIAL PESTICIDES CAN BE APPLIED TO CROPS IN THE CUCURBITACEAE FAMILY TO DECREASE THEIR ACCUMULATION OF HYDROPHOBIC POLLUTANTS[1], THEREBY IMPROVING CROP SAFETY.

The research group consisted of FUJITA Kentaro (1st year Ph.D. student) of Kobe University's Graduate School of Agricultural Science, Academic Researcher YOSHIHARA Ryouhei (now an assistant professor at Saitama University) and Associate Professor INUI Hideyuki of Kobe University's Biosignal Research Center, Senior Research Scientist KONDOH Yasumitsu, Technical Staff HONDA Kaori and Group Director OSADA Hiroyuki of RIKEN, and Lead Researcher HAGA Yuki and Senior Scientist MATSUMURA Chisato of Hyogo Prefectural Institute of Environmental Sciences.

The team developed two approaches to control the functions of plant proteins related to the transport of hydrophobic pollutants.

These findings will lead to these new functions of pesticides being utilised in agriculture, enabling safer crops to be produced.

These results were published online in the international scientific journal Science of the Total Environment in June and in Environmental Pollution' in July.

Main Points

- Crops in the Cucurbitaceae family can accumulate hydrophobic pollutants (such as dioxins) in their fruits from contaminated soil. Major latex-like proteins (MLPs)[2] play a key role in transporting hydrophobic pollutants to their fruits.
- Approach 1: Treatment with a pesticide that suppresses the expression of MLP gene decreases the concentrations of hydrophobic pollutants in the xylem sap.
- Approach 2: Treatment with a pesticide that binds to MLPs inhibits the binding of the proteins to hydrophobic pollutants. Thus, the concentrations of hydrophobic pollutants in the xylem sap that were transported via MLPs were reduced.
- It was shown that pesticides could provide a simple and low-cost solution to the production of safer crops.
- This study revealed, for the first time in the world, a new way that pesticides can be used in agriculture, which is different from current methods.

Research Background

Hydrophobic pollutants include dioxins, the insecticide dieldrin, and endocrine disruptors. These pollutants are highly toxic, and their manufacture and use are now prohibited. However, these substances were used in large quantities up until they were banned, causing widespread environmental pollution that also affects agricultural land.

The Cucurbitaceae family includes crops such as cucumbers and squashes. Members of this family are different from other plant species in that they accumulate high concentrations of hydrophobic pollutants in their fruits. Associate Professor Inui et al. previously discovered that major latex-like proteins (MLPs) in the Cucurbitaceae family play a key role in this accumulation. MLPs bind to hydrophobic pollutants taken up from the soil by the roots of the plant. The Cucurbitaceae family then accumulate hydrophobic pollutants in the leaves and fruits via the sap in the stems. Consequently, MLPs are a major factor that causes crop contamination in the Cucurbitaceae family.

When crops are found to have accumulated hydrophobic pollutants above the residual limit, all crops grown on the same land are unable to be sold, resulting in great economic losses for the producer. For this reason, much research has been conducted into ways to remove hydrophobic pollutants from agricultural soil, however a cost-effective and efficient method has yet to be found. Therefore, there is an urgent need to develop technology for the cultivation of safer crops on arable land contaminated by hydrophobic pollutants.

Research Methodology

This study focused on pesticides that have been confirmed to be safe. The researchers tried two approaches designed to suppress the accumulation of hydrophobic pollutants via MLPs: utilising a 'pesticide which suppresses MLP gene expression' and a 'MLP-binding pesticide'. They aimed to produce safer cucurbitaceous crops.

Approach 1 (published in 'Science of the Total Environment')

The application of a pesticide that suppresses MLP gene expression reduces the concentration of MLPs in the roots and xylem sap[3]. This suggested that the concentrations of hydrophobic pollutants accumulated in the fruits via MLP would also be reduced.

First, experiments were carried out to select a pesticide that could suppress MLP gene expression from five types of pesticide used on the Cucurbitaceae family (the insecticides Guardbait, Starkle, and Diazinon and the fungicides Benlate and Daconil). Daconil was chosen because treatment showed that its active ingredient[4] could reduce MLP gene expression. Next, it was confirmed that concentrations of MLPs in the roots and xylem sap of zucchini grown in soil contaminated with hydrophobic pollutants were reduced by the Daconil treatment. Furthermore, the concentrations of hydrophobic pollutants in the xylem sap decreased by 52%.

Approach 2 (published in 'Environmental Pollution')

The application of MLP-binding pesticide inhibits the binding of MLPs to hydrophobic pollutants in the roots. In other words, the amount of MLPs that binds to the pollutants is reduced. It was hypothesised that this approach would decrease the concentrations of hydrophobic pollutants accumulated in the fruits via MLPs.

First of all, chemical arrays[5] with approximately 22,000 compounds from the RIKEN NPDepo[6] were used to identify compounds that bound to MLPs. The insecticide Colt that can be applied to crops in the Cucurbitaceae family was selected from commercial pesticides with similar structures to MLP-binding compounds. When Colt's active ingredient was reacted with both MLPs and the hydrophobic pollutants, the concentration of MLPs bound to these pollutants decreased by 78%. In addition, the concentrations of these pollutants in the xylem sap fell by 15% after Colt treatment.

Further Research

This study revealed, for the first time in the world, that it is possible to cultivate safer crops in contaminated soil through the control of the plant's functions. This achievement could reduce the number of cases where producers experience economic losses due to being unable to sell crops grown in contaminated soil. Furthermore, this will also provide consumers with safe produce.

A new method of utilising pesticides has been revealed by this research. For the first time in the world, this study has revealed a novel aspect of pesticides beyond their original functions of preventing pests or weed growth. Pesticides are thought to be extremely safe because they have to pass numerous strict safety tests. Furthermore, the standardised treatment of crops with pesticides is simple and inexpensive. Therefore, it is anticipated that the method developed by this study to reduce hydrophobic pollutants using pesticides will become widespread across the globe.

This research was supported by funding from the Japan Crop Protection Association and a Sasakawa Scientific Research Grant (No. 2019-5004).

FIG. 1

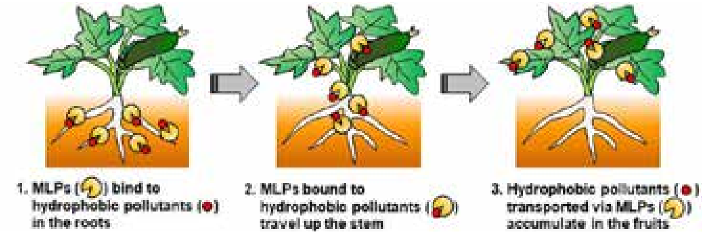
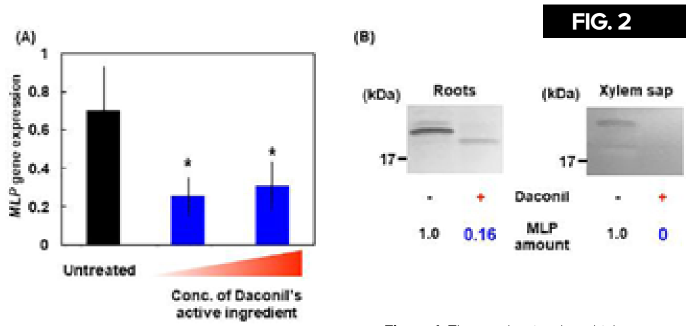


FIG. 2



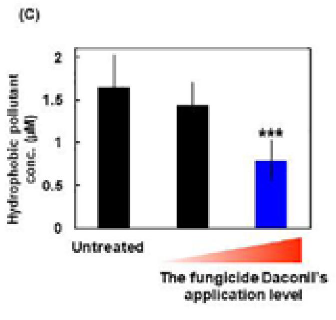


Figure 1. The mechanism by which hydrophobic pollutants are accumulated in Cucurbitaceous plants via MLPs. Photo credit: Kobe University

Figure 2. Hydrophobic pollutant concentration in zucchini was reduced by applying the insecticide Daconil to suppress MLP gene expression. A. MLP gene expression after treatment with Daconil's active ingredient. B. Accumulation of MLPs in zucchini after Daconil treatment C. Concentrations of hydrophobic pollutants in the xylem sap of zucchini grown in contaminated soil after Daconil treatment. Photo credit: Kobe University

Glossary

1. Hydrophobic pollutants Are chemical substances that do not decompose easily in the environment and accumulate easily within organisms. They are highly toxic and have been shown to be carcinogenic and neurotoxic in humans. Hydrophobic pollutants include dioxins, polychlorinated biphenyls, and dieldrin. Their use and manufacture have been banned in 181 countries.

