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THE AUSTRALIAN AGRONOMIST MAGAZINE

Effects of increased temperatures on Australian wheat yields

'Sneezing' plants contribute to disease proliferation

Grazing animals drove domestication of grain crops


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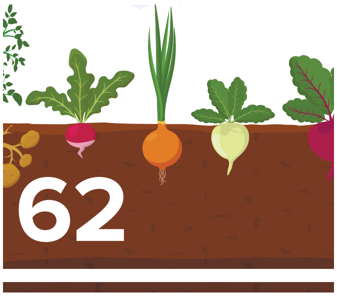

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THE AUSTRALIAN AGRONOMIST

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'SNEEZING' PLANTS CONTRIBUTE TO DISEASE PROLIFERATION

THE JUMPING DROPLETS, AT THE RATE OF 100 OR MORE AN HOUR, ARE A VIOLENT EXPULSION OF DEW FROM THE SURFACE. IT'S GOOD FOR THE PLANT BECAUSE IT IS REMOVING SPORES FROM ITSELF, BUT IT'S BAD BECAUSE, LIKE A HUMAN SNEEZE, THE LIQUID DROPLETS ARE FINDING THEIR WAY ONTO NEIGHBOURING PLANTS.

Virginia Tech researchers discovered that wheat plants "sneezing" off condensation can vastly impact the spread of spore-borne diseases, such as wheat leaf rust, which can cause crop yield losses of up to 20 percent or more in the United States and higher average losses in less developed agricultural nations.

The study, published June 19, and featured on the cover of the Journal of the Royal Society Interface, is part of a three-year grant obtained from the U.S. Department of Agriculture's National Institute of Food and Agriculture to study the dispersal of wheat pathogens by rain splash and jumping-droplet condensation.

Jonathan Boreyko, assistant professor of mechanical engineering in the College of Engineering is a co-principal investigator on the grant and David Schmale, professor of plant pathology, physiology, and weed science in the College of Agriculture and Life Sciences, is the primary investigator of the nearly $500,000 project.

"Professor Schmale had seen some of the work we've been doing on condensation and was curious to see what we could learn about condensation on wheat leaves," said Jonathan. "The project didn't start with any expectations, but people already knew that rain splash and wind caused pathogenic spores to be removed from plants and spread to others, and we wanted to see if condensation might also have a role to play in spore dispersal."

The students involved in the study were told not to expect jumping droplets in their condensation tests, as the droplets are known to only occur on specific surfaces, namely superhydrophobic surfaces normally associated with exotic materials, such as lotus leaves and gecko skin.

Superhydrophobic surfaces are non-wetting, and when spherical condensate grows, droplets merge together to release surface tension, which is converted into kinetic energy, which propels them from the surface.

"Conceptually, what the plants are doing is sneezing," Jonathan said. "The jumping droplets, at the rate of 100 or more an hour, are a violent expulsion of dew from the surface. It's good for the plant because it is removing spores from itself, but it's bad because, like a human sneeze, the liquid droplets are finding their way onto neighboring plants. Like a cold, it's easy to see how a single infected plant could propagate a disease across an entire crop."

The paper, co-first-authored by Saurabh Nath and Farzad Ahmadi, engineering mechanics graduate students in Jonathan's lab, showed the jumping droplets can dramatically increase the dispersal of disease spores.

"We wanted to find out, first if the condensation droplets can carry spores, and while 90 percent of them carry only a single spore, we have seen instances where a droplet has carried as many as 11," Farzad said. "We also looked at how high the spores can jump and whether they can get past the boundary layer of the leaf."

The boundary layer, which is about a millimeter thick, is the region of air near the leaf's surface where the wind doesn't affect the droplet. If the kinetic energy from merging moves the jumping droplet above the boundary layer, the droplet can be taken by the wind. Depending upon the wind speed, it's feasible for the droplet to then be moved great distances, including to neighboring fields or farms.

"Using water-sensitive paper we measured how high the droplets can jump," Farzad said. "A blue dot on the paper shows us a droplet, and a reddish dot shows us a spore, so in this way we can calculate both the height and the number of spores in the droplet."

The droplets in Farzad's tests routinely jumped from 2-5 millimeters from the surface of the leaf, well above the distance necessary to be taken by the wind to be re-deposited elsewhere.

"It's important to realize these droplets are microscopic in size," explained Jonathan. "Each droplet is about the same size as the thickness of a human hair - about 50 micrometers - so this is all happening at a scale we don't notice. A 0.1 meter per second wind can support the weight of a jumping droplet, whereas a droplet directly on the leaf requires a wind of 10 meters per second - 100 times stronger to be removed. Once it's in the wind, there is, hypothetically, no limit to how far it can be carried."

The low wind speed needed to carry the droplets means that the spore-ridden dew drops can have a large impact on crop health over a very wide area. "We know now that wind and rain aren't the only factors in the spread of disease among crops," Jonathan said.

The next phase of the continuing experiment for Jonathan and his team is to see how far the wind can carry the spore-bearing droplets. Using water-sensitive paper spread out in varying distances from a wheat leaf, the team will use fans to simulate wind and collect data on droplet and spore dispersal.

Journal Reference:

Saurabh Nath, S. Farzad Ahmadi, Hope A. Gruszewski, Stuti Budhiraja, Caitlin E. Bisbano, Sunghwan Jung, David G. Schmale, Jonathan B. Boreyko. 'Sneezing' plants: pathogen transport via jumping-droplet condensation. Journal of The Royal Society Interface, 2019; 16 (155): 20190243 DOI: 10.1098/rsif.2019.0243

WHEAT MYTH DEBUNKED

The myth that modern wheat varieties are more heavily reliant on pesticides and fertilisers is debunked by new research published in Nature Plants in June.

Lead author on the paper, Dr Kai Voss-Fels, a research fellow at The University of Queensland, said modern wheat cropping varieties actually out-perform older varieties in both optimum and harsh growing conditions.

"There is a view that intensive selection and breeding which has produced the high-yielding wheat cultivars used in modern cropping systems has also made modern wheat less resilient and more dependent on chemicals to thrive," said Kai.

"However, the data unequivocally shows that modern wheat varieties out-perform older varieties, even under conditions of reduced amounts of fertilisers, fungicides and water," he said.

"We also found that genetic diversity within the often-criticised modern wheat gene pool is rich enough to generate a further 23 per cent increase in yields." Kai said the findings might surprise some farmers and environmentalists.

"Quite a few people will be taken aback by just how tough modern wheat varieties proved to be, even in harsh growing conditions, such as drought, and using less chemical inputs."

Kai said the findings could have potentially important implications for raising the productivity of organic cropping systems. "It's been widely assumed that the older wheat cultivars are more robust and resilient but it's actually the modern cultivars that perform best in optimum and sub-optimum conditions."

Wheat is the world's most important food crop. However, with global wheat yields reduced due to droughts in recent years and more climate risk anticipated in the future, the hardiness of modern wheat varieties is an issue of global significance. The study is believed to provide the most detailed description of the consequences of intensive breeding and genetic selection for high grain yield and associated traits in European wheat over the past 50 years.

It was led by Professor Rod Snowdon of the Justus Liebig University Giessen (JLU), who is also an honorary Professor at UQ, in collaboration with seven other German universities.

The genetic analysis was undertaken at QAAFI under the leadership of Professor Ben Hayes.

The first part of the study involved testing 200 wheat varieties that have been essential to agriculture in Western Europe in the past 50 years.

Performance was compared between those varieties in side-by-side field trials under high, medium and low chemical input conditions. The second part of the study was undertaken at QAAFI, to match the performance differences with the different varieties' genetic make-up.

"This genetic information allows us to take the discovery to the next level," Kai says.

"We can use artificial intelligence (AI) algorithms to predict the optimal crosses needed to bring together the most favourable segments as fast as possible."

SEAWEED FEED ADDITIVE CUTS LIVESTOCK METHANE BUT POSES QUESTIONS

Supplementing cattle feed with seaweed could result in a significant reduction in methane belched by livestock, according to Penn State researchers, but they caution that the practice may not be a realistic strategy to battle climate change.

"Asparagopsis taxiformis - a red seaweed that grows in the tropics - in short-term studies in lactating dairy cows decreased methane emission by 80 percent and had no effect on feed intake or milk yield, when fed at up to 0.5 percent of feed dry-matter intake," said Alexander Hristov, distinguished professor of dairy nutrition. "It looks promising, and we are continuing research."

If seaweed feed supplement is a viable option to make a difference globally, the scale of production would have to be immense, Alexander noted. With nearly 1.5 billion head of cattle in the world, harvesting enough wild seaweed to add to their feed would be impossible. Even to provide it as a supplement to most of the United States' 94 million cattle is unrealistic.

"To be used as a feed additive on a large scale, the seaweed would have to be cultivated in aquaculture operations," he said. "Harvesting wild seaweed is not an option because soon we would deplete the oceans and cause an ecological problem."

Still, the capability of Asparagopsis taxiformis to mitigate enteric methane as a feed supplement demands attention, said Hannah Stefenoni, the graduate student working with Alexander on the research project, who will present the research to members of the American Dairy Science Association June 23 at their annual meeting in Cincinnati, Ohio. The findings of their research were published recently online in the Proceedings of the 2019 American Dairy Science Association Meeting.

"We know that it is effective in the short term; we don't know if it's effective in the long term," Alexander explained. "The microbes in cows' rumens can adapt to a lot of things. There is a long history of feed additives that the microbes adapt to and effectiveness disappears. Whether it is with beef or dairy cows, long-term studies are needed to see if compounds in the seaweed continue to disrupt the microbes' ability to make methane."

There are also questions about the stability over time of the active ingredients - bromoforms - in the seaweed. These compounds are sensitive to heat and sunlight and may lose their methane-mitigating activity with processing and storage, Alexander warned.

Palatability is another question. It appears cows do not like the taste of seaweed - when Asparagopsis was included at 0.75 percent of the diet, researchers observed a drop in the feed intake by the animals.

Also, the long-term effects of seaweed on animal health and reproduction and its effects on milk and meat quality need to be determined. A panel judging milk taste is part of ongoing research, Alexander said.

Cows burping - often incorrectly characterized as cows farting - methane and contributing to climate change has been the subject of considerable derision within the U.S., conceded Alexander, who is recognized as an international leader in conducting research assessing greenhouse gas emissions from animal agriculture. It is taken seriously in other countries, he explained, because the average dairy cow belches 380 pounds of the potent greenhouse gas a year.

"But methane from animal agriculture is just 5 percent of the total greenhouse gases produced in the United States - much, much more comes from the energy and transportation sectors," Alexander said. "So, I think it's a fine line with the politics surrounding this subject. Do we want to look at this? I definitely think that we should, and if there is a way that we can reduce emissions without affecting profitability on the farm, we should pursue it."

And there may be a hidden benefit.

"It is pretty much a given that if enteric methane emissions are decreased, there likely will be an increase in the efficiency of animal production," said Alexander. Seaweed used in the Penn State research was harvested from the Atlantic Ocean in the Azores and shipped frozen from Portugal. It was freeze-dried and ground by the researchers. Freeze drying and grinding 4 tons of seaweed for the research was "a huge undertaking," Alexander said.

Also involved in the research at Penn State were Molly Young, research technician; and Audino Melgar Moreno and Susanna Raeisaenen, graduate assistants; all in animal science. Camila Lage, a graduate student at Federal University of Minas Gerais, Brazil, also was on the project.

The U.S. Department of Agriculture's National Institute of Food and Agriculture and the Jeremy and Hannelore Grantham Environmental Trust funded this research.

Asparagopsis Taxiformis

EFFECTS OF INCREASED TEMPERATURES ON AUSTRALIAN WHEAT YIELDS

RESEARCH HAS QUANTIFIED THE TOLL THAT INCREASED TEMPERATURES AND HEAT STRESS ARE HAVING ON AUSTRALIAN WHEAT YIELDS.

Queensland Alliance for Agriculture and Food Innovation (QAAFI) researcher, Dr Karine Chenu, has found that grain yields have decreased by an average of 240 kilograms per decade since 1985. She says the trend is striking.

Working at QAAFI's Centre for Plant Science, Karine's collaborative research using the mid-maturing wheat cultivar Janz (sown on 15 May) aims to investigate wheat's response to high temperatures. The objective is to help develop management practices and breeding strategies to improve the cereal's adaptation to changing climatic conditions.

“Heat events during reproductive and grain-filling phases can heavily impact on yield. We are quantifying heat effects at those critical stages in carefully designed trials in glasshouse trials at Gatton” Karine said.

In her latest work, Karine used historical weather data from the Scientific Information for Land Owners (SILO) Patched Point Data set for 60 sites across the Australian wheatbelt.

Nine sowing dates (from 1 April to 31 July at two-week intervals), three cultivars of contrasting maturity types [Axe (PBR), Bolac (PBR) and Janz] and an improved version of the Agricultural Production Systems sIMulator (APSIM) were also called on to investigate wheat responses to increased temperatures over the 33-year period.

It showed that the frequency of hot days (where temperatures were higher than 26 degrees Celsius) around flowering (anthesis) and during grain-filling have, on average, increased by 0.6 and 1.2 days per decade, respectively, for the cultivar Janz sown on 15 May.

Karine says heat has two types of effect: stressful and non-stressful, both of which affect yield.

"Firstly, there are the effects due to a greater average temperature, which are not necessarily classed as directly stressful," she says.

"These include accelerated phenological development, shortened growth stages and increased evaporative demand, which results in decreased transpiration efficiency and increased drought stress."

Secondly, there are the impacts of heat shock or heat 'stress' events. These include damage to the photosynthetic apparatus of plants, pollen and developing embryo mortality, and scorched leaves.

An important effect is that, since 1985, accelerating phenological development has shortened key growth stages.

As an example, at the national scale, Janz sown on 15 May has experienced shorter pre and post-flowering phases and whole crop cycles of 0.09 days per year, 0.07 days per year and 0.16 days per year, respectively.

“The increasing temperatures have led the crop cycle to shorten across the whole wheatbelt for all the sowing dates and genotypes tested” Karine said.

Although it might not sound like much time each year, Karine says this shortening of the crop growth cycle is projected to substantially affect potential yield in the near to mid-term if varieties and sowing dates remain unchanged.

To keep the same example, at the national scale, Janz sown on 15 May is projected to have its growth cycle shortened by 13 days by 2050 (averaged across 33 general circulation models).

Then there are the impacts of 'heat stress', not related to shortening phenological periods.

"Assuming the same increasing rates in heat impact across the Australian wheatbelt a very conservative assumption in terms of temperature increase the effect of heat stress on Janz grain number and weight (sowed on 15 May) would increase by 3.3 per cent and 15.4 per cent by 2050, respectively, without considering the interactions with drought and carbon dioxide concentration," Karine says.

"This equates to losses of more than 15 per cent by 2050, again without considering the interactions with drought and carbon dioxide concentration."

Frost and drought effects

Karine is plant ecophysiologist and modeller.