2. Major latex-like protein (MLP) This protein is found in many species of plants, including Arabidopsis thaliana, grape and apple. Particularly in the Cucurbitaceae family, MLPs bind to hydrophobic pollutants, transporting them to the leaves and fruits, where these pollutants then accumulate. The original functions of these proteins have yet to be fully clarified.

3. Xylem sap Is a fluid found in the xylem, which is part of the vascular bundle along with phloem. It transports water and nutrients absorbed from the roots to the leaves and fruits.

4. Active ingredient The chemical in a commercial pesticide that performs the product's main function (eg. insecticide or fungicide). Pesticides also contain ingredients other than their active ingredient, such as spreading agents, which ensure that the active ingredient adheres to the plants or the pests. This study confirmed that active ingredients in pesticides could control MLP functions.

5. Chemical array An organic chemical compound is immobilised on a chip, enabling a highly efficient evaluation of the compound's physical interactions with proteins of interest. It is difficult to immobilise varied types and complex structures of organic compounds, compared to immobilising single-structured DNA for DNA arrays. RIKEN's Chemical Biology Research Group has developed an immobilisation method using a carbene with non-specific avidity (divalent carbon that only has 6 valence electrons and no charge) that will bind with the compound regardless of its functional group.

6. RIKEN NPDepo (Natural Product Depository) A chemical compound library being developed by the Chemical Resource Development Research Unit of RIKEN's Chemical Biology Research Group. In addition to collecting and storing natural compounds isolated from sources such as actinobacteria, they are also accepting deposits from researchers in order to build up a library of diverse chemical compounds.

Journal Reference:

Kentaro Fujita, Yuki Haga, Ryouhei Yoshihara, Chisato Matsumura, Hideyuki Inui. Suppression of the genes responsible for transporting hydrophobic pollutants leads to the production of safer crops. Science of The Total Environment, 2020; 741: 140439 DOI: 10.1016/j.scitotenv.2020.140439

NATIVE BUSHLAND'S FERTILITY SECRET - SOIL MICROBES COULD PROMOTE BETTER FARM OUTPUTS

In hotter, dryer conditions with climate change, a secret agent for more sustainable agricultural production could lie in harvesting the diverse beneficial soil microbiome in native bushland settings, scientists say.

New research from CSIRO, Flinders University and La Trobe University highlights the importance of soil biological health and further potential to use organic rather than chemical farm inputs for crop production.

"We know antibiotics are very useful in pharmaceuticals, and actinobacteria found plentifully and in balance in various natural environments play a vital role in the plant world," says lead author Dr Ricardo Araujo, a visiting Flinders University researcher from the University of Porto in Portugal.

"These actinobacterial communities contribute to global carbon cycling by helping to decompose soil nutrients, increase plant productivity, regulate climate support ecosystems - and are found in abundance in warm, dry soil conditions common in Australia."

A new article in Soil Biology and Biochemistry is one of the first dedicated studies of Australian actino-bacterial diversity in different areas of the Southern Hemisphere - using the bacterial gene sequence dataset generated through the 'Biomes of Australian Soil Environments' project with soil samples from across the nation, including mainland, the island state of Tasmania as well as King Island, Christmas Island and the Northern Antarctica for comparative soil profiles.

Other researchers from the La Trobe University AgriBio Centre contributed to the analysis of 2211 actinobacterial operational taxonomic units (OTUs) mapped in mainland Australia, and 490 OTUs from Tasmania, King Island, Christmas Island and Northern Antarctica.

CSIRO Agriculture and Food senior principal research scientist, Associate Professor Gupta Vadakattu, says the differences we found between mainland Australia and more remote locations showed how agriculture has had an impact on the diversity of actinobacterial.

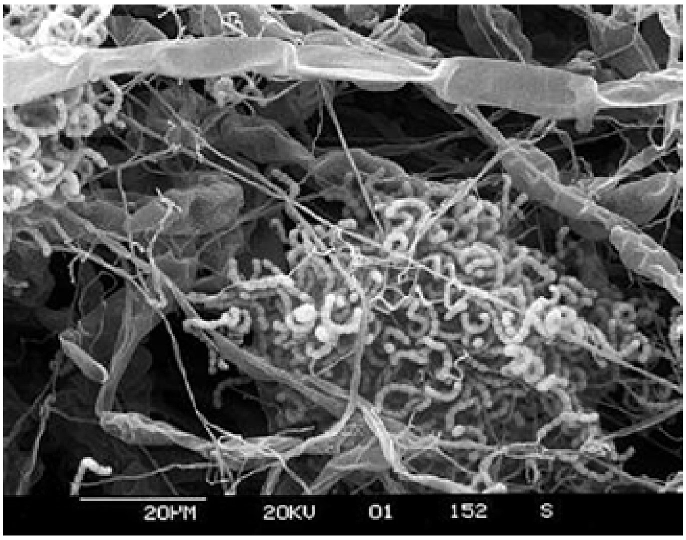
"Our study shows how native vegetation is a reservoir for these important soil microorganisms, and this could be used to enrich adjoining agricultural soils," says Associate Professor Vadakattu, adding an intriguing finding was the similarity in actinobacteria profiles of King Island and areas of Antarctica where these continents were once connected.

"Patterns of actinobacteria dispersal suggest only a small fraction of them had the capability of spreading throughout the Southern Hemisphere, especially across oceans."

Flinders University colleague Professor Chris Franco, says biotechnology has long benefited from actinobacteria for human and animal health products, and increasingly in sustainable agriculture.

"The diversity and structure of soil antinobacterial communities are influenced by multiple factors, representing one of the most abundant soil bacterial taxa across a diverse range of ecological regions - from deserts to Antarctica," Professor Franco says.

"There is much more we need to learn about their potential in primary production and retaining and incorporating native plants in our ecosystems."



An electron micrograph picture of actinobacteria that are commonly found from Australian soil. Photo credit: CSIRO

Associate Professor Gupta Vadakattu, Senior Principal Research Scientist - Soil Microbiology, CSIRO Agriculture & Food. Photo credit: CSIRO Agriculture & Food

Journal Reference:

Ricardo Araujo, Vadakattu V.S.R. Gupta, Frank Reith, Andrew Bissett, Pauline Mele, Christopher M.M. Franco. Biogeography and emerging significance of Actinobacteria in Australia and Northern Antarctica soils. Soil Biology and Biochemistry, 2020; 146: 107805 DOI: 10.1016/j.soilbio.2020.107805

NEW STUDY SHOWS HOW PLANTS REGULATE THEIR GROWTH-INHIBITING HORMONES TO SURVIVE

In a world with a consistently growing population and a climate crisis, food shortage is a looming threat. To alleviate this threat, crop scientists, botanists, genetic engineers, and others, have been exploring ways of boosting crop productivity and resilience. One way to control plant growth and physiology is to regulate the levels of "phytohormones" or plant hormones.

However, much remains to be known about the mechanisms that underlie this hormonal regulation in plants, limiting advancement in this direction. Now, in a study led by Nagoya University Japan, a team of scientists has discovered, using rice plants as the study model, that a process called "allosteric regulation" is involved in maintaining the phytohormonal balance in plants. Their findings, published in Nature Communications, could hold the key to significantly advancing the research on plant growth and development, providing a potential solution for food security.

Plants survive by adapting their development and physiology to their surrounding environments by controlling the levels of enzymes driving the synthesis of two phytohormones, gibberellin and auxin. Enzymes are proteins that bind to one or more reactant chemicals and speed up a reaction process. The binding site is called the activation site. In 1961, it was discovered that in bacteria, enzyme activity is enhanced or inhibited via allosteric regulation, which essentially is the binding of a molecule called the "effector" at a site other than the active site of the enzyme. In allosteric regulation, the structure of the enzyme changes to either support or hinder the reaction that the enzyme enables.

Professor Miyako Ueguchi-Tanaka of Nagoya University, lead scientist in the team that has now observed allosteric regulation in plants for the first time, explains their research findings, "We used a technique called X-ray crystallography and found that, as molecules of the enzymes (gibberellin 2-oxidase 3 [GA2ox3], and auxin dioxygenase [DAO]) bind to gibberellin and auxin (respectively), they interact among themselves and form 'multimeric' structures, comprising four and two units respectively. As the amounts of gibberellin and auxin increase, so does the rate of multimerization of the enzymes. And multimerization enhances the activity of the enzymes, enabling greater degradation of gibberellin and auxin. Synchronous structural changes and activity enhancement are typical of allosteric-regulation events."

The scientists further carried out "phylogenetic" analysis of GA2ox3 and DAO, which revealed that plants independently developed this hormone regulation mechanism at three separate time-points over the course of the evolutionary process.

Enthusiastic about the future prospects of these findings, Professor Ueguchi says, "The activity control system revealed here can be used to artificially regulate the activity of the growth inactivating hormones in plants. As a result, rice crop productivity can be improved and high-biomass plants can be produced in the event of food shortage or an environmental crisis."

Of course, this study is only a stepping stone for now, and much remains to be done to see how the findings of this study can be applied practically in agricultural lands. However, these findings certainly are encouraging, and they signal the coming of a new era of sustainable development fuelled by biotechnological advancements.

Journal Reference:

Sayaka Takehara, Shun Sakuraba, Bunzo Mikami, Hideki Yoshida, Hisako Yoshimura, Aya Itoh, Masaki Endo, Nobuhisa Watanabe, Takayuki Nagae, Makoto Matsuoka, Miyako Ueguchi-Tanaka. A common allosteric mechanism regulates homeostatic inactivation of auxin and gibberellin. Nature Communications, 2020; 11 (1) DOI: 10.1038/s41467-020-16068-0

A WEEDKILLER FOR A NEW GENERATION

BY ORGANIC CROP PROTECTANTS

Most of us think little about the side effects of the weedkiller we use because our primary focus is killing weeds. Like taking medicine, applying pesticides always has some sort of side effects on the host; in this case the environment. Some herbicides also cause sub-lethal effects on crops through their accumulation in the soil and ground water and others have become less effective due to herbicide resistance. The solution then is to choose a herbicide that does the job of killing the weeds but also having the least impact on everything else. SLASHER® ORGANIC WEEDKILLER is one such herbicide.

SLASHER® ORGANIC WEEDKILLER was developed for Certified Organic producers due to the need for non-selective weed control that did not disturb the soil and reduced soil compaction caused by ongoing mechanical weed control. However, in recent times with a shift in thinking by the more progressing conventional farmers who put a high value on soil fertility and biodiversity; SLASHER® has found its way into non-organic weed control programs. Because SLASHER® contains mostly modified canola oil and nonanoic acid (pelargonic acid) from safflower, it is very easily degraded by soil bacteria and fungi with a half-life of 24 hrs. All of the carbon in the C9 – nonanoic acid is returned to soil so you could say that SLASHER® is a carbon positive!

SLASHER®'s mode of action is a contact desiccant whereby as soon as the spray contacts the plant is causes irreversible effects on the epidermal layers of the vegetative parts of the plant, killing the targeted weeds in under an hour. Due to this mode of action, herbicide resistant weeds can be targeted. SLASHER® is most effective on smaller and more succulent weeds so it is important to spray early in the weed cycle. It is also used effectively as a tank mix with other non-selective herbicides to "hot-up" the mix and increase the speed of kill and spectrum of kill on weeds that have developed lower sensitivity to certain herbicide groups. SLASHER® can be used in most weed control situations and because it's also an effective moss & algae killer Council Parks & Gardens and other spray contractors appreciate the utility and safety of the product.

Finally, it is important to note that because SLASHER® is an ACO Registered Organic weedkiller, it can be used in both conventional and in Certified Organic crops. Also, pelargonic acid naturally occurs in many plants including grape seeds so there are absolutely no issues with residues when used under grape vines or in and around other food crops.

Visit www.ocp.com.au for SLASHER® Spring offers for Farmers and Agronomists

Slasher used in a vineyard situation. Photo credit: Organic Crop Protectants

PROTECTING WINTER 2020 STORED CEREALS

A 53 per cent increase in Australia's 2020-21 winter crop production was forecast by ABARES, with an expected 23 per cent jump in area planted, wheat yield of 26.7 million tonnes (up 76 per cent) and barley yield of 10.6 million tonnes (up 17 per cent).

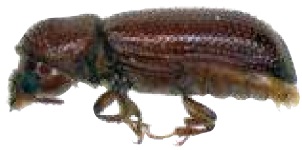
The Bureau of Meteorology's spring outlook supports those forecasts, predicting a wetter-than-average spring with cooler-than-average days and warmer-than-average nights over much of Australia.

Storage capacity on Australian cropping farms continues to increase, as growers hold grain for longer, seeking more flexibility and control over market and price, strategically selling grain direct to purchasers. By 2017, Rabobank reported 90 per cent of growers storing grain on-farm, with a forecast 20 million tonnes of on-farm storage by 2025.

However, simply building and filling on-farm grain storage doesn't guarantee market success, with buyers selecting only good quality, insect-free grain.

Australian Agribusiness technical manager Dr Brett Morris said inspecting and treating any grain still in storage; hygienic preparation of storages, harvesters and handling equipment – including clearing grain residues in and around empty storages, and treating storage and equipment to destroy existing insect pests – were key to retaining high grain quality in the 2020-21harvest.

"The aim is to eliminate potential sources of infestation for newly-harvested grain. A bag's worth of old infected grain can produce a million insects a year, which fly or walk to other stored grain, starting new infestations. One Queensland trial at the start of the season also revealed more than 1000 lesser grain borers in the first 40 litres of grain through a harvester – even though the machine was cleaned at the end of the previous season."



Lesser grain borer Photo credit: CSIRO

He advised growers to always check with potential buyers before using any treatment.

"Once storage facilities and equipment are cleaned, our company's contact insecticide Methograin Fenitrothion 1000, supplied through our agriculture division Barmac, can be applied to kill pests in any remaining residues. (In WA, fenitrothion can only be used by bulk handlers).

"We also have a simple protective solution for stored and new-season grain, to kill established insect pests and prevent reinfestation – our Methograin IGR Grain Protection Pack, which ensures exact dosage of insect growth-regulator and contact insecticide for 50 tonnes of grain.

"Tipping the pack's 300-ml can of Methograin Fenitrothion 1000 insecticide and 1-litre can of Methograin IGR Grain Protectant into 50 litres drum of good quality, clean water provides treatment of 50 tonnes of grain with exactly the prescribed amount of protectant.

"It's an easy, safe and effective pre-calculated combination – saving growers from calculating 'on the-run' and underdosing with less-effective results, or overdosing, increasing the required WHP and potentially rendering grain unsaleable."

Approved for use on all cereal grains (only by bulk handlers in WA), Methograin IGR Grain Protection Pack protects uninfested grain against lesser grain borer, rust-red flour beetle, and saw-toothed grain beetle for up to 9 months; and rice weevils, flour beetles, tropical warehouse moth, and Indian meal moth for up to 6 months.

SCIENTISTS UNLOCK GENETIC SECRETS OF WINE GROWERS' WORST ENEMY

Following a decade-long effort, scientists have mapped out the genome of an aphid-like pest capable of decimating vineyards. In so doing, they have discovered how it spreads - and potentially how to stop it.

The research team's work on the genome was published this past week in a BMC Biology paper. In it, they identified nearly 3,000 genes enabling the insect, phylloxera, to colonise and feed on grape vines by creating what are essentially nutritionally enhanced tumours. The insects live in and feed off of the structures they create.

"In effect, phylloxera creates its own refrigerator on the plant that it can feed from whenever it wants," said Paul Nabity, an assistant professor of plant-insect ecology at UC Riverside. In addition to feeding the insects, these structures also protect them from attack by other parasites.

A heavy phylloxera infestation, as occurred in the Pacific Northwest last year, could cause grapevines to lose their leaves. If the infestation reaches the roots, the plants could die.

The tumour-like structures, known as galls, disrupt the vine's ability to move nutrients and feed itself. They also create wounds in roots that make grapevines more susceptible to fungi and other pathogens, ultimately killing the vines.

Claude Rispe from the French National Institute for Agriculture, Food, and Environment led the research team, while Nabity helped identify how phylloxera secrete molecules that can change the immune system of grapevines.

"These molecules alter the plant's defence systems and make it so that the plant doesn't know it's being attacked," Nabity said.