Her research also encompasses frost and drought and the impacts they have on winter cereals. Across these areas, she works with Dr Behnam Ababaei, Dr Bangyou Zheng, Professor Scott Chapman, Dr James Watson, Dr Troy Frederick and Dr Jack Christopher.

She says that since 1957, when reliable temperature records became available, researchers have noted a number of trends in relation to frost.

"There are more frosts in the south and west, with frost days occurring later in the year, and potentially increasing yield losses," she says.

"What's important is when the last frost occurs.

"Since 1957, the last frost days have been getting later in most parts of the wheatbelt, thus affecting yield more often, or with a bigger impact.

"Taking expert knowledge from frost physiologists into account, we have found that frost accounts for 10 per cent of yield losses in Australian wheat, with another 10 per cent due to the indirect costs related to later sowing constraints. In the northern region, these indirect costs can be as high as 20 per cent."

Together, the researchers' work feeds into breeding and adaptive management programs and points to the need for earlier sowing and longer-season crops, particularly in the eastern part of the wheatbelt.

Karine says the idea is simple. "The first step is to get the combination of sowing by genotype maturity right," she says.

"It is the best way to reduce the effects of abiotic stress on yield and is a strategy of escape or avoidance.

"The second step is to look at crop tolerance to different stresses, such as heat, drought and frost. This is what we are trying to do."

To counteract the effect of a higher mean temperature, longer-season genotypes are needed to increase, or at least maintain, the yield potential.

"One of the main problems is that to avoid the last frost event, crops need to flower relatively late," Karine says. "But they are then at increasing risk of being affected by heat and drought.

"Overall, to minimise frost, heat and drought at the most sensitive stages, while maintaining the growing period, growers will have to sow longer-season crops earlier in major parts of the wheatbelt, especially in the south and south-east."

"Heat events during reproductive and grain-filling phases can heavily impact on yield." Dr Karine Chenu

EXCITING HIGH RAINFALL RESEARCH AIMS TO BOOST CEREAL PRODUCTIVITY

Commencing last year, the research is being led by the Foundation for Arable Research (FAR) Australia in collaboration with the South Australian Research and Development Institute (SARDI). Last year it was funded predominantly by Landmark, with individual trials at the site also funded by the Grains Research and Development Corporation (GRDC), the South Australian Grain Industry Trust Fund (SAGIT) and the MacKillop Farm Management Group. From 2019, the research will be majority funded by GRDC.

Landmark Lucindale Agronomist James Heffernan said the SA Crop Technology Centre site, situated at Hatherleigh near Millicent, would also help provide an independent training platform for agronomists and advisers.

“It will independently bring agronomists and advisers up-to-speed, including with their continued learning on fungicides and resistance management,” James said.

Set over 4 ha and comprising about 920 trial plots last season, the research includes germplasm screening, the response of germplasm to different management strategies, and the use of plant growth regulators and fungicides.

“Being in a 650 mm plus rainfall zone, we recognise we should be striving for yields of 10-12 t/ha,” James said.

He said germplasm, disease management and nutrition were the key areas to help achieve that.

The research already has aided the commercialisation of a new cereal that has been a top performer in trials at Millicent, as well as in Tasmania, the past two years.

James said “pulling the levers” for higher yielding cereals, mainly earlier sowing and enhanced nutrition, effectively increased disease management issues due to the resulting higher density crops.

“Pushing yields produces bigger canopies and this creates issues with standability and disease.”

“Septoria tritici and eyespot in wheat and leaf rust and net blotches in barley are the main diseases. We have different strains of septoria tritici and we are seeing some tolerance to fungicides.”

He said last year the disease pressure in barley and wheat at the trial site was enormous.

“The disease loads were high all the way through. As a very fertile site with black organosols, it is one of the best sites in Australia for disease research.”

James said Aviator Xpro fungicide, which achieved wider crop registrations last year including use in wheat, barley and other crops, was a focus product in the trial up against the high loadings of net blotch in barley and septoria tritici in wheat.

Developed by Bayer, Aviator Xpro contains bixafen, a novel member of the Group 7 (SDHI) fungicides, which also offers an alternate mode of action for resistance management, as well as the proven performance of prothioconazole.

It already has shown to be a strong option for disease control in various pulse crops and canola and can now be used, including by aerial application, for control of septoria tritici, eyespot, stripe rust, yellow leaf spot, septoria nodorum and powdery mildew in wheat, as well as net form net blotch, spot form net blotch, leaf rust, powdery mildew and leaf scald in barley.

Aviator Xpro also offers good compatibility and its patented LeafShield™ formulation technology enhances its activity against diseases. It has a short rain-fast period, estimated at around 30 minutes to one hour in most situations, which is particularly beneficial in high rainfall environments.

James said Aviator® Xpro® was a “really good fit for the area”, with the LeafShield technology a major bonus for a region that can receive rain every day.

“It dries and it is into the plant very quickly. There can be rain coming across the range and it will be fine. I’ve seen other treatments affected by rain two days later (after application).”

He said from an agronomist point of view, the Crop Technology Centre site was looking at the interaction between germplasm and management of winter wheat and spring wheat and what this meant for disease control.

“And we are looking at the best stewardship with fungicides, given SDHIs will be overcome with resistance if they are mismanaged.”

“So we are evaluating the best timing of applications both for the best result and for protecting the longer-term use of the fungicides.

“From an agronomic perspective, we are trying to ‘unpack’ whether to go with an SDHI (fungicide) early or later in-crop. And how to best use the product is dictated by the germplasm - an early-sown winter wheat will have maximum exposure to the disease.”

James said they were currently recommending full rates of a curative or protective fungicide, such as Prosaro®, applied early, followed by Aviator Xpro on the flag leaf as a full protectant, and then finally with a strobilurin/triazole mix.

“You want some backup for the SDHI.”

“Aviator Xpro, with SDHI and triazole chemistry, is a very high quality product. It’s a great fit for the 32-37 growth stage as a very good middle shot for maximum protective benefit against predominantly septoria tritici,” he concluded.

SCIENTISTS DISCOVER HOW PLANTS BREATHE - AND HOW HUMANS SHAPED THEIR 'LUNGS'

Scientists have discovered how plants create networks of air channels - the lungs of the leaf - to transport carbon dioxide (CO_2) to their cells.

Botanists have known since the 19th century that leaves have pores - called stomata - and contain an intricate internal network of air channels. But until now it wasn't understood how those channels form in the right places in order to provide a steady flow of CO_2 to every plant cell.

The new study, led by scientists at the University of Sheffield's Institute for Sustainable Food and published in Nature Communications, used genetic manipulation techniques to reveal that the more stomata a leaf has, the more airspace it forms. The channels act like bronchioles - the tiny passages that carry air to the exchange surfaces of human and animal lungs.

In collaboration with colleagues at the University of Nottingham and Lancaster University, they showed that the movement of CO_2 through the pores most likely determines the shape and scale of the air channel network.

The discovery marks a major step forward in our understanding of the internal structure of a leaf, and how the function of tissues can influence how they develop - which could have ramifications beyond plant biology, in fields such as evolutionary biology.

The study also shows that wheat plants have been bred by generations of people to have fewer pores on their leaves and fewer air channels, which makes their leaves more dense and allows them to be grown with less water.

This new insight highlights the potential for scientists to make staple crops like wheat even more water-efficient by altering the internal structure of their leaves. This approach is being pioneered by other scientists at the Institute for Sustainable Food, who have developed climate-ready rice and wheat which can survive extreme drought conditions.

Professor Andrew Fleming from the Institute for Sustainable Food at the University of Sheffield said "Until now, the way plants form their intricate patterns of air channels has remained surprisingly mysterious to plant scientists.

"This major discovery shows that the movement of air through leaves shapes their internal workings - which has implications for the way we think about evolution in plants.

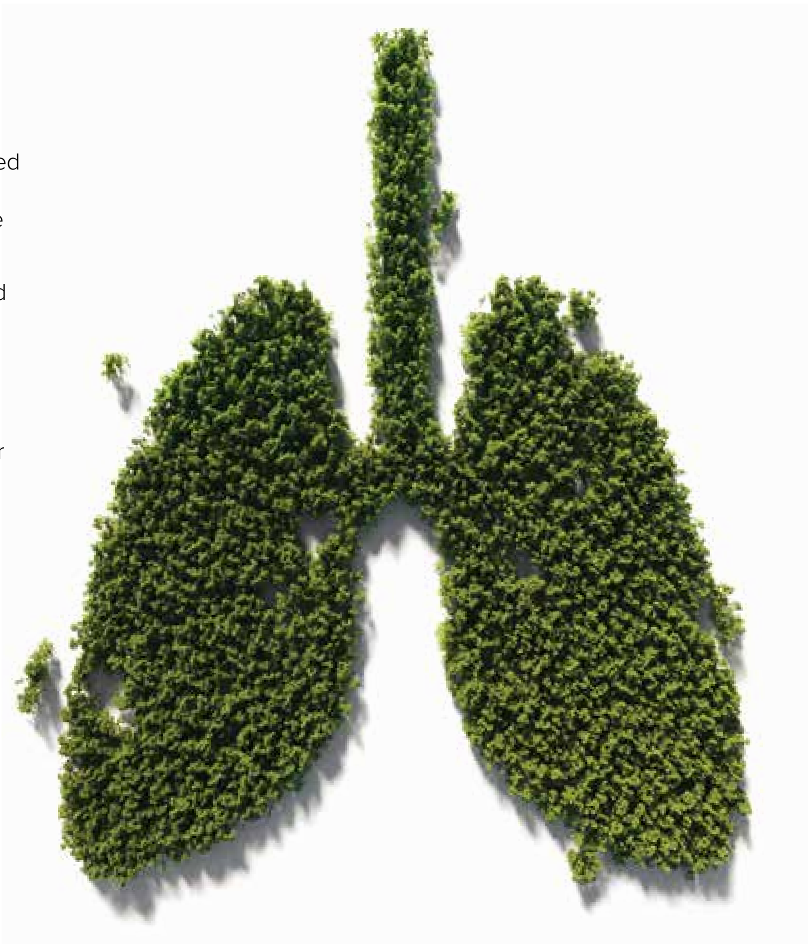
"The fact that humans have already inadvertently influenced the way plants breathe by breeding wheat that uses less water suggests we could target these air channel networks to develop crops that can survive the more extreme droughts we expect to see with climate breakdown."

Dr Marjorie Lundgren, Leverhulme Early Career Fellow at Lancaster University, said "Scientists have suspected for a long time that the development of stomata and the development of air spaces within a leaf are coordinated. However, we weren't really sure which drove the other. So this started as a 'what came first, the chicken or the egg?' question.

"Using a clever set of experiments involving X-ray CT image analyses, our collaborative team answered these questions using species with very different leaf structures. While we show that the development of stomata initiates the expansion of air spaces, we took it one step further to show that the stomata actually need to be exchanging gases in order for the air spaces to expand. This paints a much more interesting story, linked to physiology."

The X-ray imaging work was undertaken at the Hounsfield Facility at the University of Nottingham. The Director of the Facility, Professor Sacha Mooney, said "Until recently the application of X-ray CT, or CAT scanning, in plant sciences has mainly been focused on visualising the hidden half of the plant - the roots - as they grow in soil.

"Working with our partners in Sheffield we have now developed the technique to visualise the cellular structure of a plant leaf in 3D - allowing us to see how the complex network of air spaces inside the leaf controls its behaviour. It's very exciting."



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RESEARCH CONTINUES INTO CROP EFFECTS OF CANOLA FUNGICIDE MIXES

Continued concern over canola leaf burn from applying foliar fungicides in mixture with other products such as selective grass herbicides and oil-based spray adjuvants is set to trigger further research into the treatments this season.

Tim Murphy, Customer Advisory Representative with Bayer in South Australia, coordinated a canola trial near Riverton last year in conjunction with the Mid North High Rainfall Zone Group.

Tim said the compatibility trial included application of the company's new Aviator® Xpro® fungicide at the four to six leaf stage for early control of blackleg disease, tank mixed with other products including grass herbicides. This was compared with other industry standards for blackleg control mixed with similar treatments.

"Aviator Xpro was applied in different mixes and at different rates and compared to industry standard mixes," Tim said.

"The Bonito canola variety grown in the trial is susceptible to blackleg and the disease level was extremely high."

He said a level of phytotoxicity occurred across all treatments, although most of them recovered by the 12-14 leaf stage.

"Plants pushed through and their vigour remained strong. However, there was one treatment where the leaf burn appeared similar to the other treatments, but the crop growth was retarded."

Tim said the level of blackleg control achieved by Aviator Xpro was exceptional.

"It was equal to, if not better than, the standards."

He said the trial also assessed later applications of Aviator Xpro at 20% flowering to control sclerotinia, as well as for managing blackleg disease in the upper crop canopy.

"On the Lower Eyre Peninsula, rain can fall at petal drop with the wet springs there and blackleg can appear in the upper canopy of crops."

Aviator Xpro contains bixafen, a novel member of the Group 7 (SDHI) fungicides, which also offers an alternate mode of action for resistance management, as well as the proven performance of prothioconazole.

It has shown to be a strong option for controlling blackleg and sclerotinia disease in canola, as well as for control of ascochyta blight in chickpeas, and now can be used across wheat, barley and more pulse crops, including for aerial application.

Aviator Xpro offers good compatibility and its patented LeafShield™ formulation technology enhances its activity against diseases. Its short rain-fast period, estimated at around 30 minutes to one hour in most situations, is particularly beneficial for spraying ahead of rainfall events.

Tim said compatibility research with selective grass herbicides would continue this year to help further understand how the mixes affected crop growth and performance.

BENEFITS OF VETCH IN CROPPING ROTATIONS

Vetch is a winter and spring sown annual legume that is commonly used as a disease break in cereal cropping rotations. A true multi-purpose crop, it offers high feed value and is ideal for hay production, early grazing as green pasture, dry grazing or green/brown manure.

Vetch is often sown in combination with cereals for quality hay. It is also highly sought as fodder to support dairying due to excellent quality and palatability. Common vetch may also be used for grain.

Poor soils can be revived by vetch's nitrogen rich organic matter boosting soil fertility, which helps to meet the needs of following crops.

Another benefit is that vetch after cereals can lower the ratio of carbon to nitrogen, improving soil health along with mineralisation and stubble decomposition.

In partnership with The South Australian Research Development Institute (SARDI), Heritage Seeds has been breeding vetch for a number of years, from which a collection of different varieties have been released including both common and woolly pod types.

Key releases are Morava and Rasina (common types) along with Capello and Haymaker (woolly pod). The primary objectives of the breeding program are to increase dry matter yield, create highly palatable and nutritious hay, be soft seeded and to build in disease resistance or tolerance to some of the more devastating diseases that attack vetch crops. These diseases include rust, acochyta blight, chocolate spot and botrytis grey mould. Rust is probably still the biggest threat on common types although newer cultivars are generally resistant.

One of the most recent releases, Volga has been bred as a high yielding grain/seed variety for low and mid rainfall areas. It is particularly suited to shorter season areas where the growing season finishes sharply. RM4 vetch has better early establishment than present woolly pod varieties. It is earlier in flowering and grain / seed maturity up to 10-15 days earlier than Haymaker or Capello.

CROP PESTS MORE WIDESPREAD THAN PREVIOUSLY KNOWN

Insects and diseases that damage crops are probably present in many places thought to be free of them, new research shows.

Pests that have not been reported in a certain area are usually assumed to be absent, but analysis by the University of Exeter, England shows many pests are "currently unobserved, but probably present" (a likelihood of more than 75%).

The study identified large numbers of pests in this category in China, India, southern Brazil and some countries of the former USSR.

The researchers used data for 1,739 pests in the Centre for Agriculture and Bioscience International (CABI) pest distribution database.

"Our model allows us to quantify the risk that a certain pest is present in a certain place," said Dr Dan Bebber, of the University of Exeter.

"Our trick for testing model accuracy was to use pest observations from China published in the Chinese literature, which have not yet been incorporated into global pest databases.

"A lot of species that people are worried about finding in certain places are probably already there. That early stage is crucial if we want to stop the spread - so these are the pests we should be focussing our efforts on."

The discovery of crop pests and pathogens in new areas has accelerated in recent years, driven primarily by global trade, but also potentially by climate change.

Targeting areas where new pests are probably present - or are highly likely to arrive - could be a key aspect of tackling their spread and reducing the resulting crop damage.

"Prior studies have often assumed that unreported pests in a global distribution database represent a true absence," Dan said.

"Our analysis provides a method for quantifying these 'pseudo-absences' to enable improved distribution modelling and risk analysis."

CEREAL GRAINS SCIENTISTS FIGHT HIDDEN HUNGER WITH NEW APPROACH

After a prolonged decline, global hunger is on the rise - affecting more than 820 million individuals in 2017. Additionally, more than 2 billion people suffer from "hidden hunger," which occurs when individuals eat foods that don't provide the nutrients they need to lead healthy, productive lives. Children who suffer from hidden hunger have more difficulty developing to their full mental and physical potential.

Hidden hunger is more prevalent in developing countries that rely heavily on staple crops like wheat, maize, and rice. These populations often do not have access to nutrient-rich foods, such as fruits, vegetables, and fish, and tend to suffer from vitamin A and zinc deficiencies. Vitamin A deficiencies can lead to vision-related disorders, such as corneal scarring and blindness, while zinc deficiencies increase the risk of diarrheal diseases, pneumonia, malaria, and even mortality.

Global demand for staple crops like maize, wheat, and rice is on the rise - making these crops ideal targets for improving nutrition through biofortification. Biofortification is the process of developing micronutrient-dense staple crops by combining traditional breeding practices with modern biotechnology.

Biofortification crop systems are highly sustainable one-time investments - the varieties developed and released will continue to grow annually, even without government attention or external funding, and breeding for higher levels of vitamin A and zinc does not penalize yield. There are currently 290 varieties of 12 biofortified crops, including rice, wheat, maize, that target the low-income households who rely on these staple crops and may suffer from hidden hunger.

According to the authors of 'Improving Nutrition through Biofortification: Preharvest and Postharvest Technologies,' published in Cereal Foods World.

"Maize and wheat are excellent targets for biofortification because they are widely cultivated, have wide agroecosystem coverage, are important in diets and trade, have useful native genetic variation for improving micronutrient density in the grain, and have a long history as subjects of breeding and genetic research,"

Organizations such as the International Maize and Wheat Improvement Center (CIMMYT), HarvestPlus, and the International Institute of Tropical Agriculture have worked to develop provitamin A-enriched maize varieties and zinc-enriched maize varieties, which have been released in South America and Africa. These organizations have also worked on enhancing levels of iron and zinc in wheat grain, releasing six biofortified wheat varieties in Pakistan and India in recent years.

Nutritional studies have found these biofortified varieties to be effective. A study in India found that young children who ate zinc-biofortified wheat experienced 17% fewer days with pneumonia and 39% fewer days vomiting than those children who ate conventional wheat products. Provitamin A-biofortified maize is a proven source of vitamin A. Additional studies are likely to reveal more positive effects of biofortified staple crops on nutrition.

Biofortification is one way to address hidden hunger, but it is not without challenges. According to the Cereal Foods World article, "To realize their full potential, biofortified maize and wheat varieties must be integrated as a core products in research, policy, and food value chains for these crops, which implies that all participants in the value chain, particularly farmers and consumers, must be convinced of their value."

PRINCETOWN DAIRY FARMERS ARE CORN SILAGE CONVERTS

Princetown dairy farmer Steven Brown is reducing the impact of feed prices and drought-prone pasture by trying his hand at homegrown corn silage.

Steven had been feeding his 450 Fresian and Jersey cows a ration of barley, soybean meal, baled grass silage, corn grain, and pasture, but with the price of hay and grain fetching up to $450 and pasture being depleted by the dry, his bottom line was taking a big hit.

"We envisage grain getting dearer and while we believe grass is the best feed - usually perennial grasses - a few years ago we lost our grass due to dry season," Steven said.

"It costs time and money to get that established again.

"If you look at dollars - buying in vetch is $300-450 and cereal hay is $400 - it's getting too dear.

"We've been feeding whole corn from farms adjacent to the Western Treatment Plant near Werribee, but even if corn silage costs you $200-220/t in the pit, it's cheap feed.

"We're trying to be more self-sufficient."

Steven attempted his first corn silage crop four years ago, but the small input program and dry conditions hampered the crop.

Their second attempt last season was a different story, with his 34ha dryland crop of PAC 440 yielding an average of 18t/ha of dry matter or 48t/ha wet (1660t harvested).

"We were staggered by the result. We went in thinking we'd get 12 or 13 tonnes per hectare, but to get 18t/ha was outstanding.

"We weighed the cobs and were getting 265-270 grams per cob. Most plants were single cob, but some were double.

"We believe the fresh corn is better than dried whole corn. It helps with cow health and getting cows in calving. Our cows are consuming 12kg per cow, per day dry."

Steven said every load was weighed to get an accurate yield, and while the tonnage was nice, it wasn't the primary goal.

"You can go on about how tall your crop is, but the cob is what we're after - the size of the grain relative to the cob and the quality.

"The cobs were slightly smaller than other varieties, but the smaller core meant larger kernels.

Steven and his wife Jo, in partnership with their son Travis and his partner Sarah, run the 480ha property.

Steven and Travis put a large part of the success down to their agronomist Harrold Hanlon at MG Trading Colac, Brown McNeill Contracting for preparation and harvesting, and Logan Contracting, who used their brand new, state-of-the-art planter.

"Harrold really got the program going for us. He advised on the inputs and the corn variety, which has a medium CRM of 108.

"That works for us southern corn growers because we want the crop off early.

"We only calve in autumn, so we want it off early and put it back to grass before it gets too wet.

"Spraying out the paddock early so we had plenty of soil moisture also made a big difference. We're doing that a lot earlier now."

Steven said the fertiliser program was designed with enough inputs to aim for a 20-tonne crop.

The program began with a pre-plant deep band application of 92kg/ha of nitrogen (Entec treated urea).

This was followed by an at-plant application of 27/30/0/3 zinc-coated DAP and a broadcasted blend of 27/20/280/22.

The PAC 440 crop was sown on November 17 and received 75mm GSR before being harvested on April 12 and put into aboveground silage with plastic wrap near the feed pads.

"We didn't get a lot of rain this summer last summer, but we did get some good rain right on tasselling."

Steven said they are increasing the hectares planted to PAC 440 to 50ha this season.

"If we could average 14-15t/ha dry over the next eight years, I see it as very high-quality feed and great value."

Steven Brown in his crop of PAC 440

SCIENTISTS UNEARTH GREEN TREASURE - ALBEIT RUSTY - IN THE SOIL

Cornell University engineers have taken a step in understanding how iron in the soil may unlock naturally occurring phosphorus bound in organic matter, which can be used in fertilizer, so that one day farmers may be able to reduce the amount of artificial fertilizers applied to fields.

"This component of the phosphorus cycling process has been largely neglected," said senior author Ludmilla Aristilde, associate professor in biological and environmental engineering, "but now we're figuring out phosphorus recycling mechanisms by soil minerals that could benefit the environment."

"Phosphorus is a finite resource, but in agriculture we often apply it - and over-apply it - together with nitrogen on crops to amend soil health and boost crop growth," said co-author Annaleise Klein, a postdoctoral researcher in Ludmilla's lab. "If we could understand the molecular mechanisms of these natural processes in the soil, and how those processes may be used by plants and bacteria, we can help the environment and thwart runoff from farms into streams and lakes - and possibly prevent algae blooms in nearby waters."

For farmers growing crops, phosphate fertilizer - derived from mining inorganic phosphate rock - is a dwindling resource. Once depleted, it is gone.

"The big picture is that phosphorus is a limited nutrient in the environment," said Annaleise. "Instead of mining rock phosphate for a farmer's fields - or a homeowner's lawn - now we can exploit the natural soil mechanism of phosphate release from organics and decrease our reliance on mined phosphorus."

Ludmilla said "We are unraveling phosphorus cycling pathways that we didn't know about before. We don't want to keep adding more phosphorus ... The less we mess with nature, the better."

2019 YOUNG GROWER OF THE YEAR

35-year-old vegetable grower Daniel Hoffman from Penfield, South Australia has been named as the 2019 Young Grower of the Year.

The award, sponsored by Corteva Agriscience, was announced at the AUSVEG National Awards for Excellence held at the Hort Connections Gala Dinner in Melbourne tonight.

In a competitive crop of 10 nominees from around Australia shortlisted for the prestigious award, Daniel was recognised as the best in his field based on his advocacy work for local growers seeking access to water on the Northern Adelaide Plains, strong R&D involvement and his own innovative on-farm practices.

Growing tomatoes, capsicums, eggplant, cucumber and bunch lines as part of the family farming enterprise, Hoff Family Trust, Daniel's expertise areas include plant nutrition and fertiliser, as well as pest and plant health management.

Daniel Hoffman said he was honoured to be nominated for the Award and was thrilled to win the accolade.

"It feels really nice to be recognised for years of work," he said. "Young growers will be our future and if we can use things like the Young Grower of the Year Award to encourage us all to strive for better practices and share knowledge then I think that's great."

"If we, as the next generation of farmers, are working in an environment where we feel appreciated then the industry is going benefit from proud growers. This is a very noble and hard profession and we should be damn proud of the industry."

Nick Koch, Marketing Manager for Horticulture & Insecticides for Corteva Agriscience said Daniel is a great example of the impact younger farmers can have on the industry.

"At just 35, Daniel has proved himself to be a well-respected leader within the grower community and beyond, becoming a well-known advocate for the Northern Adelaide Plains water security issue on behalf of the broader farming sector," Nick said.

"In addition to his strong advocacy work, Daniel has supported a number of researchers as part of the AUSVEG South Australia Integrated Pest Management (IPM) program and helped to host a number of field walks on his farm also," he said.

Daniel Hoffman, Penfield, South Australia

"He's successfully managed to breed and maintain his own healthy population of the beneficial bug nesidiocoris tenuis as part of his IPM and biodynamic method of farming to produce high quality crops, which he supplies to key wholesalers such as Premier Fruits Group."

AUSVEG, the industry representative body for the Australian vegetable and potato industries, manages the 2019 National Awards for Excellence, including the Young Grower of the Year Award.

SEED BANK REPLENISHED 100 TIMES OVER WITH RARE CENTURY-OLD CORN

Stocks of a rare local maize variety have been boosted 100 times over after century-old seeds planted on the Richmond lowlands resulted in a bumper harvest.

The one-kilo remaining bag of Hawkesbury maize was planted earlier this year at the Greater Sydney Local Land Services' (GSLLS) demonstration farm after being discovered at the Henry Double Day Research Association (HDDRA) seedbank.

The project was hugely successful, and the May 31 harvest will see an estimated 100 kilograms of the rare seeds collected go to replenish the seedbank and fuel Western Sydney University's (WSU) student research.

GSLLS farm manager, Peter Conasch, said the success of the trial crop went beyond expectations.

"What we've harvested from a tiny bag of seedlings is truly remarkable," he said.

"It's a great result for sure and our project partners given the historical significance of this particular maize variety which was developed by some of the Hawkesbury's pioneer farmers."

The project is a collaboration between GSLLS, the university, the HDDRA and Hawkesbury Harvest and Farmgate Trails (HHFT).

WSU Sustainable Futures manager Jen Dollin said the harvested seed would allow for further student projects including exploring the nutritional profile of the heirloom vegetable and research into the provenance and genetic profile.

"We see valuable potential for continuing this collaboration link this to our teaching programs," she said.

Hawkesbury Harvest and Farmgate Trails chief executive Dr Ian Knowd said the network would like to see a re-emergence of heritage and heirloom vegetables in the Hawkesbury region.

"This enables our local farmers to explore new commercial opportunities that could occur as a result," he said.

Peter hoped the success of the partnership would inspire further trials on heirloom vegetable crops.

"Collaborations like this one which not only support real research into local agriculture and its proud history in this Sydney basin, but also give local growers tangible insight into productive and sustainable farming practices is exactly what our Demonstration Farm is all about," he said.

"It's a real privilege to play a part in keep this history alive and well."

LEGUMES FOR SUSTAINABLE FARMING FUTURE

Climate change and food security are two of the greatest challenges facing humanity. At Swinburne, Professor Mark Adams is exploring how legumes can play a role in sustainable agriculture.

Professor Adams, Professor of Bioscience and Innovation, says we should be growing chick peas, lentils and other legumes, at least as often as we do wheat, barley and rice.

Cutting down on synthetic fertiliser

Approximately half the world's food production is supported by the use of synthetic nitrogen fertiliser, which helps crops grow faster and more productively.

Over-use of fertiliser nitrogen pollutes water and air, and can have knock-on effects that include loss of species, depletion of other soil nutrients, and contamination of drinking water.

Because they make their own nitrogen from the atmosphere, legumes are not as restricted by soil or fertilizer nitrogen. Professor Adams recent research shows that they are also not as heavily reliant on water as other crops.

"On a hot day they can close their leaf pores and save some water," Professor Adams says. He says growing legumes can help reduce water and fertiliser demand and help meet nutritional needs.

"If we grew more legumes and less wheat, corn and rice, it would be a good thing."

Creating healthy soil

Professor Adams says rotating cereal crops with leguminous crops would also top up the soil with nitrogen without any need for synthetic fertiliser.

"The beauty of legumes is that their biological nitrogen fixation is self-regulating. Once the plant has enough, it shuts it down. It's a much more sustainable system."

He says substituting legume grains for cereal grains in both human and animal diets would reduce the water and energy demands of agriculture, while maintaining the availability of protein.