When phylloxera was accidentally introduced to Europe in the 1860s, it nearly brought French viticulture to an end, causing vines to weaken and die. French and American scientists collaborated on a solution that is still used today.

Native North American grapevines co-evolved with phylloxera and are now resistant to it. However, most of the grapes we eat and drink are European varieties. As a result, growers have to graft North American roots onto their European grapevines to give them tolerance to this insect.

Though phylloxera are considered negative, not all of their effects on plants are necessarily bad. When they feed on plants and start creating gall structures, they change the cells in the leaf surface. Protective cells on the leaves become tiny pores called stomata, which allow movement of gases in and out of the cells.

"We think this is a means to reduce the negative impact on its host," Nabity said. "Stomata can create carbon gains for plants that can offset how much the insects are taking from it."

Now that the genes involved in the attack on non-native grapes have been identified, it may be possible to engineer phylloxera-resistant grapevines.

"Growers currently have to graft roots to make their plants viable," Nabity said. "A lot of money and effort could be saved with pest-resistant rootstocks."

Phylloxera damage to grape leaf. Photo credit: Paul Nabity/UCR

Journal Reference:

Claude Rispe, Fabrice Legeai, Paul D. Nabity, Rosa Fernández, Arinder K. Arora, Patrice Baa-Puyoulet, Celeste R. Banfill, Leticia Bao, Miquel Barberà, Maryem Bouallègue, Anthony Bretaudeau, Jennifer A. Brisson, Federica Calevro, Pierre Capy, Olivier Catrice, Thomas Chertemps, Carole Couture, Laurent Delière, Angela E. Douglas, Keith Dufault-Thompson, Paula Escuer, Honglin Feng, Astrid Forneck, Toni Gabaldón, Roderic Guigó, Frédérique Hilliou, Silvia Hinojosa-Alvarez, Yi-min Hsiao, Sylvie Hudaverdian, Emmanuelle Jacquin-Joly, Edward B. James, Spencer Johnston, Benjamin Joubard, Gaëlle Le Goff, Gaël Le Trionnaire, Pablo Librado, Shanlin Liu, Eric Lombaert, Hsiao-ling Lu, Martine Maïbèche, Mohamed Makni, Marina Marcet-Houben, David Martínez-Torres, Camille Meslin, Nicolas Montagné, Nancy A. Moran, Daciana Papura, Nicolas Parisot, Yvan Rahbé, Mélanie Ribeiro Lopes, Aida Ripoll-Cladellas, Stéphanie Robin, Céline Roques, Pascale Roux, Julio Rozas, Alejandro Sánchez-Gracia, Jose F. Sánchez-Herrero, Didac Santesmasses, Iris Scatoni, Rémy-Félix Serre, Ming Tang, Wenhua Tian, Paul A. Umina, Manuella van Munster, Carole Vincent-Monégat, Joshua Wemmer, Alex C. C. Wilson, Ying Zhang, Chaoyang Zhao, Jing Zhao, Serena Zhao, Xin Zhou, François Delmotte, Denis Tagu. The genome sequence of the grape phylloxera provides insights into the evolution, adaptation, and invasion routes of an iconic pest. BMC Biology, 2020; 18 (1) DOI: 10.1186/s12915-020-00820-5

SUSTAINABLE AGRICULTURE FOR A SUSTAINABLE FUTURE

In the summer of 1982, a research scientist took a well-earned holiday in the sunny Caribbean. While touring the local sights with his wife, he visited an abandoned rum distillery on a tiny tropical island.

Quietly wandering through the old buildings, he was struck by the ghostly, eerie silence. In a climate where the incessant buzz of insect life droned 24 hours a day, the sudden quiet was deafening.

Intrigued, he took some soil samples and transported them back to the United States for testing. What he and his team discovered was a unique soil bacterium that produces active metabolites (spinosyns) that gave excellent control of certain insect pests.

Years of development and exhaustive testing followed, culminating in the release of Entrust® Organic, a product characterised by its efficacy equivalent to synthetic insecticides, but with the safety and environmental profile of a biological.

Entrust® Organic received regulatory approval by the Australian Pesticides and Veterinary Medicines Authority (APVMA) in July 2020, and will be available this October.

Naturally derived, highly effective and fast-acting, Entrust Organic has long been anticipated by the Australian agricultural market. Its organic certification, favourable environmental profile and selectivity to key beneficial insects make it ideally suited to many Integrated Pest Management (IPM) systems.

Entrust Organic belongs to a unique insecticide group known as the 'Spinosyns'. A group 5 insecticide for resistance management, shared only by one other product, Success® Neo.

The introduction of Entrust Organic offers organic growers a new resistance management tool for the selective control of some of Australia's most damaging pests. As with all insecticides, it is beholden on users to rotate between different chemical Modes of Action (MoA) in accordance with label directions to prevent the onset of resistance.

The broad label covers more than 80 registered crops, including a wide range of fruit and vegetables, making it extremely versatile for farmers with mixed enterprises.

Entrust Organic offers growers effective control of several damaging Lepidoptera species including Diamondback moth, Heliothis, Cluster caterpillar, Light brown apple moth and many other caterpillar pests including loopers. It also controls Western flower thrip, leaf miner and Cherry slugs (Diptera).

Nick Koch. Photo credit: CortevaAgriscience

The recent arrival of Fall Army Worm (FAW) in Northern Australia earlier this year presented significant challenges for organic producers. Subsequently, the APVMA approved an emergency use permit (PER89870) for the use of Entrust Organic which is welcome news for growers struggling to control FAW.

Corteva Agriscience Marketing manager Nick Koch said "Biological products are often associated with lower levels of performance compared to that of synthetic insecticides." Contrary to belief, this could not be further from the truth when assessing the performance of Entrust Organic.

"Growers will be delighted with the speed of control and activity across multiple life stages. The largest larval instars prove to be no match for Entrust Organic".

Trans-laminar activity is a useful feature of this product. The active ingredient moves into the leaf tissue allowing it to control pests, such as leaf miner. However, it is not systemic, and thorough coverage is required to protect the entire crop and repeated application to protect new growth.

"It's hard to imagine a product that is so effective at controlling pests being environmentally sustainable, but this is certainly the case," said Mr. Koch.

"Entrust Organic degrades quickly through exposure to sunlight light, breaking down into carbon dioxide and water within a matter of days which means producers can grow a healthy crop and maintain a healthy farm".

"Organic and conventional producers of fruit and vegetables now have a pest control option that ticks all the boxes. They can rest assured knowing that their crop protection choices will provide them with a sustainable future for this generation into the next."

Entrust® Organic will be available in limited supply from October. To register your interest, visit entrust-organic.corteva.com.au or call Corteva Agriscience toll free on 1800 700 096.

THE SILVER LININGS OF BORDER CLOSURES

BY CROP CONSULTANTS AUSTRALIA

What has become evident though, is that there is still much capacity with the ag industry to better co-ordinate our service delivery. In an industry where many of us work independently, there can be a reluctance to share information with others. Whether for competitive of personal reasons, 'silo thinking' has the undeniable outcome of stifling innovation and progress. Out of necessity though, we have seen examples of consultants delivering extension to growers and independent consultants developing unlikely partnerships with cross border competitors to ensure their clients are serviced.

COVID has shown us also show that an inability to travel by some in our industry has presented new business opportunities and alliances for others. One such opportunity has arisen when many of our industry researchers have been unable to travel to complete ongoing trial work. Due to both border closures and employer imposed WH & S restrictions, there has been a gaping hole left in some trials that required a timely solution. It has been pleasing to see the calls for assistance from these researchers being met by the consulting sector.

Crop Consultants Australia members Emma Ayliffe and Heath McWhirter have always considered research delivery to be a core element of the business model of their Griffith based consultancy Summit Ag. Their COVID experience however, has been that the demand for their research and development services has risen markedly.

Emma says that the combination of research, development and extension enables the business to ensure they are on the forefront of new products.

"This means as advisors we are better equipped to determine the best fit of products, technology and management techniques for our clients," says Ms Ayliffe.

"Our growers have also really embraced the concept of having trials on their own properties. They get to gauge the success of a product themselves in their own environment without any investment," she says.

"It has also enabled us to build on the profitability of some of clients with smaller operations."

Ms Ayliffe is quick to point out that given their own reduced travel, the COVID period has given them additional time to reexamine their own business plan and its fit for their clients going forward. She acknowledges that there will be changes they will take with them into the future.