"Creating fertiliser, applying it to fields, growing grain, and feeding it to cattle involves releasing greenhouse gases every step along the way.

"By growing legumes and then letting the cattle loose in the paddock some of those steps and their associated greenhouse gases are removed, but with the same end result: fertilised fields and steak for dinner."

"Having chick-pea curry for dinner instead of beef vindaloo would remove yet another step and the associated greenhouse gases."

Professor Adams led a team of researchers from the University of Sydney, ETH Zurich, the University of Dundee and the University of California, Davis.

TAKING THE LONG TERM APPROACH TO MANAGING WEEDS

As agronomists, we often view ourselves as problem solvers. Something is going on in the crop - we need to solve it in as short a timeframe as possible. No doubt this is also our client's expectation. But while the temptation is to provide a short term fix to a problem, sometimes the long term approach is more appropriate.

This was the message for those that attended the 2019 Weedsmart Week event in Emerald Qld in early August.

Despite the international warnings and ever growing on shore issues with herbicide resistance, it would appear that in some quarters, the message is just not getting through. Perhaps we are all just getting tired of hearing about it, or perhaps believe that it is only a problem in other cropping regions areas but not our own. The bottom line is that resistance development is a natural process in plants, and we are always going to be confronted with this issue in varying degrees. It is how we choose to manage it that will make a difference for our clients.

As scientists we have a tendency to put our hope in the next silver bullet. We have had our silver bullet in our industry that revolutionised the way that we farm. It is called glyphosate. This product, developed originally as an industrial descaler, has enabled us to move away from continuous cultivation and in the age of Roundup Ready® crops, control weeds within the cropping window. Now the future of this product from both an availability and efficacy perspective is in doubt.

The cloud that hangs over its commercial availability can be debated long and hard. However, the recent experiences of Australia's live export trade have taught us that decisions in the name of the 'greater good' can and will be made at the stroke of a pen. Without setting off alarm bells, it is possible that our industry may need to put a Plan B in action - and quickly. This of course is all based on speculation, media attention and the outcomes of domestic court cases. The efficacy discussion however is a different ballgame. Herbicide resistance in some of our major weeds including those found in northern growing regions is real. It is already with us, and is calling for the Plan B.

Plan B however, may not look anything like anything we're used to. Integrated weed management is not new concept to any practicing agronomist, but the ability to spray for immediate control or eradication has become a quick fix option. As agronomists, it is our role to ensure that the solution we recommend befits the problem. Before opting for the short term fix, it is worthwhile taking the time to ask yourself, and the grower a few important questions...

- How long has the weed been a problem in that field?
- What are the past control options that have been used and their success rate?
- Where did it come from and can the seed spread be halted in the future?
- Do neighboring blocks have the same problem and what are they doing about it?
- If you could turn back the clock five years, could you have done anything to stop this current problem? Therefore, can you be influencing future weed issues by what you choose to do now?

The story of that weed in your crop much longer than the current growing season, and we need to treat weed infestation and eradication with long term strategies.

The Western Australian Herbicide Resistance Initiative (WAHRI) was launched in 1998 as part of a GRDC initiative in response to the emergence of herbicide resistance in the State's cropping systems. In 2009, following a recognition that herbicide resistance was not limited to one state and that a national approach was required, the organisation changed its name to the Australian Herbicide Resistance Initiative (AHRI).

Much of the work and recommendations of AHRI and their industry partner WeedSmart are highly transferable to most farming systems and their website and publications are a valuable resource in terms of farming options. (They are also well worth following on social media.) Crop Consultants Australia (CCA) member and AHRI Northern Weeds and Crops Extension Agronomist Paul McIntosh says that the message though is really a simple one.

"Whatever you do - Stop the seed set. If you stop an annual plant from going to seed you will never have Herbicide Resistance," says Paul.

Weedsmart, are currently promoting their 'Big 6' approach to wise crop weed management where they recommend additional measures such as rotation of crops and pastures and mixing and rotating (full rate) herbicides. At their Emerald event and the 2019 Crop Consultants Australia Seminar in Narrabri, attendees were also shown firsthand the technical developments and research being undertaken by some of agriculture's youngest and brightest stars.

The work being done in many of our Universities provides exciting opportunities for "high tech" and targeted weed control options.

Just as glyphosate has shaped our farming systems, so too will the next wave of mechanical and management options that we will need to incorporate in our future integrated weed management practices.

Upcoming developments such as instant resistance testing options, robotics and even new herbicides based on microbial action are already not far from commercial reality.

These options will provide new tools in our toolbox, but it is up to us as agronomists how we choose to apply our trade. Long term management recommendations sometimes come at an economic cost to those of us who also rely on commission from chemical sales as part of their income.

The most appropriate recommendation for our clients may not be the most profitable for us in the current growing season but will undoubtably have a better outcome in the long term - not just for our client, but for industry as a whole.

Visit **www.weedsmart.org.au, www.ahri.uwa.edu.au** & **www.cropconsultants.com.au** for information on membership and professional development opportunities.

NEXT GEN GENETIC TESTING TO GIVE GROWERS COMPETITIVE EDGE

Horticulture growers will benefit from faster access to new plant stock through next-generation genetic sequencing technology designed to reduce port of entry quarantine delays by more than two years.

The project, funded by Hort Innovation and facilitated by the Plant Biosecurity Research Initiative (PBRI), is being led by the Queensland University of Technology (QUT), drawing in expertise from the Victorian Department of Jobs, Precincts and Regions, the Federal Department of Agriculture and Water Resources and the New Zealand Ministry for Primary Industries.

QUT project lead, Associate Professor Roberto Barrero, said the project looked at optimising the next-generation sequencing technologies for screening pathogens in a range of crops - starting with grapes, citrus fruits, berries and potatoes.

“At the moment the traditional biological testing platforms used for screening imported plant species are resource-intensive, time-consuming, and may produce ambiguous results,” he said.

> **“Imported plants can spend up to three years undergoing pathogen testing, potentially impacting the ability of agricultural industries to access new crop varieties and adapt quickly to global market opportunities. Next generation sequencing technologies offer a faster, more reliable and cost-effective way to identify all known plant pathogens without having to run numerous tests."**

"These technologies are capable of sequencing multiple DNA molecules in parallel, enabling hundreds of millions of DNA molecules to be sequenced at a time.

“This project will assess the robustness, accuracy and reliability of these methods compared to existing testing protocols.”

Hort Innovation Research and Development Manager Dr Penny Measham said reducing the time that imported plants spend in Australia’s quarantine system has a direct benefit for growers.

“Rapid and safe access to new plant genetic stocks, supported by appropriate policy, is crucial for primary industries to remain productive, profitable, sustainable and internationally competitive,” she said.

"Next Generation Sequencing offers a fast, reliable and cost-effective method to identify all known plant pathogens in a single test with the potential to reduce quarantine periods from three years to around six-12 months.

"This will enable our growers to stay abreast of current trends and improve their competitive edge."

The research team will work closely with quarantine agencies in Australia and New Zealand and policy groups to develop operating procedures and a quality assurance program for next-generation sequencing testing.

FAST FACTS

- Rapid and safe access to new plant genetic stocks is crucial for plant primary industries to remain profitable, sustainable and internationally competitive.
- Next Generation Sequencing (NGS) offers a fast, reliable and cost-effective method to identify all known plant pathogens in a single test.
- Current quarantine screening for pathogens in new plant genetic stocks can take up to 3 years
- Next generation high throughput sequencing technologies could reduce this to 6-12 months

LOW LEVEL SULFOXAFLOR RESISTANCE DISCOVERED IN GREEN PEACH APHIDS

Researchers have discovered evidence of Green Peach Aphid (GPA) populations with sensitivity shifts to sulfoxaflor, the active ingredient in the insecticide Transform.

The research points to the first signs of resistance to Transform evolving in Australia where GPA is also known to have developed resistance to synthetic pyrethroid, carbamate, organophosphate and neonicotinoid insecticides.

The resistance to dosages below the field rate of sulfoxaflor was recently detected in a small number of GPA populations collected near Esperance, in Western Australia.

GPA is a widespread pest of canola and pulse crops and a key vector of turnip yellows virus (TuYV), which severely affected crops in parts of south-eastern Australia in 2014.

Sulfoxaflor, a group 4C insecticide, is an important tool in GPA management in canola, particularly since effective chemistries are limited.

The discovery was made through collaborative research by cesar, the CSIRO and the WA Department of Primary Industries and Regional Development (DPIRD).

The research was the result of a co-investment by GRDC and Corteva Agriscience. The low-level resistance has been shown to persist after multiple generations of culturing in the laboratory, demonstrating there is an underlying genetic basis.

In parts of Europe, GPA has developed high levels of resistance to neonicotinoids, due to a mutation known as R81T, which also confers cross-resistance to sulfoxaflor, albeit at a reduced level.

Importantly, Australian populations of GPA have tested negative to this genetic mutation, including those collected near Esperance.

While Transform remains a highly effective means to control GPA, this discovery serves as an important reminder to use the product judiciously.

For species such as GPA, which have a high propensity to evolve new resistance, this means only spraying insecticides when absolutely needed.

There are unlikely to be yield losses from TuYV infections after the rosette stage in canola.

The risk of direct feeding damage from GPA is also low in later-stage canola crops. Although, in seasons such as 2018, aphids can build up to high population levels and inflict serious damage, particularly when plants are moisture-stressed.

When applying chemicals to control GPA, the Grains Research and Development Corporation recommends that the full label rate for Transform is used, as lower rates will often prove to be ineffectual and only serve to increase selection pressure for further resistance.

For canola, the label rate of Transform WG is 50 grams per hectare.

THE WORLD NEEDS A GLOBAL SYSTEM TO DETECT AND HALT THE SPREAD OF EMERGING CROP DISEASES

CLIMATE CHANGE AND GLOBAL TRADE DRIVE THE SPREAD, EMERGENCE, AND RE-EMERGENCE OF CROP DISEASE, AND CONTAINMENT ACTION IS OFTEN INEFFICIENT, ESPECIALLY IN LOW-INCOME COUNTRIES.

A Global Surveillance System (GSS) to strengthen and interconnect crop biosecurity systems could go a long way to improving global food security, argues a team of experts in the June 28 issue of Science.

"As part of efforts to satisfy global demand for food - which could mean increasing agricultural production by as much as 70 percent by 2050 - we need a GSS to reduce food lost to pests," said Mónica Carvajal, a researcher at the International Center for Tropical Agriculture (CIAT) and lead author. "A lot of collaboration and discussion is needed to rapidly take action and avoid outbreaks that could negatively impact food security and trade."

Mónica and colleagues hope the GSS framework they propose gains traction in 2020, which was designated International Year of Plant Health by the United Nations. The system would prioritize six major food crops - maize, potato, cassava, rice, beans, and wheat - as well as other important food and cash crops that are traded across borders. The GSS proposal is the result of a scientific meeting convened by CIAT and held in 2018 at the Rockefeller Foundation's Bellagio Center in Italy.

Inspired by recent outbreaks

In 2015, Cassava Mosaic Disease (CMD) was discovered in Cambodia but the findings were not reported until 2016. By 2018, the disease had spread to Thailand and Vietnam, and is now estimated to be present in 10 percent of the surfaces cultivated in the region, threatening millions of smallholders who cultivate cassava and generate US$4 billion in export revenue.

This year, agricultural authorities from four countries - Cambodia, Thailand, Vietnam, and Lao PDR -supported by research organizations including CIAT, published an emergency control plan for CMD in Southeast Asia.

Mónica, who studied the CMD outbreak after its initial report, says that a GSS would help expedite action for future outbreaks.

"The question I asked was why does it take so long to respond to crop diseases in some cases?" said Mónica. "What is the limitation to responding faster from the outset?"

The GSS proposal draws on lessons learned from the wheat blast outbreak that hit Bangladesh in 2016 and the bacterial outbreak of Xylella fastidiosa that started affecting olive trees in Europe in 2013. The proposal is from a multidisciplinary group of experts from academia, research centers, and funding organizations that work on issues related to plant health and human health.

What would GSS do?

The GSS would focus on tightening networks "active surveillance" and "passive surveillance" personnel who are on the front lines of disease outbreaks. Active surveillance consists of laboratories at agriculture inspection stations, and customs and phytosanitary inspectors at borders and ports of entry. Despite their formal infrastructure, only an estimated 2-6 percent of cargo can be effectively screened.

The second group includes loose networks of farmers, extension workers with national agricultural organizations, scientists and agronomists at research centers and universities, and specialists in agriculture industries.

"For this infrastructure to be effective, connections between first detectors and downstream responders must be enhanced and actions coordinated," said the authors. "But diagnostic capacity, information sharing, and communications protocols are lacking or weakly established in some regions, especially in low-income countries. Our reflection on many disease outbreaks is that whether in high-income countries or low-income countries, the passive surveillance infrastructure has the most in-field monitoring eyes but the least coordination from local to global."

The GSS would tap into cutting-edge technology for rapid disease diagnostics and take advantage of communications networks, including social media, to rapidly share information. The system would have regional hubs and consist of five formal global networks. These would include a diagnostic laboratory network, a risk assessment network, a data management network, an operational management network, and a communications network.

"Our team realized that there is a big issue with communication, even when we speak the same language and use the same technologies," said Mónica. "One of the most relevant components is the communications network."

The GSS team hopes to contribute to future efforts on strengthening pest outbreak response systems within the International Plant Protection Convention's (IPPC) 2020-2030 Strategic Framework.

"We encourage the annual G20 Agriculture Ministers Meeting, the World Bank Group, and FAO, among others, to join efforts toward enhancing cooperation for a multi-year action plan for the proposed GSS to more effectively reduce the impact of crop diseases and increase global food security," the authors conclude.

"Our team realized that there is a big issue with communication, even when we speak the same language and use the same technologies, one of the most relevant components is the communications network"

Mónica Carvajal

Journal Reference: M. Carvajal-Yepes, K. Cardwell, A. Nelson, K. A. Garrett, B. Giovani, D. G. O. Saunders, S. Kamoun, J. P. Legg, V. Verdier, J. Lessel, R. A. Neher, R. Day, P. Pardey, M. L. Gullino, A. R. Records, B. Bextine, J. E. Leach, S. Staiger, J. Tohme. A global surveillance system for crop diseases. Science, 2019; 364 (6447): 1237 DOI: 10.1126/science.aaw1572

RE-ENGINEERING SOILS PROJECT TO UNEARTH CROP PROFITS

Field trials were established recently for a new research project that seeks to boost grains yields by up to one tonne per hectare on sandy, gravel and duplex soils.

The project is exploring the use of a combination of soil amelioration techniques and full soil profile re-engineering to address multiple constraints typically associated with these soils.

Constraints, such as subsoil compaction, subsoil acidity and soil water repellence, result in shallow crop root systems, poor access to subsoil water and up to a 50 per cent gap between actual and potential grain yield.

The $22.09 million project, with co-investment from the Department of Primary Industries and Regional Development and the Grains Research and Development Corporation (GRDC), will identify the most profitable and long lasting strategies to manage these constraints.

The research will build on previous work that identified the benefits of soil amelioration, such as liming, deep ripping, spading and soil inversion.

It will examine how re-engineering the soil profile through a combination of deep soil loosening, reconstituting profile layers and deep placement of nutrients and soil amendments can optimise water use and nutrient supplies.

Project leader Steve Davies said the five year project aimed to develop targeted amelioration packages that would be applicable across an estimated 12 million hectares of sandy surfaced soils in the Western Australian grainbelt.

"Soil amelioration has predominantly been adopted in WA on deep sands and sandy earths to a depth of 40 centimetres with good results, however, the potential benefits from re-engineering the soil profile to a depth of 80 centimetres is unknown," Steve said.

"This project will assess whether the fundamental redesign of the soil profile through soil re-engineering can achieve dramatic improvements in critical measures of cropping performance, including water and nutrient use efficiency, grain yield and grower profitability."

The work will include at least 10 field trials spread across the port zones, glasshouse and laboratory experiments to examine how soils can be best re-engineered to optimise water and nutrient supply to crops.

The project will also draw from existing long term soil amelioration trials, some of which will be re-ripped and re-limed, to provide data on crop and soil responses and financial returns over an extended time period.

Steve said a key aim of the research was to extend and upgrade the department's Ranking Options for Soil Amelioration (ROSA) financial modelling tool to incorporate the economic benefit of soil re-engineering.

"ROSA is a valuable tool to help growers understand the costs and benefits of soil amelioration and re-engineering strategies," he said.

Steve said the potential benefits to be gained by addressing multiple soil constraints were considerable.

"If soil re-engineering could overcome the 1-1.4 tonne per hectare yield gap on these soils on just 20 per cent of the 12 million hectares with these soils, it would generate an additional $600-840 million per year in yield benefits for WA grain growers and the industry," he said.

NEW ONLINE TOOLS AND EXPERTISE FOR APPLE AND PEAR GROWERS

A new website is now providing independent, expert advice on integrated pest and disease management (IPDM) to the apple and pear industries and service providers.

Agriculture Victoria and Hort Innovation developed this website in response to an increased interest and need for these industries to reduce chemical use to maintain access to markets and to avoid insects developing chemical resistance.

Agriculture Victoria Principal Research Scientist David Williams said IPDM is a tool that promotes monitoring for pests and disease and sets thresholds for control management.

"IPDM can mean using natural predator insects and orchard management techniques such as weed control. It also means getting smart about what chemicals to use, and when, to avoid wiping out the beneficial insect population," Mr Williams said.

Through this website, David and his Australia-wide specialist team will provide independent, expert, practical advice, tools and the latest research information, therefore furthering the users' skills and knowledge.

An 'Ask the Expert' function is provided so growers or service providers can have their questions on IPDM answered and seek assistance in identifying a pest or disease.

David said growers like to learn from other growers, so this webpage also provides case studies, featuring a grower in each state implementing IPDM and detailing their journey.

"Timely warnings on pest or disease outbreaks, and seasonal reminders on management strategies are published on the site and the group Facebook page," he said.

"This website is purposely designed for Australia's growing conditions and orchards."

The project is funded by Hort Innovation using the Apple and Pear research and development levy and funds from the Australian Government. Agriculture Victoria is delivering the project with Queensland Department of Agriculture and Fisheries, NSW Department of Primary Industries, Western Australia Primary Industries and Regional Development, Tasmania's Institute of Agriculture; and Lenswood Cooperative.

Please visit the new website at **extensionaus.com.au/ozapplepearipdm/home** or on Facebook: **facebook.com/ozapplepear**

ORGANIC FARMING ENHANCES HONEYBEE COLONY PERFORMANCE

Bees are valuable to humans not only because they produce honey, but also because they pollinate wildflowers and food crops. They exclusively eat nectar and pollen. So in areas where intensive agriculture is practised, they suffer from the thin supply of flowers in May and June, when cultivated oilseed rape (colza) and sunflower are not in bloom. During that period, pollen collection, honey production, and colony growth slow.

An article published in the Journal of Applied Ecology shows that organic farming can limit this decline. Land on which organic crops are grown offers domesticated bees more resources, especially spontaneous vegetation (unjustly dubbed 'weeds').

After examining data spanning six years for 180 hives in west central France, the researchers found that - compared with bee colonies in areas farmed conventionally - colonies living amid organic farm fields boast 37% more brood, 20% more adult bees, and 53% greater honey production.

The implication is that organically cultivated fields exert unique effects on the bee population. The swell in brood, destined to yield new workers, may be the result of a wider diversity of pollen resources or of lower mortality from local application of pesticides. The surge in honey reserves may reflect availability of melliferous flowers in greater numbers - and over a greater area, corresponding to the range covered by bees in their quest for resources (one to three kilometres in zones where large farm fields are found).

This study was made possible through Ecobee (INRA/CNRS), a unique bee colony monitoring system. Ecobee uses annual data from 50 experimental hives in southwest France to measure the effects of farming practices under real conditions.

Previous research conducted by the same team showed that shrinking of brood during the period of flower scarcity resulted in lower colony survival in winter. The present study shows that organic farming can blunt the negative effects of intensive agriculture and increase the survival of bees, which play essential roles as pollinators.

FARMERS AND CONSERVATIONISTS JOIN CALL FOR URGENT ACTION ON WEED CRISIS

Queensland's peak agriculture body AgForce and global conservation organisation The Pew Charitable Trusts have joined forces to fight for funds to manage a noxious weed that could devastate western Queensland's wildlife and pastoral industries.

AgForce and The Pew Charitable Trusts believe a joint plea by producers and conservationists may be the only way to force the State Government to honour its $5 million funding commitment to manage the prickly acacia infestation.

Seeds from the highly prolific and difficult-to-eradicate prickly acacia, an introduced pest plant native to Africa, have been spread throughout vast tracts of western Queensland by the floodwaters flowing south across the Channel Country and north into the Gulf.

It is estimated that 33 million hectares are already infested with the weed, and with floodwaters spreading the seed and providing perfect growth conditions, the problem is expected to intensify.

On March 29, then Federal Agriculture and Water Resources Minister David Littleproud and Queensland Agriculture and Fisheries Minister Mark Furner jointly announced each government would contribute $5 million over five years to create a $10 million war chest to combat the infestation.

In a media statement on 14 June, David confirmed that the Commonwealth's $5 million contribution was assured as part of the disaster recovery fund.

However, the State Government's share seems less certain. The funding did not appear in the Budget and Minister Furner subsequently claimed in an interview on Queensland Country Hour that the $5 million was to fund the entire Queensland Feral Pest Initiative, not just prickly acacia.

Fiona Maxwell, Queensland Manager of the Pew Charitable Trusts, said the risk to the environment was becoming more severe the longer the standoff went on.

"Millions of seedlings are now emerging, particularly in the Diamantina river system," Fiona said.

"Left unchecked this could become an environmental disaster putting large areas of western Queensland at risk."

"This noxious tree grows rapidly into large thorny thickets. It chokes out native grasses vital to native wildlife and the grazing industry and significantly degrades our waterways."

"Local people are reporting that some stands that germinated after the flood are already more than half a metre high, so action needs to be taken immediately.

"The State Government must urgently honour its promise to the disaster hit people of western Queensland and address this problem before it becomes a catastrophe."

AgForce General President Georgie Somerset said the funding squabble between the Federal and State Governments threatened to compound a flood disaster into a weed disaster and was a low blow for communities already doing it tough.

"Prickly acacia is recognised as a major threat to primary production for the region - it chokes out pasture, making it difficult to graze livestock and resulting in both soil erosion and stream degradation," Georgie said.

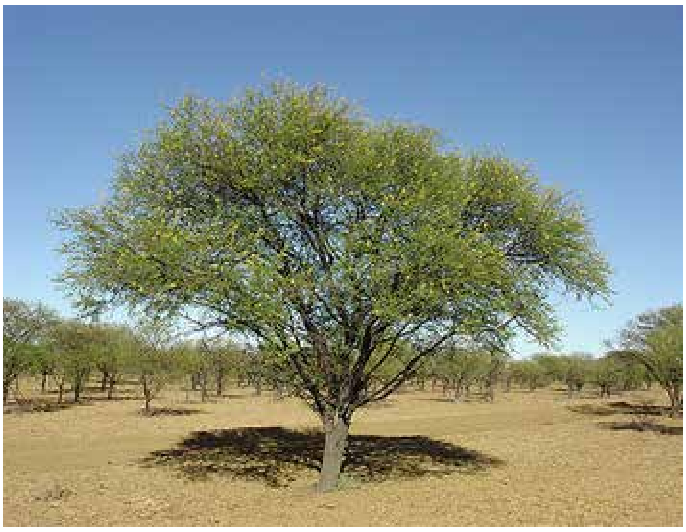
"The State Government acknowledges the threat that prickly acacia poses to the environment and to agriculture but are prepared to allow this crisis to worsen over what is a relatively small investment of resources."

"The producer-led group tasked with managing the program in the channel country - Desert Channels Queensland (DCQ) - say they are ready to go to work but are waiting for the funds."

"They have a highly sophisticated, long-term eradication program using drones which has been working."

"Similarly, the Southern Gulf NRM group are ready to continue strategic prickly acacia work across the Lower Gulf country."

"But this lack of certainty from funding, coupled with the blow from the floods, could result in all previous gains made being lost."



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NEW MICRONEEDLE TECHNIQUE SPEEDS PLANT DISEASE DETECTION

Researchers have developed a new technique that uses microneedle patches to collect DNA from plant tissues in one minute, rather than the hours needed for conventional techniques. DNA extraction is the first step in identifying plant diseases, and the new method holds promise for the development of on-site plant disease detection tools.

"When farmers detect a possible plant disease in the field, such as potato late blight, they want to know what it is right away; rapid detection can be important for addressing plant diseases that spread quickly," says Qingshan Wei, an assistant professor of chemical and biomolecular engineering at North Carolina State University and co-corresponding author of a paper on the work.

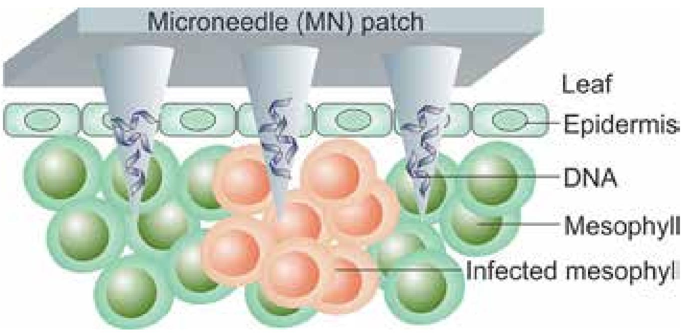
"One of the obstacles to rapid detection is the amount of time it takes to extract DNA from a plant sample, and our technique provides a fast, simple solution to that problem," Qingshan says.

"Some plant diseases have similar leaf symptoms, such as late blight caused by the famed Irish famine pathogen Phytophthora infestans, and Phytophthora blight caused by a sister species P. nicotianae," says Jean Ristaino, William Neal Reynolds Distinguished Professor of Plant Pathology at NC State and co-corresponding author of the paper. "The gold standard for disease identification is a molecular assay. Our new technique is important because you can't run an amplification or genotyping assay on strains of P. infestans, or any other plant disease, until you've extracted DNA from the sample."

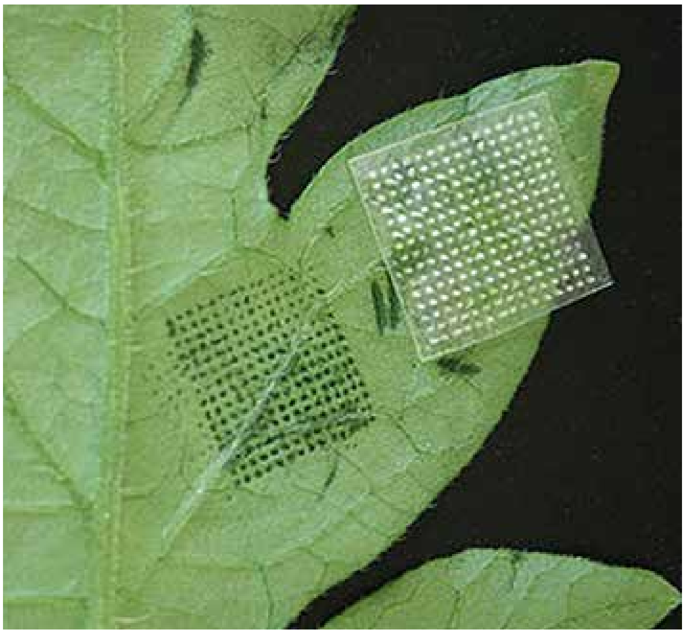
Typically, DNA is extracted from a plant sample using a method called CTAB extraction, which has to be done in a lab, requires a lot of equipment, and takes at least 3 to 4 hours. CTAB extraction is a multi-step process involving everything from tissue grinding to organic solvents and centrifuges.

By contrast, the new DNA extraction technique involves only a microneedle patch and an aqueous buffer solution. The patch is about the size of a postage stamp and is made of an inexpensive polymer. The surface on one side of the patch is made up of hundreds of needles that are only 0.8 millimeters long.

A farmer or researcher can apply the microneedle patch to a plant they suspect is diseased, hold the patch in place for a few seconds, then peel it off. The patch is then rinsed with the buffer solution, washing genetic material off of the microneedles and into a sterile container. The entire process takes about a minute.



A diagram depicting how the microneedles gather DNA. Credit: NC State University



The disposable patch gathers genetic material containing both plant DNA, and the DNA of disease-causing organisms. Credit: NC State University

"It is exciting to see the new application of microneedle patch technology in agriculture and plant science," says Zhen Gu, a professor of bioengineering at the University of California, Los Angeles and co-corresponding author of the paper, who developed several microneedle-based drug delivery systems for human health.

"In experimental testing, we found that the microneedle technique does result in slightly higher levels of impurities in the sample, as compared to CTAB," Qingshan says. "However, the microneedle technique's purity levels were comparable to other, validated laboratory methods of DNA extraction. Most importantly, we found that the slight difference in purity levels between the microneedle and CTAB samples did not interfere with the ability to accurately test the samples by a PCR or LAMP assay."

"The fact that microneedles extract a smaller sampling volume seems not to be an issue," says Rajesh Paul, a Ph.D. student at NC State and first author of the paper. "The microneedle technique successfully extracted pathogen DNA from all field-collected infected tomato leaves in a recent blind test."

"DNA extraction has been a significant hurdle to the development of on-site testing tools," Qingshan says. "We are now moving forward with the goal of creating an integrated, low-cost, field-portable device that can perform every step of the process from taking the sample to identifying the pathogen and reporting the results of an assay."