When restrictions lift and life returns to normal, we will all have the opportunity to reshape our business operations. Some amongst us may be tempted to slip back into our old methods of service delivery and there are elements of that which we must never dismiss completely including taking the time for a cuppa and a chat. Ultimately, it will be our clients' preferences which will determine our service proposition in the 'new world.' The astute amongst us will take the best that COVID 'forced' upon us and recognise the future opportunities it presents.

Emma Ayliffe and Heath McWhirter - directors of Summit Ag. Photo credit: Summit Ag

COVER CROP ROOTS ARE AN ESSENTIAL KEY TO UNDERSTANDING ECOSYSTEM SERVICES

TO JUDGE THE OVERALL EFFECTIVENESS OF COVER CROPS AND CHOOSE THOSE OFFERING THE MOST ECOSYSTEM SERVICES, AGRICULTURAL SCIENTISTS MUST CONSIDER THE PLANTS' ROOTS AS WELL AS ABOVE-GROUND BIOMASS, ACCORDING TO PENN STATE RESEARCHERS WHO TESTED THE CHARACTERISTICS OF COVER CROP ROOTS IN THREE MONOCULTURES AND ONE MIXTURE.

"Almost everything that we know about the growth of cover crops is from measuring the above-ground parts and yet some of the benefits that we want to get from cover crops come from the roots," said researcher Jason Kaye, professor of soil biogeochemistry. "This study shows us that what we see above ground is sometimes - but not always - reflective of the benefits below ground."

Cover crops are widely used to increase the quantity of organic carbon returned to the soil between cash crops such as corn, wheat and soybean, as well as to limit erosion and to fix or add nitrogen to the soil. Cover crop roots are known to play an essential role in increasing soil organic carbon levels, Kaye noted, but the root traits that impact carbon levels vary widely among cover crop species, and this variation has yet to be characterised.

Recently, Kaye pointed out, cover crop mixtures have expanded in popularity as a way to increase the diversity of cover crop benefits. His research group in the College of Agricultural Sciences has been conducting a continuous experiment evaluating the effectiveness of various cover crop mixtures since 2011.

In the latest study, conducted at Penn State's Russell E. Larsen Agricultural Research Center at Rock Springs, recently published in Renewable Agriculture and Food Systems, researchers evaluated cover crop treatments including monocultures of triticale, canola and crimson clover as well as a five-species mixture dominated by those three species.

They tested the quantity, quality and spatial distribution of those cover crop roots to learn about root-trait variation among species, and how that variation impacts mixture design. They took root cores from in-row and between-row locations to a depth of about 16 inches in both fall and spring from cover crops planted after winter wheat.

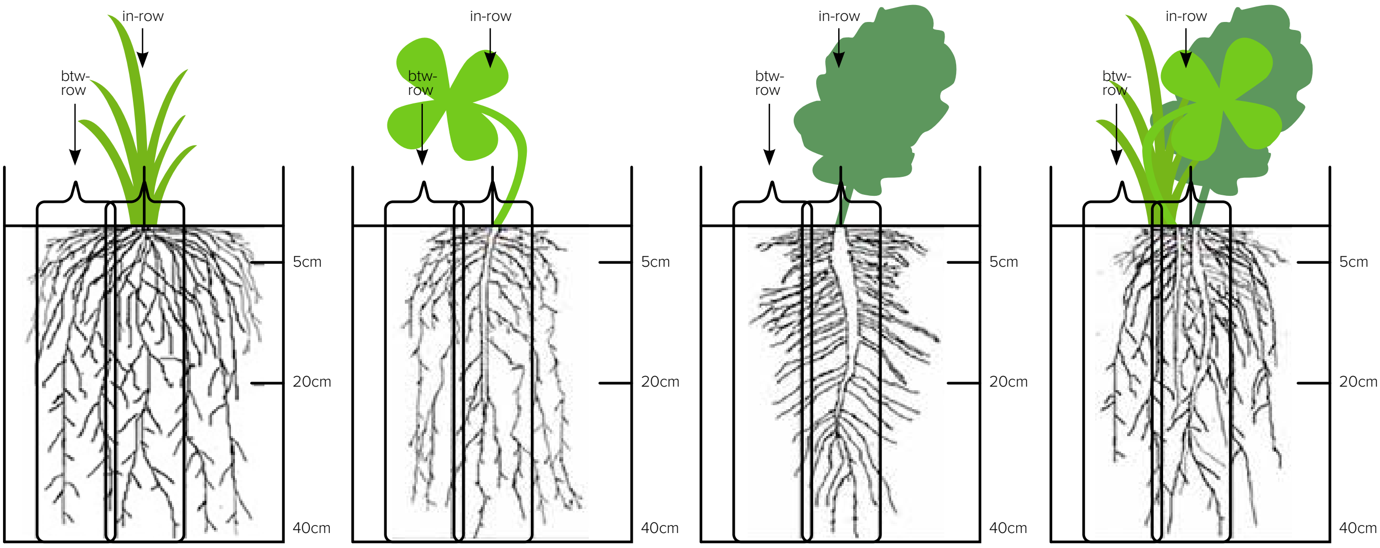
Researchers also assessed cumulative carbon inputs for the entire rotation to determine cover crop and cash crop root carbon contributions. They measured the vertical and horizontal distribution of root biomass, the ratio of root biomass to aboveground biomass - known as the root-to-shoot ratio - and related that to the amount of nitrogen in the plants to determine how these parameters differed between cover crop treatments.

Cover crop mixtures increased total carbon inputs to soil because they simultaneously had high root and shoot inputs and they promoted higher carbon inputs from corn crop residues, Kaye explained.

"The corn crop was more productive following the mixtures than following grasses, and while we harvest a lot of that productivity,

Lead researcher Joseph Amsili taking core samples of cover crops at the Russell E. Larson Agricultural Research Center. The study revealed that cover crop mixtures increased total carbon inputs to soil because they simultaneously had high root and shoot inputs and they promoted higher carbon inputs from residues left by the following corn cash crop. Photo credit: Jason Kaye Research Group, Penn State

The study revealed root trait differences among the three important winter annual cover crops - canola, crimson clover and triticale. The research uncovered several important root traits, including the high root-to-shoot ratio and large production of between-row roots for triticale, which is a hybrid of winter wheat and cereal rye. Photo credit: Joseph Amsili, Penn State



Cover crop root distribution patterns of four cover crop treatments are shown in this artist's conception, including (from left) triticale, crimson clover, canola and a five-species mixture. Photo credit: Joseph Amsili, Penn State

some gets left behind in residues," he said. "I think this is really interesting because it shows that the effect of cover crops on soil carbon are not just related to their own roots and shoots, but also how they affect growth of the cash crops."

The study revealed root trait differences among the three important winter annual cover crops, canola, crimson clover and triticale, lead researcher Joseph Amsili pointed out. The research uncovered several important root traits, he added, including the high root-to-shoot ratio and large production of between-row roots for triticale, which is a hybrid of winter wheat and cereal rye.

"The five-species mix was associated with increased quantity and distribution of roots compared to a crimson clover monoculture, which shows the benefits of combining legumes that have limited root biomass with brassica and grass species that produce greater root biomass, but provide more nitrogen," said Amsili. Now an extension associate in the Soil and Crop Sciences Section in the School of Integrative Plant Sciences at Cornell University, he was a graduate student in the Department of Ecosystem Science and Management at Penn State when he spearheaded the research.

The study is important because the increased knowledge of cover crop root traits it yielded improves the understanding of the linkages between root traits and the services cover crops provide, Kaye explained. Going forward, he expects to find cover crops and design cover crop mixtures that deliver unexpected ecosystem benefits and added boosts to cash crops that follow.

"We'll now be able to think about what we want to occur in the soil and then design mixtures that have the root traits that are best able to provide those benefits," he said. "Advancing research on cover crop root traits serves as a strong foundation for designing mixtures with complementary root traits. I envision that we will exploit lots of different cover crop plants for different traits, both above and below ground."

This research was funded by the U.S. Department of Agriculture's National Institute of Food and Agriculture, Organic Research and Extension Initiative.

Journal Reference:

Joseph P. Amsili, Jason P. Kaye. Root traits of cover crops and carbon inputs in an organic grain rotation. Renewable Agriculture and Food Systems, 2020; 1 DOI: 10.1017/S1742170520000216

FLAVONOIDS' PRESENCE IN SORGHUM ROOTS MAY LEAD TO FROST-RESISTANT CROP

Flavonoid compounds - produced by the roots of some sorghum plants - positively affect soil microorganisms, according to Penn State researchers, who suggest the discovery is an early step in developing a frost-resistant line of the valuable crop for North American farmers.

That is important because sorghum is a crop that can respond to climate change because of its high water- and nitrogen-use efficiency, according to Surinder Chopra, professor of maize genetics, and Mary Ann Bruns, professor of soil microbiology. A close relative to corn, it is the fifth most valuable cereal crop globally.

"Sorghum can be used for human food and animal feed and also can be grown as a bioenergy crop, producing more ethanol than corn when grown on marginal lands," they said. "Sorghum is better adapted than corn to stresses such as drought, salinity and heat. But increased sorghum production requires increasing its tolerance to chilling and frost stress, and this is especially true for the northeastern U.S."

Showing red flavonoids

To reach its full potential, sorghum needs to grow five months after being planted in the first week of June. If a frost occurs in early October - which is not unusual in the U.S. Northeast - farmers can be devastated. Because sorghum is so sensitive to being chilled, even a mild frost or an early cold snap can kill the crop.

Earlier studies by Chopra's research group in the College of Agricultural Sciences showed that sorghum produces potent flavonoids in its leaves when exposed to stresses such as fungi, insect feeding or frost. These flavonoids can allow the plant to adapt and survive. Bruns group has been working on understanding soil microbiomes in various stressed ecosystems.

Together, the researchers are testing whether interactions between those flavonoids and microorganisms in the root zone can lead to the development of sorghum varieties and compatible soil microbial additions to provide resistance to cold and frost. A collaborative effort between the two research groups enables them to connect the prevalence of plant-associated microbiomes, plant genetics and flavonoids.

In this study, researchers found evidence that plant genetic variation influences root flavonoids and the composition of the soil microbial community, and that low temperatures affect these relationships. In findings recently published in Phytobiomes Journal, they contend that plant-microbe interactions and secondary metabolite production may be important components to include for selective breeding of sorghum for frost stress tolerance.

"We think that the flavonoids can provide the needed tolerance against the stress of cold and frost," Bruns and Chopra said. "In addition, certain microorganisms present in the soil can interact with flavonoids to provide adaptability to the plant when it perceives cold or frost above ground."

The researchers grew selected lines of sorghum at Penn State's Russell E. Larson Agricultural Research Center at Rock Springs from seeds they acquired from the Grain, Forage and Bioenergy Research Laboratory maintained by the U.S. Department of Agriculture's Agricultural Research Service in Lincoln, Nebraska.

Of those "near-isogenic" lines of sorghum - alike except for two genes involved in the production of flavonoids - one set of lines inherently produced flavonoids, the second set lacked genes to produce flavonoids, and the third type only produced flavonoids when the plants were exposed to stress such as frost and fungal pathogens.

Researchers analysed the community of microorganisms in the soils surrounding the roots to see if the presence or absence of flavonoids in the roots of some of the sorghum plants impacted communities of fungi and bacteria. Lead researcher Mara Cloutier, doctoral candidate in soil science and biogeochemistry, led the evaluation of microbiomes in the vicinity of the roots before and after a late-season frost.

Seed multiplication plot

The researchers analysed roots for total flavonoids, total phenolics and antioxidant activity to determine whether sorghum genetic variation influenced root flavonoid concentrations and soil microbial communities. The researchers wanted to identify how frost affected these relationships.

"We found that a greater number of bacterial strains were correlated with total flavonoids compared with fungal species," she said. "Collectively, this study provides evidence that plant genetic variation influences root flavonoids and the soil microorganism community composition in the vicinity of the plant roots, and that these relationships are affected by frost."

Also involved in the research were Debamalya Chatterjee, Dinakaran Elango and Jin Cui, graduate students in plant science.

The Sun Grant Initiative and the U.S. Department of Agriculture's National Institute of Food and Agriculture funded this research.

Journal Reference:

Mara Cloutier, Debamalya Chatterjee, Dinakaran Elango, Jin Cui, Mary Ann Bruns, Surinder Chopra. Sorghum Root Flavonoid Chemistry, Cultivar, and Frost Stress Effects on Rhizosphere Bacteria and Fungi. Phytobiomes Journal, 2020; PBIOMES-01-20-0 DOI: 10.1094/PBIOMES-01-20-0013-FI

CROP COMPETITION GIVES GROWERS A FREE KICK FOR RYEGRASS CONTROL

BY CINDY BENJAMIN

Wheat and canola crops offer growers some really practical options to improve crop competition against weeds, particularly grasses, and vastly reduce weed seed set.

Researchers at the University of Adelaide, led by Dr Chris Preston and with GRDC investment, conducted an extensive study to identify the agronomic factors that promote strong early crop growth.

They found that simple strategies of growing hybrid canola and sowing wheat early, can couple with pre-emergent herbicides to achieve a very effective double-knock. The result is more yield, less weed seed produced and less selection pressure on the herbicides.

“In the canola trial we used a range of pre-emergent herbicides and compared open pollinated and hybrid canola,” says Chris. “The bottom line of our trial is that if you grow a hybrid canola with pre-emergent herbicides and do nothing else different, you’re going to reduce your grass weed seed set by 50 per cent.”

This level of non-herbicide weed control was also measured in an Australian-first study that looked at the competitive ability of 16 canola genotypes against annual ryegrass and volunteer wheat over two contrasting seasons, led by Professor Deirdre Lemerle at Charles Sturt University.

In a separate trial conducted by Rohan Brill, former research and development agronomist, NSW DPI based in Wagga Wagga, and colleagues at Trangie and Tamworth, a rule of thumb was established that seed size had a greater effect on early biomass production in canola than did cultivar type (hybrid vs OP). This gave rise to the recommendation that all farmer-retained OP canola seed be cleaned and graded to collect planting seed that is 2mm in diameter or larger.

Their study showed that sowing large canola seed, regardless of the cultivar, is key to strong early crop growth and the crop’s ability to compete with weeds.

Having observed that later planted wheat often hosts more weeds, the Adelaide University team looked at the effect of planting wheat as early as possible.

“Our previous idea for managing weedy paddocks was to delay sowing, apply another knockdown treatment to control more weeds and then put the crop in,” says Chris. “In this trial we found that even in weedy paddocks you can put the wheat in early with a robust pre-emergent herbicide package, and the result is more wheat yield and less ryegrass seed at the end of the season.”

> **“If you sow the right variety early and apply the right pre-emergent herbicide package, again you can halve your grass weed numbers, just from competition in the middle part of the season and you don’t have to change anything else.”**

There are a few practicalities to consider when looking to sow wheat earlier. Firstly, you need to choose a variety that will still flower in the right flowering window for your location. If you are sowing several weeks earlier than normal you need a longer season variety to manage frost and heat risk at the end of the season.

Secondly, if you are sowing completely dry, then most of the pre-emergent herbicide options are open to you. If there is some soil moisture, but not enough for crop germination, some of the pre-emergent herbicides will not perform well. You need to give careful consideration to your choice of herbicide to suit the environmental conditions of each season.

These findings underpin WeedSmart’s aim, to promote farming systems that produce ‘more yield and less weeds’.

For more information about non-herbicide tools to combat weeds, visit the website: www.weedsmart.org.au

If you grow a hybrid canola with pre-emergent herbicides (left) and do nothing else different, you’re going to reduce your grass weed seed set by 50 per cent (right, conventional canola and no pre-emergent herbicide). Photo credit: WeedSmart

Dr Chris Preston, University of Adelaide, says if you sow the right wheat variety early and apply the right pre-emergent herbicide package, you can halve your grass weed numbers, just from competition in the middle part of the season, and you don’t have to change anything else. Photo credit: WeedSmart

Crop competition trial site at Roseworthy, SA. Photo credit: WeedSmart

AG-BIOTECH INNOVATIONS REAP REWARDS FOR FARMERS, FOOD SECURITY AND THE ENVIRONMENT

An international report just released shows the significant economic, environmental and agronomic benefits of farmers adopting GM crops.

Chief Executive Officer of the national peak industry organisation for the plant science sector, Mr Matthew Cossey, said, "The international report from London based PG Economics confirms the importance of Australian farmers having access to innovative, safe and approved technologies to remain globally competitive and farm sustainably in a changing climate.