The paper, "Extraction of Plant DNA by Microneedle Patch for Rapid Detection of Plant Diseases," is published in the journal ACS Nano. The paper was co-authored by Amanda Saville, lab manager in Jean's lab; Jeana Hansel, a graduate student at NC State; Carmin Ball and Alyssa Williams, undergraduates at NC State; Yanqi Ye, a former graduate student in the Joint Biomedical Engineering Department at NC State and the University of North Carolina, Chapel Hill; Xinyuan Chang, an undergraduate at Tianjin University who worked as a visiting researcher at NC State; and Guojun Chen, postdoctoral researcher at UCLA.

PLANTS' OIL-PRODUCTION ACCELERATOR ALSO ACTIVATES THE BRAKES

Scientists discover seemingly paradoxical mechanism for regulating oil synthesis

Scientists studying plant biochemistry at the U.S. Department of Energy's Brookhaven National Laboratory recently made a surprising discovery.

They found that a protein that turns on oil synthesis also activates a protein that puts the brakes on the same process. In a paper just published in the journal Plant Physiology, they describe how this seemingly paradoxical system keeps oil precursors perfectly balanced to meet plants' needs.

"We were initially surprised by our discovery that the signaling protein that turns on the oil synthesis pathway also turns on the off switch," said Brookhaven Lab biochemist John Shanklin, who led the research.

But after further investigation it made perfect sense. Fatty acids - the precursors to oils - can be toxic if allowed to accumulate. If the levels increase beyond the cell's requirements for making lipid components of membranes or oils, the cells need a way to shut production off.

The key is that the off switch, a protein known as BADC, is a "conditional inhibitor," John said. It only puts on the brakes when the level of free fatty acids is high.

This work could advance the team's efforts to find new ways to control oil production in plants with the goal of making fuels or other useful products.

Putting the pieces together

The new study builds on previous work by John's group. One of those studies revealed that BADC exerts its braking mechanism by inserting itself into a key enzyme involved in making fatty acids, ACCase.

"We were interested to learn more about the BADC proteins, and how the genes for these proteins were regulated," John said.

In another study, the team had explored details of the signaling protein known as WRINKLED1, which turns on the enzymes for fatty acid synthesis, including parts of ACCase, and therefore serves as the on switch for the oil-synthesis pathway.

The scientists had little reason to suspect a direct connection between WRI1 (the on switch) and BADC (the off switch) until the lead authors, Hui Liu and Zhiyang Zhai, observed that plants with mutations in genes for either protein had unusually short roots.

"It would have been easy to overlook this connection as a coincidence, but Hui and Zhiyang's observation turned out to be central to the mechanism we discovered," John said.

Further investigation showed that the aberrant hormone levels seen in WRI1 mutant roots were like those found in roots of the BADC mutant.

Closer biochemical-genetic investigations led the team to conclude that both proteins were indeed linked to this growth defect - which triggered them to explore the connection further.

Working with Brookhaven colleague Jorg Schwender, they showed that the WRI1 on switch bound tightly to the BADC gene, enabling it to be turned on. They confirmed the connection by showing that adding more BADC to the WRI1 mutant made the roots grow longer.

The key point is that having the on switch turn on genes for the off switch doesn't necessarily turn fatty acid synthesis off. It just gives the cell a way to turn synthesis off if fatty acid levels get too high. And the more WRI1 ramps up fatty acid production, the more the cell also needs to ramp up BADC to be able to stop that process.

"It's like giving a faster car the bigger brakes it would need to stop if a deer runs into the road," John said.

"Making lots of membranes or oil will keep fatty acid levels low, and the BADC braking system won't be needed," John explained. "It's only when production exceeds demand and fatty acids build up that the brakes need to be applied."

The scientists are now conducting further biochemical studies to explore how elevated free fatty acids trigger BADC to become inserted into ACCase to put the brakes on.

ANT FARMERS BOOST PLANT NUTRITION

A study has found Ant farmers boost plant nutrition with their feces, offering clues for future food security

Humans began cultivating crops about 12,000 years ago. Ants have been at it rather longer. Leafcutter ants, the best-known insect farmers, belong to a lineage of insects that have been running fungus farms based on chopped-up vegetable matter for over 50 million years. The ant farming of flowering plants, however, started more recently, about 3 million years ago in the Fiji Islands.

Research, led by Dr Guillaume Chomicki from the Department of Plant Sciences, University of Oxford, has demonstrated that millions of years of ant agriculture has remodelled plant physiology. Farming ants deposit nitrogen-rich faeces directly inside plants, which has led to the evolution of these ultra-absorptive plant structures. This means that ant-derived nutrients are actively targeted on the hyper-absorptive sites, rather than deposited as a result of by-products. This new understanding may offer important clues in our fight for food security.

Guillaume, the lead author of the study, says

"The speed at which plants can take up nitrogen is a key limitation to plant growth rate. Most plants, including our crops, take up nitrogen from the soil and are thus not naturally exposed to very high nitrogen concentrations. Here, for millions of years, ants have deposited nitrogen-rich faeces directly inside the plants."

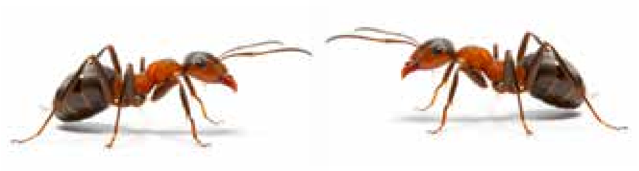
Ongoing work aims to decipher the genetic basis of the ultra-absorptive plant structures discovered in this study, which may ultimately be transferred to our crops and thereby increase their nitrogen uptake rate.

It's a unique kind of farming where the ants grow not only their food, but also their home: the plants provide ready-made cavities in which the ants nest. This relationship is essential for both parties: the ants have lost the nest-building ability that most other tropical tree-dwelling ants have, and the plants - which are epiphytes (plants growing on the surface of trees) - rely on ants for nutrients and defence.

To test whether the ant-farmed plants' nutrition has itself changed, Guillaume tracked the deposition of nutrients by ants inside these Fiji-island plants. In the farmed plant species, specialized ants exclusively defecate on hyper-absorptive warts on the walls inside the plant. In closely-related non-farmed plant species living in the same Fijian rainforests, the ants do not show this farming behaviour. This research shows that similar hyper-absorptive warts have evolved repeatedly in plants colonized by farming ants.

The research published recently in New Phytologist, reveals that because insect farmers supply their crops with nutrients, they have the potential to modify crop nutrition, and in the case of ants, this has led to evolutionary changes in both partners; the ants and the plants.

Professor Renner, from the University of Munich, and senior author of the study, said "Domestication of plants by ants has led to a >2-fold increase in uptake of ant-derived nitrogen, and this tight nutrient recycling is a key asset for the epiphytes to live in soilless canopies."



This supports the notion that millions of years of ant agriculture have remodelled plant physiology, shifting from ant-derived nutrients as by-products to active and targeted fertilization on hyper-absorptive sites. Much like our emerging 'precision agriculture' where computer-controlled devices and drones are used to target nutrients to the spots in the field where they are most needed, these ants have evolved a special kind of precision farming. They target nutrients to specific tissues in the plants that are hyper-absorptive.

LUCERNE TRIALS REVEAL WATER STRESS RESPONSE

Twenty-nine commercial and pre-release lucerne varieties have been put to the test under modified irrigation management systems

The trials funded by AgriFutures Australia and Lucerne Australia showed a significant boost in seed yield when a delay in irrigation increased plant stress.

Annelies McGaw, AgriFutures Australia Manager, Research said the trials run by Lucerne Australia at Keith, South Australia provided all-important data for lucerne grown under Australian conditions.

"The trials provide vital and scientifically-rigorous information for Australian lucerne seed producers," said Annelies. "It builds on a previous variety trial funded by AgriFutures™ Pasture Seeds Program which shows imported genetics have generally struggled to produce consistent seed yield under Australian conditions."

AgriFutures Australia Pasture Seeds Program Advisory Panel Chair, Lisa Anderson welcomed the investment in research with such clear benefits to industry.

"For more than 40 years lucerne has been an important pastures species in Australia and Australian lucerne seed producers now better understand the impact of their watering strategies on yield."

The trials were run at Simon Allen's Warrawee Park, south of Keith with seed supplied by Alforex Seeds, Heritage Seeds, Naracoorte Seeds, Pasture Genetics, PGG Wrightson Seeds, Seed Force, S&W Seed Co, and Upper Murray Seeds.

Heritage 10 and SW18NPK91 were consistently the highest yielding seed varieties across all three watering strategies.

Lucerne Australia Chair, Josh Rasheed said the results reflected seed harvest from March this year and the executive committee was keen to see how the trial progressed.

"These early results are a summary of the first-year seed production from a seedling crop so, while we are confident with the statistical information, data should be read with that in mind," Josh said. "We look forward to having data from the mature crop over the next two years."

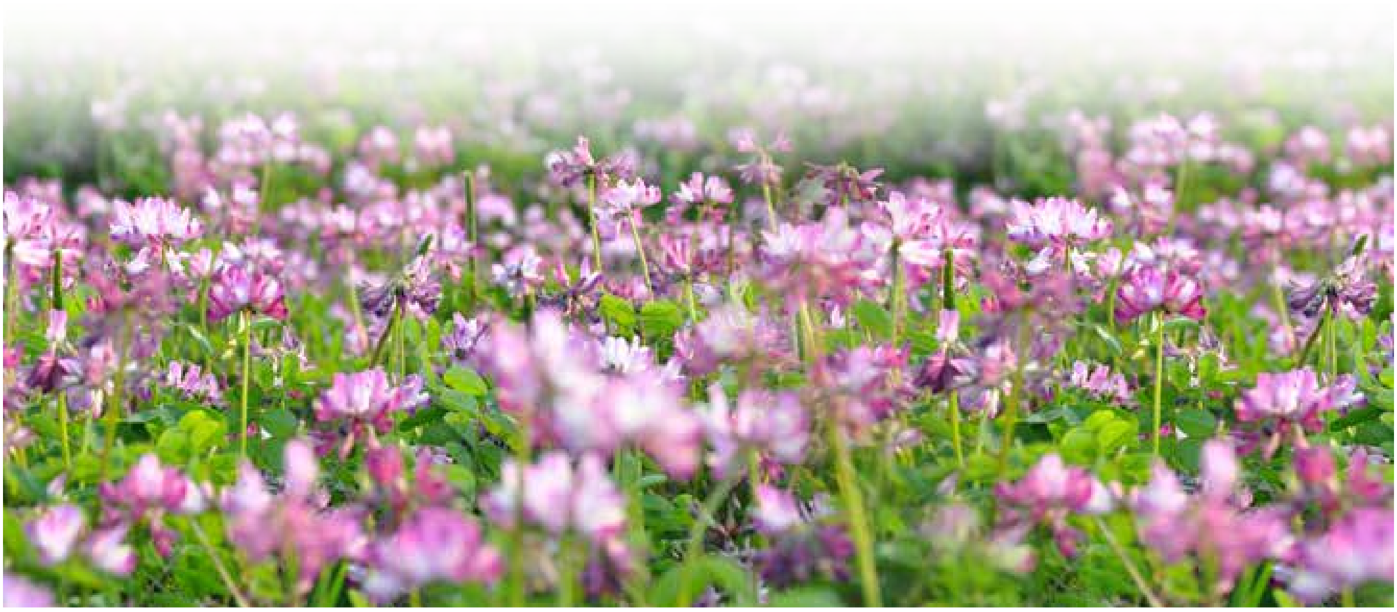
"Delaying irrigation timings statistically increased seed yield. Under the trial conditions a 14% seed yield increase was observed across the moderate watering strategy.

"The high and moderate stress watering strategies respectively had 11.5% and 14.4% higher yields when compared to the standard watering strategy."

The highest yielding varieties for the high stress watering strategy were Heritage 10, SFR27-032, Silverland (D5), AR245, SW18NPK91 and SW18NPK92 which yielded between 0.652t/ha and 0.721t/ha.

SW18NPK91 and Heritage 10 were the highest yielding varieties across the moderate stress watering strategy with clean seed weights of 0.789t/ha and 0.783t/ha respectively.

The highest yielding varieties across the standard watering strategy were SW18NPK91, SW18NPK92 and Heritage 10 with clean seed weights between 0.673t/ha and 0.726t/ha.



GRAZING ANIMALS DROVE DOMESTICATION OF GRAIN CROPS

MANY FAMILIAR GRAINS TODAY, LIKE QUINOA, AMARANTH, AND THE MILLETS, HEMP, AND BUCKWHEAT, ALL HAVE TRAITS THAT INDICATE THAT THEY COEVOLVED TO BE DISPERSED BY LARGE GRAZING MAMMALS.

During the Pleistocene, massive herds directed the ecology across much of the globe and caused evolutionary changes in plants. Studies of the ecology and growing habits of certain ancient crop relatives indicate that megafaunal herds were necessary for the dispersal of their seeds prior to human intervention. Understanding this process is providing insights into the early domestication of these plants.

The domestication of small-seeded annuals involved an evolutionary switch from dispersal through animal ingestion to human dispersal. Those are the findings of a new study by Robert Spengler, director of the Paleoethnobotany Laboratories at the Max Planck Institute for the Science of Human History, and Natalie Mueller, a National Science Foundation fellow at Cornell University, published in Nature Plants. Robert and Natalie demonstrate, by looking at rangeland ecology and herd-animal herbivory patterns, that the progenitors of small-seeded crops evolved to be dispersed by megafaunal ruminants. Although today the wild varieties of these species grow in small, isolated patches, the researchers illustrate that heavy grazing of these plants by herd animals causes dense patches to form near rivers or other areas that the animals frequent. In ancient times, these dense patches of plants could have easily been harvested, just like modern farmers' fields - explaining how and why ancient people might have focused on these specific plants. This study provides an answer for this long-standing mystery of plant domestication.

Small-seeded crops are products of another age

During the mid-Holocene (7,000-5,000 years ago), in ecologically rich river valleys and grasslands all around the world, people started to cultivate small plants for their seed or grain. Wheat, barley, and rice are some of the earliest plants to show signs of domestication and scientists have extensively studied the domestication process in these large-seeded cereal crops. Researchers know significantly less about the domestication of small-seeded grain crops, such as quinoa, amaranth, buckwheat, the millets, and several now-lost crops domesticated in North America.

The wild ancestors of these crops have small seeds with indigestible shells or seed coats. Today, these wild plants exist in small fragmentary patches dispersed across huge areas - the fact that they do not grow in dense clusters, like the ancestors of wheat and rice, would seem to have made these crop ancestors unappealing targets for foragers. The small seed sizes and hard seed shells, combined with the lack of dense wild populations, led many researchers to argue that they must have been a famine food.

Foraging enough wild seeds from these varieties to grind into flour to bake a loaf of bread would take weeks, especially for rarer or endangered crop ancestors. So why did early foragers focus so heavily on these plants and eventually adopt them as crops?