"Australia was an early adopter of GM technology in cotton. We've been growing cotton with GM traits since 1996 and now almost all of Australia's cotton production is GM. The economic gains and savings have been significant with an average increase of on-farm income at $27.87 per hectare and the average reduction in weed control costs at $90.95 per hectare.

"Since 1996 GM cotton has gained Australian farmers almost $1.1 billion.

"Canola is another important crop for Australia's farming sector with GM varieties delivering yield gains of between five to 22 per cent over their conventional counterparts. GM cotton and canola have also allowed for reductions of on-farm inputs and a reduced and more sustainable use of important crop protection chemistry.

"On a global scale, GM crops are just as beneficial. The report shows that when farmers are given access to GM crops, more food is grown, less fuel is being used on farm and less land is needed for production."

Mr Cossey concluded, "In May, South Australian growers became the last mainland farmers to finally be granted access to GM crops long after their interstate competitors. South Australia embracing this agricultural technology from next season will see significant environmental and agronomic benefits with the farming sector in SA and nationally continuing to thrive."

Visit pgeconomics.co.uk to read the full report GM crops: Global socio-economic and environmental impacts

CNH INDUSTRIAL AND NEXT INSTRUMENTS SIGN A SUPPLY AGREEMENT FOR THE CROPSCAN 3300H ON COMBINE GRAIN ANALYSER

The CropScan 3300H On Combine NIR Analyser is proving to be the most dramatic development in Precision Agriculture in 20 years. No other piece of PA technology offers to pay for itself in 1 or 2 fields in the first year. With more than 350 systems now installed around the world, this Australian developed and manufactured technology is now available to Australian and New Zealand farmers directly through the CNH Industrial dealer network.

Next Instruments has been manufacturing the CropScan range of NIR analysers for 20 years. The CropScan 3000H was introduced in 2013. Under a Supply Agreement with CHNi in 2016, an OEM version called the Model 3000H has been installed on new and existing CASE IH and New Holland combines across Australia and New Zealand.

In May 2020 Next Instruments signed a new Supply Agreement with CNH Industrial whereby CASE IH and New Holland dealers in Australia and New Zealand can supply the CropScan 3300H to their customers with direct shipment from the Next Instruments' factory in Sydney. CNHi dealers will be able to access Next Instruments' sales, technical and service support team directly. This move will ensure faster and better support for dealers and their customers.

The new CropScan 3300H is similar to the previous Model 3000H however there are several added features.

- New Sample Head: Increases the flow rate of grain and reduces the scan time to 5-10 seconds per measurement.
- A FREE CropScanAg Cloud account: Captures and stores the Protein, Moisture, Oil, Yield and GPS data from the CropScan 3300H and the combines Yield Monitor and GPS Transponder and posts it to the Cloud whenever the CropScan 3300H is within internet connection range.
- FREE CropScanAg Cloud Portal: Provides access to the CropScanAg Cloud to download the farm field data to any tablet or PC.
- New Touch Screen Tablet PC: Less weight, less heat and faster interface for the combine operator.
- Agrimatics Libra Cart Weigh Scale and Digi Star Cart Weight system communications so that the chaser bin weights can be collected in the field thus providing more accurate grain tonnage data.

For more information on the CropScan 3300H On Combine NIR Analyser, visit our web site: www.cropscanag.com

THE BIG PROBLEM: REDUCED YIELD DUE TO STRESS

Once a seed is planted, a range of environmental factors can start to reduce its full potential by up to 70%. These environmental stressors can include nutritional deficiencies, water stress, high or low temperatures, pests, weeds, and diseases.

Crops can be impacted at various stages of growth with some crops experiencing the greatest loss early due to seedling death. Some will be affected later with flower bud failure, and others will be closer to harvest with grain abortion, fruit drop, or fruit damage. This reduction in yield impacts the grower's bottom line and can cause significant financial loss.

According to the Australian Department of Agriculture, environmental stress has been identified as one of the major issues facing the Australian agriculture industry.

Stoller Australia's Technical Manager, Domenic Cavallaro, has conducted numerous trials on one of Stoller's proprietary products, Bio-Forge, which works to maintain the genetic potential of plants, improve growth, and increase yield in a variety of crops.

Producing favourable results across tree and vine, field and greenhouse, and broadacre Bio-Forge is proving to reduce the effects of stress on a large range of crops. In a program with optimum nutrition, Bio-Forge can help to maximise the genetic potential of the crop resulting in increased yield and profit.

"Bio-Forge has demonstrated again and again the improvement that it can have on yield across a variety of crops, which is really exciting. This is helping farmers across the country to get the most out of their crop's genetic potential." – Domenic Cavallaro, Technical Manager, Stoller Australia.

A Summary of Bio-Forge trial results

Bio-Forge on Potatoes*

- Bio-Forge applications resulted in 23% more marketable tubers and 15.7% more marketable weight than the control.
- A 7.1 tonne per hectare yield leads to a return on investment of $15 to every $1 spent.**
- Bio-Forge can help restore nutrient status and normal plant growth.

Bio-Forge on Cotton*

- Cotton treated with Bio-Forge (300ml per hectare) at the Squaring phase produced an 9% increase on yield.
- The application of Bio-Forge led to a $4:1 per hectere return on investment

Bio-Forge on Sorghum

- Bio-Forge when used as a seed treatment on sorghum crops generated a 12% increase in yield.

Bio-Forge on Wine Grapes*

- Bio-Forge can assist in regrowth of shoots after frost.
- Applied on wine grapes after frost, there were 3.4 more bunches per vine than the control.
- A 31% increase in yield lead to a return on investment of $6.25 to every $1 spent.

***For more information on Stoller's Bio-Forge trials and rates of application, please contact Stoller Australia, info@stoller.com.au or 1800 337 845.**

Dominic Cavallaro, Stollers Technical Manager. Photo credit: Stoller

On the left is cotton treated with Stoller Bio-Forge, on the right cotton not treated with Bio-Forge. Photo credit: Stoller

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BEYOND THE GARNISH: WILL A NEW TYPE OF PRODUCE GET THE MICROGREEN LIGHT?

MICROGREENS. THEY'RE LEAFY GREEN VEGETABLES THAT ARE RELATIVELY NEW TO THE DINING ROOM, BUT A STUDY BY A COLORADO STATE UNIVERSITY TEAM INDICATES THAT THEY WILL BE WELCOME COMPANY AT THE TABLE.

"You've probably heard of sprouts and baby greens," said lead researcher and registered dietitian nutritionist Sarah Ardanuy Johnson, an assistant professor and director of the Functional Foods & Human Health Laboratory in CSU's Department of Food Science and Human Nutrition. "These are somewhere in the middle."

Sarah Ardanuy Johnson with microgreens. Photo credit: Colorado State University

Microgreens are young and tender leafy greens of most vegetables, grains, herbs and flowers that are harvested when their first leaves appear. Their rapid maturity of a few weeks and affinity for controlled-environment agriculture (also known as indoor farming) means they use very little water and can be harvested quickly. It makes them a model of sustainability: They can be grown indoors, year-round, in cities and rural communities, in greenhouses, warehouses, vertical farms and even homes.

"I came across microgreens and had never heard of them before," said Johnson, who initially studied environmental science and ecology as an undergraduate before realising her true academic passion was in nutrition and food science. "The need for our food to be more sustainable is greater than ever. I love the idea that they can be grown in an urban environment, indoors in big cities and smaller towns. We can't just grow everything in the soil outside anymore, and we need to conserve what natural resources we still have."

Nutritional benefits

Johnson described them as leafy greens that pack a punch. They carry fewer food safety concerns than sprouts because they are grown in an environment with less moisture and, unlike sprouts, the roots of microgreens are removed during harvest. Nutritionally, they have been shown to have higher concentrations of phytochemicals and nutrients like beta-carotene (which can be converted to Vitamin A) than mature plants.

"Vitamin A deficiency is the leading cause of blindness worldwide," Johnson said, explaining that microgreens may become a key food source for preventing nutrient deficiencies and promoting global health and environmental sustainability. "That potential is pretty cool."

But she and her fellow researchers wanted to find out if microgreens are acceptable to consumers, and possible factors in how much consumers like or dislike them. They sought to understand if microgreens' appearance, taste and other considerations make them an appealing addition to people's plates. The answer? Signs point to more and more people exhibiting a microgreen palate.

Results of the study were published in the Journal of Food Science. Johnson's team surveyed 99 people about their reactions to six different types of microgreens: arugula, broccoli,

bull's blood beet, red cabbage, red garnet amaranth and tendril pea. The microgreens were grown in the CSU Horticulture Center. The participants, who didn't know in advance what they would be trying, answered a variety of questions about things like flavour, aroma, texture and appearance.

'Funfetti'

"Some people call them 'vegetable confetti' or 'funfetti' because they're small, colourful and flavourful," Johnson said, adding that they have historically been used as a garnish or topping in restaurants.

The red-coloured ones - beet, cabbage and amaranth - received top marks for appearance, but broccoli, red cabbage, and tendril pea got the highest grades overall. Arugula was ranked lowest, on average, likely due to its somewhat spicy and bitter flavour, although many people did like the taste. Overall, microgreens that rated highly for appearance, flavour and texture also scored lower on factors like astringency, bitterness, heat and sourness. Food neophobia, or the fear of trying new foods, was found to also be an important factor driving consumer acceptability.

"But they were all liked well enough that people said they would consume them and purchase them," Johnson said. "I feel like they should be used more as a vegetable and not just a garnish. That's part of the reason why I wanted to do this study."

Increasing demand

In fact, that was one of her key goals in launching the research: Can the appeal of microgreens lead to more popularity, more demand, more production and more grocery stores carrying them? Such products can be expensive due to markup and packaging.

"But people's mindsets are changing," Johnson said. "People don't want to buy something that's going to just end up in the landfill. They are looking for something that can benefit their health and the environment."

Participants said factors they would consider in buying microgreens included familiarity and knowledge, cost, access/availability and freshness/shelf-life.

For the research project, Johnson teamed up with Steven Newman, a professor and greenhouse crops specialist in CSU's Department of Horticulture and Landscape Architecture. Johnson found him online in her quest to find a collaborator with expertise in greenhouse crops; Newman has provided leafy greens grown in the Horticulture Centre to campus dining halls. Newman's team grew the microgreens used in the study with help from Johnson's team, in a classic example of the type of cross-disciplinary research that's on the rise at CSU.

"This has been a fun project with fruitful outcomes," Newman said. "This is how transdisciplinary research is supposed to work."

Other partners

Study co-author Marisa Bunning, a food science professor and Extension food safety specialist, has become a microgreens fan and now grows them at home. Laura Bellows, an associate professor with expertise in public health and health behaviours, helped assess factors contributing to consumer acceptability, such as food neophobia.

Other members of Johnson's team included Hanan Isweiri, Newman's former postdoctoral fellow; first author Kiri Michell, one of Johnson's graduate students; graduate student Michelle Dinges; undergraduate Lauren Grabos; Associate Professors Michelle Foster and Tiffany Weir of the Department of Food Science and Human Nutrition; Assistant Professors Adam Heuberger and Mark Uchanski, Associate Professor Jessica Prenni, and Professor Henry Thompson of the Department of Horticulture and Landscape Architecture; and Assistant Professor Sangeeta Rao of the Department of Clinical Sciences.

Experts say that by 2050, there will be more than 10 billion people in the world to feed, making it more important than ever to think about ways to produce and grow nutritious food, as well as diversify the food supply in a sustainable way.

'Small but mighty'

"This was a very exciting, interdisciplinary study, and I am glad I was able to take part and help lead it," Michell said. "I look forward to more research regarding these small but mighty greens and their role in our food supply and on human health."

"I don't know that we could have done the advanced interdisciplinary research without Kiri's hard work and leadership," Johnson said. "But this was truly a team effort."

Michell noted that The Foundry dining hall on the CSU campus has started using microgreens in some of its dishes, and even has a viewing window where students can see them being grown.

The large collaboration aims to advance research on microgreens, and to increase knowledge of microgreens and their integration into the global food system. The group is conducting additional research, such as examining the feasibility, tolerability and potential health impacts of daily microgreen consumption at a higher dose (two cups per day, which is a typical serving size for leafy green vegetables), and comparing the nutritional value of microgreens to that of their more mature counterparts.

Journal Reference:

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SOURCE OF PATHOGEN THAT CAUSES BITTER ROT DISEASE

Fungal spores responsible for bitter rot disease, a common and devastating infection in fruit, do not encounter their host plants by chance. Turns out, they have a symbiotic association with the plant, often living inside its leaves.

The new way of looking at the fungal pathogen, Colletotrichum fioriniae, as a leaf endophyte - bacterial or fungal microorganisms that colonise healthy plant tissue - was the outcome of a two-year study conducted by researchers in Penn State's College of Agricultural Sciences.

According to Phillip Martin, a doctoral candidate in plant pathology, the findings, which were published recently in the journal Phytopathology, have important implications for the management of the pathogen in fruit trees.

Colletotrichum fioriniae causes diseases, often called anthracnoses, in more than 100 fruit and vegetable plants, including apple, peach, pear and strawberry. The fungus infects the fruit under warm and wet conditions and causes brown, sunken lesions; occasionally, orange spores will be seen on the surface.

The disease is of concern to the Pennsylvania apple industry, which produces 400 million to 500 million pounds of apples per year. The state ranks fourth in the nation for apple production, per statistics from the U.S. Department of Agriculture.

"The research was based on the idea that if we can determine where the spores are coming from, then maybe we can eliminate the source and break the bitter rot disease cycle," said Martin, who carried out the study under the guidance of Kari Peter, associate research professor of tree-fruit pathology. "Unfortunately, from this perspective, many of the spores come from leaves, including apple leaves, and from trees and shrubs that are everywhere in Pennsylvania."

Previously, the spores in question were thought to originate mostly from diseased fruits and twigs. However, even when infected fruits and twigs were removed from a tree, the disease, while reduced, often still was present, a circumstance that puzzled scientists.

The research, which took place in 2018 and 2019, focused on apples and involved the placement of rain-splash spore traps in orchards at Penn State's Fruit Research and Extension Centre, at Hollabaugh Bros. Inc. fruit and vegetable farm, and at a satellite location in Arendtsville, all of which are located in Adams County. Traps also were placed in two forested areas - comprised mostly of deciduous trees - near the orchards.

Based on previous research that indicated that Colletotrichum fioriniae could survive on leaves, the team collected more than 1,000 leaves of apple and of 24 forest plant species. The leaves were disinfected to kill fungi on the leaf surface, frozen to kill the leaves and incubated to allow the fungi inside of the leaves to grow out and sporulate.

This test found Colletotrichum fioriniae in more than 30% of leaves sampled, with most spores coming from the forest samples. In orchards that were managed with fungicides, up to 8% of apple leaves were infected with the fungus. In the untreated orchard, Martin said, the spores were abundant, meaning they were found in 15-80% of the leaves. The infections did not seem to be causing any leaf diseases, however.

"While unexpected, these findings did explain why growers struggle with bitter rot even when they remove all diseased fruits and twigs - the fungus was living in the leaves during the season," Martin said. "The fungus was present in all the tested orchards and could not be traced to infection from a nursery, which makes sense since the initial infections likely are coming from surrounding forests and fence rows."

Since the fungus is abundant in the forest canopy, eradication from nearby areas would be impractical, Martin added. However, the spatial limitations of rain-splash dispersal mean that forests are not regular sources of fungus spread; they likely serve only as primary introduction sources during extreme rain and wind events, after which the fungus becomes established in agricultural areas.

"Our study changes how we think about this fungus," Martin said. "While it may not supply quick fixes, it provides the basis for further research aimed at developing better management techniques, such as selecting resistant cultivars and breeding for genetic resistance."

Peter agreed. "Although it's exciting to understand that Colletotrichum fiorinae's niche in the environment is more sophisticated than we had appreciated, it does make managing bitter rot in apple orchards less straightforward," she said. "As researchers, we can view this is an opportunity to think outside the box and to be creative in figuring out a sustainable bitter rot management strategy."

In the meantime, Martin noted, disease-management tactics stay the same. "We don't believe most spores are overwintering in the leaves," he said. "Growers should continue to remove the infected fruits and twigs to help reduce disease spread season to season."

Journal Reference:

Phillip L. Martin, Kari Peter. Quantification of Colletotrichum fioriniae in orchards and deciduous forests indicates it is primarily a leaf endophyte. Phytopathology®, 2020; DOI: 10.1094/PHYTO-05-20-0157-R

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