Robert and Natalie present a new model, suggesting that when humans first encountered these plants, they would have grown in dense stands created by grazing megafauna, making them easy to harvest. As humans began to cultivate these plants, they took on the functional role of seed dispersers, and eventually the plants evolved new traits to favor farming and lost the old traits that favored being spread by herd animals.

The earliest traits of domestication, thinning or loss of indigestible seed protections, loss of dormancy, and increased seed size, can all be explained by to the loss of the ruminant dispersal process and concomitant human management of wild stands.

A novel model for the domestication of small-seeded grain crops

Robert and Natalie have been interested in plant domestication since graduate school, when they studied under Dr. Gayle Fritz, one of the first scholars to recognize the importance of the American Midwest as a center of crop domestication. Despite decades of research into the nature of plant domestication in North America, no one recognized that the true key was the massive bison herds. The plants that were domesticated, what Natalie calls the "Lost Crops," would have been dispersed by bison in large swaths, making them easy to collect by ancient people and perhaps encouraging these communities to actively plant them themselves. When Europeans exterminated the herds, the plants that relied on these animals to disperse their seeds began to diminish as well. Because the wild ancestors

of these lost crops are rare today and the bison herds are effectively extinct, researchers have overlooked this important coevolutionary feature in the domestication process.

However, this process is not unique to the American Midwest and the researchers suggest that there may be links between buckwheat domestication and yak herding in the Himalaya and amaranth domestication and llama herding in the Andes. The authors have identified parallel patterns in rangeland ecology studies, noting that heavy herd animal herbivory can homogenize vegetation communities. For example, heavy pastoralist grazing in the mountains of Central Asia causes many plants to die, but certain plants with adaptations for dispersal by animals thrive. The depositing of plant seeds in nutrient rich dung leads to ecological patches, often called hot spots, that foragers can easily target for seed collecting.

For over a century, scholars have debated why early foragers targeted small-seeded annuals as a major food source (eventually resulting in their domestication). Today, the progenitors of many of these crops have highly fragmentary populations and several are endangered or extinct. Likewise, without large dense homogenous stands of these plants in the wild, such as what exists in the wild for the progenitors of large-seeded cereal crops, it would have been impossible to harvest their seeds. The conclusions that Robert and Natalie draw help explain why people targeted these plants and were able to domesticate them. "Small-seeded annuals were domesticated in most areas of the world," explains Robert. "So the ramifications of this study are global-scale. Scholars all over the world will need to grapple with these ideas if they want to pursue questions of domestication."

Robert and Natalie are continuing their research into the role that grazing animals played in plant domestication. "Currently, we're studying the ecology of fields where modern herd animals graze as proxies to what the ecology would have looked like during the last Ice Age, when large herds of bison, mammoths, and wooly horses dictated what kinds of plants could grow across the American Midwest and Europe," explains Robert. "We hope these observations will provide even greater insight into the process of domestication all over the world."

Journal Reference:
Robert N. Spengler III and Natalie G. Mueller. Grazing Animals Drove Domestication of Grain Crops. Nature Plants, 2019 DOI: 10.1038/s41477-019-0470-4

MILLING OATS AN OPTION FOR PADDOCKS WITH CROWN ROT

Milling oats may be a more profitable option than wheat in paddocks where there is a high level of fusarium crown rot, although it is unsuitable as a break crop to reduce the risk of the fungal disease.

Those were the key findings of a two year Grain Flagship project, funded by the Department of Primary Industries and Regional Development, opening the door to expanded oat production in Western Australia.

Crown rot costs WA wheat and barley growers an estimated $7 million per annum, however, relatively little was known about its impact on milling oats.

The disease is widespread across the WA grainbelt, particularly in low to medium rainfall areas, where oats have not typically been grown.

With competitive prices for milling oats, growers in low rainfall areas have become more interested in sowing the crop, prompting the need to investigate variety susceptibility to crown rot.

Department research officer Daniel Hüberli said all seven oat varieties tested were more tolerant to crown rot than the two benchmark wheat varieties, suggesting oats could be a cereal alternative for paddocks where there was a disease risk.

"In fact, average yield losses for milling oats to the predominant crown rot pathogen, Fusarium pseudograminearum, was four per cent, which is about four times lower than that measured in wheat," he said.

The trials showed no oat varietal differences in yield responses to crown rot.

"These results are good news for growers, as it means there is a more tolerant cereal crop option that can be used in rotations where crown rot is a problem," Daniel said.

"So in paddocks where the crown rot risk is high and non-host options are limited, oats appear to be a better choice than wheat to limit the extent of yield loss."

The field trials tested the milling oats varieties Bannister, Carrolup, Durack, Kojonup, Mitika, Williams and Yallara and two benchmark wheat varieties, Mace and Emu Rock, in inoculated versus uninoculated replicated plot trials at Merredin and Pingelly in 2016 and Merredin and Muresk in 2017.

At both sites, the pre-sowing inoculum levels in 2017 following the oat trials the previous year were not different among wheat and oats or between varieties sown in 2016.

Daniel said this meant oats could not be used as a break crop for wheat and barley crops, which are known to increase crown rot inoculum levels, as both trials had similar levels of inoculum in 2017.

"The trials showed there was no difference in disease levels in the 2017 Mace wheat crop following the different oat and wheat varieties," he said.

"If the management strategy is to reduce the level of crown rot in a paddock, then a non-cereal crop, like canola or lupins, would be preferable to optimise profitability and provide good grass weed control."

An economic analysis suggested milling oats was the most profitable crop for paddocks where crown rot was a problem, provided the price of oats was above $270 per tonne.

"The economics of oats compared with wheat becomes more attractive in the presence of high levels of crown rot," Daniel said.

"In GRDC funded trials, wheat and barley varieties were found to vary significantly in relative yield losses due to crown rot, as documented in the current crop variety guides.

"It is important for growers with paddocks that have a high risk of crown rot to select the most appropriate cereal crop, based on the forecast for the season and yield potential."

The outcomes from the department's research will be included in the next edition of the Oat Variety Guide, while the new findings will be updated in the soon to be released GRDC Crown rot Tips & Tactics publication.

Photo credit: CSIRO

ROBOT USES MACHINE LEARNING TO HARVEST LETTUCE

A vegetable-picking robot that uses machine learning to identify and harvest a commonplace, but challenging, agricultural crop has been developed by engineers.

The 'Vegebot', developed by a team at the University of Cambridge, was initially trained to recognise and harvest iceberg lettuce in a lab setting. It has now been successfully tested in a variety of field conditions in cooperation with G's Growers, a local fruit and vegetable co-operative.

Although the prototype is nowhere near as fast or efficient as a human worker, it demonstrates how the use of robotics in agriculture might be expanded, even for crops like iceberg lettuce which are particularly challenging to harvest mechanically. The results are published in The Journal of Field Robotics.

Crops such as potatoes and wheat have been harvested mechanically at scale for decades, but many other crops have to date resisted automation. Iceberg lettuce is one such crop. Although it is the most common type of lettuce grown in the UK, iceberg is easily damaged and grows relatively flat to the ground, presenting a challenge for robotic harvesters.

"Every field is different, every lettuce is different," said co-author Simon Birrell from Cambridge's Department of Engineering. "But if we can make a robotic harvester work with iceberg lettuce, we could also make it work with many other crops."

"At the moment, harvesting is the only part of the lettuce life cycle that is done manually, and it's very physically demanding," said co-author Julia Cai, who worked on the computer vision components of the Vegebot while she was an undergraduate student in the lab of Dr Fumiya Iida.

The Vegebot first identifies the 'target' crop within its field of vision, then determines whether a particular lettuce is healthy and ready to be harvested, and finally cuts the lettuce from the rest of the plant without crushing it so that it is 'supermarket ready'. "For a human, the entire process takes a couple of seconds, but it's a really challenging problem for a robot," said co-author Josie Hughes.

The Vegebot has two main components: a computer vision system and a cutting system. The overhead camera on the Vegebot takes an image of the lettuce field and first identifies all the lettuces in the image, and then for each lettuce, classifies whether it should be harvested or not. A lettuce might be rejected because it's not yet mature, or it might have a disease that could spread to other lettuces in the harvest.

The researchers developed and trained a machine learning algorithm on example images of lettuces. Once the Vegebot could recognise healthy lettuces in the lab, it was then trained in the field, in a variety of weather conditions, on thousands of real lettuces.

A second camera on the Vegebot is positioned near the cutting blade, and helps ensure a smooth cut. The researchers were also able to adjust the pressure in the robot's gripping arm so that it held the lettuce firmly enough not to drop it, but not so firm as to crush it. The force of the grip can be adjusted for other crops.

"We wanted to develop approaches that weren't necessarily specific to iceberg lettuce, so that they can be used for other types of above-ground crops," said Iida, who leads the team behind the research.

In future, robotic harvesters could help address problems with labour shortages in agriculture, and could also help reduce food waste. At the moment, each field is typically harvested once, and any unripe vegetables or fruits are discarded. However, a robotic harvester could be trained to pick only ripe vegetables, and since it could harvest around the clock, it could perform multiple passes on the same field, returning at a later date to harvest the vegetables that were unripe during previous passes.

"We're also collecting lots of data about lettuce, which could be used to improve efficiency, such as which fields have the highest yields," said Josie. "We've still got to speed our Vegebot up to the point where it could compete with a human, but we think robots have lots of potential in agri-tech."

PLANT NUTRIENT DETECTOR BREAKTHROUGH

Findings from La Trobe University-led research could lead to less fertiliser wastage, saving millions of dollars for Australian farmers.

The international research team has uncovered a protein that can sense vital phosphorus levels - the 'fuel in the tank' - in plants and then adjust growth and flowering in response.

Published in the journal Plant Physiology, the findings provide a deeper understanding of the mechanisms whereby plants sense how much and when to take in the essential nutrient, phosphorus, for optimal growth.

Lead author Dr Ricarda Jost, from the Department of Plant, Animal and Soil Sciences at La Trobe University said the environmental and economic benefits to farmers could be significant.

"In countries like Australia where soils are phosphorus poor, farmers are using large amounts of expensive, non-renewable phosphorus fertiliser, such as superphosphate or diammonium phosphate (DAP), much of which is not being taken up effectively by crops at the right time for growth," Ricarda said.

"Our findings have shown that a protein called SPX4 senses the nutrient status - the 'amount of fuel in the tank' of a crop - and alters gene regulation to either switch off or turn on phosphorus acquisition, and to alter growth and flowering time."

Using Arabidopsis thaliana (thale or mouse-ear cress) shoots, the research team conducted genetic testing by adding phosphorus fertiliser and observing the behaviour of the protein.

For the first time, the SPX4 protein was observed to have both a negative and a positive regulatory effect on phosphorus take-up and resulting plant growth.

"The protein senses when the plant has taken in enough phosphorus and tells the roots to stop taking it up," Ricarda said. "If the fuel pump is turned off too early, this can limit plant growth.

"On the other hand, SPX4 seems to have a 'moonlighting' activity and can activate beneficial processes of crop development such as initiation of flowering and seed production."

This greater understanding of how SPX4 operates could lead to a more precise identification of the genes it regulates, and an opportunity to control the protein's activity using genetic intervention - switching on the positive and switching off the negative responses.

La Trobe agronomist Dr James Hunt said the research findings sit well with the necessity for Australian farmers' to be as efficient as possible with costly fertiliser inputs.

"In our no-till cropping systems, phosphorus gets stratified in the top layers of soil. When this layer gets dry, crops cannot access these reserves and enter what we a call a phosphorus drought," James said.

"The phosphorus is there, but crops can't access it in the dry soil. If we could manipulate crop species to take up more phosphorus when the top soil is wet, we'd be putting more fuel in the tank for later crop growth when the top soil dries out."

The research team will now be investigating in more detail how SPX4 interacts with gene regulators around plant development and controlling flowering time.

The research was published in Plant Physiology with collaborators from Zhejiang University (China), Ghent University & VIB Center for Plant Systems Biology (Belgium), French Alternative Energies and Atomic Energy Commission (CEA) and the Australian Research Council Centre of Excellence in Plant Energy Biology.

Journal Reference:

Marina Borges Osorio, Sophia Ng, Oliver Berkowitz, Inge De Clercq, Chuanzao Mao, Huixia Shou, James Whelan, Ricarda Jost. SPX4 Acts on PHR1-Dependent and -Independent Regulation of Shoot Phosphorus Status in Arabidopsis. Plant Physiology, 2019; pp.00594.2018 DOI: 10.1104/pp.18.00594

SKELETON WEED UNDER DRONE SPOTLIGHT

Drones have been taking to Wheatbelt skies in a bid to improve surveillance and control of a key agricultural pest plant, skeleton weed.

Skeleton weed is a declared plant in Western Australia and can reduce crop yields by competing for moisture and nutrients.

The Skeleton Weed Program, funded through the Grains, Seeds and Hay Industry Funding Scheme (IFS), is adopting new remote sensing data collection technology to complement traditional surveillance methods.

Grains, Seeds and Hay IFS Management Committee chair Rohan Day said the IFS began a project in 2015 to investigate the potential of remotely piloted aircraft, or drones, as a more efficient way to search for skeleton weed.

“There were two key areas of the project, to test the abilities of various drones and camera technologies, and to promote the development of machine learning software to identify and map skeleton weed from images captured by drones,” Rohan said.

This has resulted in Precise AI, a company specialising in developing software applications to process large amounts of remote sensing data, to apply its Optiweed program, a unique weed mapping and detection platform, to the detection of skeleton weed.

“This platform has progressed from detecting clumps of skeleton weed to being able to detect individual skeleton weed plants and their precise GPS location within the paddock,” Rohan said.

Skeleton Weed Program manager Martin Atwell, of the Department of Primary Industries and Regional Development, said the skeleton weed surveillance activity aimed to cover up to 40,000 hectares of farmland per year.

The surveillance activity is a vital part of the overall program.

“Drone technology was used in the 2018/19 search season to undertake targeted surveillance of uninfested areas where skeleton weed plants were most likely to spread,” Martin said.

Previously all surveillance was undertaken by farmers and program staff in vehicles. While this has worked well, there are some potential advantages in using drones.

“This first large-scale surveillance test of the drone and software application system worked well,” Martin said.

“The work is currently delivering a good skeleton weed detection rate at a similar cost to the current methods of surveillance.

“This work is still new, and many important procedures and workflows were developed in the 2018/19 search season which will greatly improve the drone surveillance undertaken in future.”

Rohan said the future potential offered by the technology included improved cost-effectiveness of skeleton weed surveillance.

“This means reduced costs to the industry for funding for the program,” Rohan said. “It also minimises the impact of vehicle traffic on farmland.”

More information is available at **wa.gov.au/skeletonweed**

RESEARCHERS CAN FINALLY MODIFY PLANT MITOCHONDRIAL DNA

RESEARCHERS HAVE EDITED PLANT MITOCHONDRIAL DNA FOR THE FIRST TIME, WHICH COULD LEAD TO A MORE SECURE FOOD SUPPLY.

Nuclear DNA was first edited in the early 1970s, chloroplast DNA was first edited in 1988, and animal mitochondrial DNA was edited in 2008. However, no tool previously successfully edited plant mitochondrial DNA.

Researchers used their technique to create four new lines of rice and three new lines of canola.

"We knew we were successful when we saw that the rice plant was more polite - it had a deep bow," said Associate Professor Shin-ichi Arimura, joking about how a fertile rice plant bends under the weight of heavy seeds.

Shin-ichi is an expert in plant molecular genetics at the University of Tokyo and led the research team, whose results were published in Nature Plants. Collaborators at Tohoku University and Tamagawa University also contributed to the research.

Genetic diversity for the food supply

Researchers hope to use the technique to address the current lack of mitochondrial genetic diversity in crops, a potentially devastating weak point in our food supply.

In 1970, a fungal infection arrived on Texas corn farms and was exacerbated by a gene in the corn's mitochondria. All corn on the farms had the same gene, so none were resistant to the infection. Fifteen percent of the entire American corn crop was killed that year. Corn with that specific mitochondrial gene has not been planted since.

"We still have a big risk now because there are so few plant mitochondrial genomes used in the world. I would like to use our ability to manipulate plant mitochondrial DNA to add diversity," said Shin-ichi.

Plants without pollen

Most farmers do not save seeds from their harvest to replant next year. Hybrid plants, the first-generation offspring of two genetically different parent subspecies, are usually hardier and more productive.

To ensure farmers have fresh, first-generation hybrid seeds each season, agricultural supply companies produce seeds through a separate breeding process using two different parent subspecies. One of those parents is male infertile - it cannot make pollen.

Researchers refer to a common type of plant male infertility as cytoplasmic male sterility (CMS). CMS is a rare but naturally occurring phenomenon caused primarily by genes not in the nucleus of the cells, but rather the mitochondria.

Green beans, beets, carrots, corn, onions, petunia, canola oil, rice, rye, sorghum, and sunflowers can be grown commercially using parent subspecies with CMS-type male infertility.

Beyond green

Plants use sunlight to produce most of their energy, through photosynthesis in green-pigmented chloroplasts. However, chloroplasts' fame is overrated, according to Shin-ichi.

Most of a plant isn't green, only the leaves above the ground. many plants don't have leaves for half the year," said Shin-ichi.

Plants get a significant portion of their energy through the same "powerhouse of the cell" that produces energy in animal cells: the mitochondria.

"No plant mitochondria, no life," said Shin-ichi.

Mitochondria contain DNA completely separate from the cell's main DNA, which is stored in the nucleus. Nuclear DNA is the long double-helix genetic material inherited from both parents. The mitochondrial genome is circular, contains far fewer genes, and is primarily inherited only from mothers.

The animal mitochondrial genome is a relatively small molecule contained in a single circular structure with remarkable conservation between species.

"Even a fish's mitochondrial genome is similar to a human's," said Shin-ichi.

Plant mitochondrial genomes are a different story.

"The plant mitochondrial genome is huge in comparison, the structure is much more complicated, the genes are sometimes duplicated, the gene expression mechanisms are not well-understood, and some mitochondria have no genomes at all - in our previous studies, we observed that they fuse with other mitochondria to exchange protein products and then separate again," said Shin-ichi.

Manipulating plant mitochondrial DNA

To find a way to manipulate the complex plant mitochondrial genome, Shin-ichi turned to collaborators familiar with the CMS systems in rice and canola. Prior research strongly suggested that in both plants, the cause of CMS was a single, evolutionarily unrelated mitochondrial gene in rice and in canola: clear targets in the perplexing maze of plant mitochondrial genomes.

Shin-ichi's team adapted a technique that had previously edited mitochondrial genomes of animal cells growing in a dish. The technique, called mitoTALENs, uses a single protein to locate the mitochondrial genome, cut the DNA at the desired gene, and delete it.

"While deleting most genes creates problems, deleting a CMS gene solves a problem for plants. Without the CMS gene, plants are fertile again," said Shin-ichi.

The fully fertile four new lines of rice and three new lines of canola that researchers created are a proof of concept that the mitoTALENs system can successfully manipulate even the complex plant mitochondrial genome.

"This is an important first step for plant mitochondrial research," said Shin-ichi.

Researchers will study the mitochondrial genes responsible for plant male infertility in more detail and identify potential mutations that could add much-needed diversity.

"We knew we were successful when we saw that the rice plant was more polite, it had a deep bow"

Associate Professor Shin-ichi Arimura

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REGISTRATION PENDING

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YIELD-BOOSTING STAY-GREEN GENE IDENTIFIED FROM 118-YEAR-OLD EXPERIMENT IN CORN

A corn gene identified from a 118-year-old experiment at the University of Illinois could boost yields of today's elite hybrids with no added inputs. The gene, identified in a recent Plant Biotechnology Journal study, controls a critical piece of senescence, or seasonal die-back, in corn. When the gene is turned off, field-grown elite hybrids yielded 4.6 bushels more per acre on average than standard plants.

Dating back to 1896, the Illinois experiment was designed to test whether corn grain composition could be changed through artificial selection, a relatively new concept introduced by Charles Darwin just 37 years earlier. Repeated selection of high- and low-protein corn lines had the intended effect within about 10 generations. As selection for the traits continued, however, additional changes were noticeable.

"One of the things that was noted as early as the 1930s was that the low-protein line stays greener longer than the high-protein line. It's really obvious," says Stephen Moose, professor in the Department of Crop Sciences at Illinois and co-author of the study.

Staying green longer into the season can mean more yield. The plant continues photosynthesizing and putting energy toward developing grain. But, until now, no one knew the specific gene responsible for the stay-green trait in corn.

"The stay-green trait is like a 'fountain of youth' for plants because it prolongs photosynthesis and improves yield," says Anne Sylvester, a program director at the National Science Foundation, which funded this research. "This is a great basic discovery with practical impact."

The discovery of the gene was made possible through a decade-long public-private partnership between Illinois and Corteva Agriscience. Stephen and Illinois collaborators initially gave Corteva scientists access to a population derived from the long-term corn protein experiment with differences in the stay-green trait. Corteva scientists mapped the stay-green trait to a particular gene, NAC7, and developed corn plants with low expression for the trait. Like the low-protein parent, these plants stayed green longer. They tested these plants in greenhouses and fields across the country over two field seasons.

Not only did corn grow just fine without NAC7, yield increased by almost 5 bushels per acre compared to conventional hybrids. Notably, the field results came without added nitrogen fertilizer beyond what farmers typically use.

"Collaborating with the University of Illinois gives us the opportunity to apply leading-edge technology to one of the longest running studies in plant genetics," says Jun Zhang, research scientist at Corteva Agriscience and co-author of the study. "The insights we derive from this relationship can result in more bushels without an increase in input costs, potentially increasing both profitability and productivity for farmers."

Stephen's team then sequenced the NAC7 gene in the high- and low-protein corn lines and were able to figure out just how the gene facilitates senescence and why it stopped working in the low-protein corn.

"We could see exactly what the mutation was. It seems to have happened sometime in the last 100 years of this experiment, and fortunately has been preserved so that we can benefit from it now," Stephen says.

He can't say for sure when the mutation occurred, because in the 1920s crop sciences faculty threw out the original seed from 1896.

"They had no way of knowing then that we could one day identify genes controlling these unique traits. But we have looked in other corn and we don't find this mutation," Stephen says.

Future potential for this innovation could include commercialized seed with no or reduced expression of NAC7, giving farmers the option for more yield without additional fertilizer inputs.

Stephen emphasizes the advancement couldn't have happened without both partners coming to the table.

"There's value to the seed industry and society in doing these long-term experiments. People ask me why university scientists bother doing corn research when companies are doing it," he says. "Well, yeah they are, and they can do things on a larger and faster scale, but they don't often invest in studies where the payoffs may take decades."

Journal Reference:

Jun Zhang, Kevin A. Fengler, John L. Van Hemert, Rajeev Gupta, Nick Mongar, Jindong Sun, William B. Allen, Yang Wang, Benjamin Weers, Hua Mo, Renee Lafitte, Zhenglin Hou, Angela Bryant, Farag Ibraheem, Jennifer Arp, Kankshita Swaminathan, Stephen P. Moose, Bailin Li, Bo Shen. Identification and characterization of a novel stay- green QTL that increases yield in maize. Plant Biotechnology Journal, 2019; DOI: 10.1111/pbi.13139

IMPROVED MODEL COULD HELP SCIENTISTS BETTER PREDICT CROP YIELD, CLIMATE CHANGE EFFECTS

A new computer model incorporates how microscopic pores on leaves may open in response to light - an advance that could help scientists create virtual plants to predict how higher temperatures and rising levels of carbon dioxide will affect food crops, according to a study published in a special July 2019 issue of the journal Photosynthesis Research.

"This is an exciting new computer model that could help us make much more accurate predictions across a wide range of conditions," said Johannes Kromdijk, who led the work as part of an international research project called Realizing Increased Photosynthetic Efficiency (RIPE).

RIPE, which is led by the University of Illinois, is engineering crops to be more productive without using more water by improving photosynthesis, the natural process all plants utilize to convert sunlight into energy to fuel growth and crop yields. 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).

The current work focused on simulating the behavior of what are known as stomata - microscopic pores in leaves that, in response to light, open to allow water, carbon dioxide, and oxygen to enter and exit the plant. In 2018, the RIPE team published a paper in Nature Communications that showed increasing one specific protein could prompt plants to close their stomata partially - to a point where photosynthesis was unaffected, but water loss decreased significantly. This study's experimental data was used to create the newly improved stomata model introduced today.

"We've known for decades that photosynthesis and stomatal opening are closely coordinated, but just how this works has remained uncertain," said Stephen Long, Ikenberry Endowed University Chair of Crop Sciences and Plant Biology at the University of Illinois. "With this new computer model, we have a much better tool for calculating stomatal movements in response to light."

The ultimate goal, Stephen said, is to identify opportunities to control these stomatal gatekeepers to make drought-tolerant crops.

"Now we're closing in on the missing link: How photosynthesis tells stomates when to open."

Computer modeling has been a major advance in crop breeding. The father of modern genetics, Gregor Mendel, made his breakthrough discovery that pea plants inherit traits from their parents by growing and breeding more than 10,000 pea plants over eight years. Today, plant scientists can virtually grow thousands of crops in a matter of seconds using these complex computer models that simulate plant growth.

Stomatal models are used together with models for photosynthesis to make wide-ranging predictions from future crop yields to crop management, such as how crops respond when there is a water deficit. In addition, these models can give scientists a preview of how crops like wheat, maize, or rice could be affected by rising carbon dioxide levels and higher temperatures.

"The previous version of the stomatal model used a relationship that wasn't consistent with our current understanding of stomatal movements," said Kromdijk, now a University Lecturer at the University of Cambridge. "We found that our new version needs far less tuning to make highly accurate predictions."

Still, there's a lot of work to be done to show that this modified model functions in a wide variety of applications and to underpin the relationship between stomata and photosynthesis further.

"We have to show that this model works for a diverse range of species and locations," said former RIPE member Katarzyna Glowacka, now an assistant professor at the University of Nebraska-Lincoln. "Large-scale simulation models string together models for atmospheric turbulence, light interception, soil water availability, and others - so we have to convince several research communities that this is an improvement that is worth making."

Journal Reference:

Johannes Kromdijk, Katarzyna Głowacka, Stephen P. Long. Predicting light-induced stomatal movements based on the redox state of plastoquinone: theory and validation. Photosynthesis Research, 2019; 141 (1): 83 DOI: 10.1007/s11120-019-00632-x

PLANT PROBE COULD HELP ESTIMATE BEE EXPOSURE TO NEONICOTINOID INSECTICIDES

Bee populations are declining, and neonicotinoid pesticides continue to be investigated - and in some cases banned - because of their suspected role as a contributing factor. However, limitations in sampling and analytical techniques have prevented a full understanding of the connection. Now, researchers describe in the ACS journal Environmental Science & Technology a new approach to sample neonicotinoids and other pesticides in plants, which could explain how bees are exposed to the substances.

Neonicotinoids are water-soluble insecticides that are applied to seeds or foliage. But non-target organisms such as pollinating bees can also be exposed to the substances, mainly through residues in nectar and pollen of flowering plants, which bees use to make honey. Most studies to-date have relied on correlating the presence of neonicotinoid residues in plant samples with bee declines. A few studies have measured total neonicotinoids in plants but laborious methods were used. Jay Gan and colleagues wanted to develop a simpler, more direct way to monitor neonicotinoids in living plants that would capture spatial and temporal movement of the insecticides.

The researchers developed a new type of solid-phase microextraction (SPME) probe, a device that can track concentration changes over time in biological systems. SPME probes use a fiber coated with a liquid or solid to quickly extract analytes from a sample. The team developed an SPME probe that they inserted into plants through a needle, allowing repeated sampling of seven neonicotinoids in plant sap. The method was demonstrated in lettuce and soybean plants, with each sampling taking only 20 minutes. The analytes were then recovered from the probe and analysed. This procedure allowed the researchers to quantify neonicotinoids in plants and study their movement and distribution throughout the plants over time. This method could be used to monitor movement of pesticides into flowers, nectar and pollen to pinpoint where and when maximal pesticide exposure occurs for bees and other pollinators, the researchers note.

Journal Reference:

Junlang Qiu, Gangfeng Ouyang, Janusz Pawliszyn, Daniel Schlenk, Jay Gan. A Novel Water-Swelling Sampling Probe for in Vivo Detection of Neonicotinoids in Plants. Environmental Science & Technology, 2019; DOI: 10.1021/acs.est.9b01682

RISING CO2 LEVELS COULD BOOST WHEAT YIELD BUT SLIGHTLY REDUCE NUTRITIONAL QUALITY

Levels of atmospheric carbon dioxide (CO2) are rising, which experts predict could produce more droughts and hotter temperatures. Although these weather changes would negatively impact many plants' growth, the increased CO2 availability might actually be advantageous because plants use the greenhouse gas to make food by photosynthesis. Now, researchers reporting in ACS' Journal of Agricultural and Food Chemistry say that a much higher CO2 level could increase wheat yield but slightly reduce its nutritional quality.

Wheat is one of the world's most important crops; its flour is used as a major ingredient in a large variety of foods such as bread, pasta and pastries. Previously, scientists have shown that elevated CO2 can increase wheat yields at the expense of grain quality traits such as nitrogen and protein content. However, scientists don't yet know the full range of grain quality changes that can occur at different stages of wheat development or the biochemical mechanisms behind them. Iker Aranjuelo and colleagues wanted to examine the effects of elevated CO2 on wheat yield, quality and metabolism during grain formation and at maturity.

The researchers grew wheat in greenhouses at normal (400 parts per million; ppm) or elevated (700 ppm) CO2 concentrations. The team found that wheat grown under elevated CO2 levels showed a 104% higher yield of mature grain. However, the nitrogen content of the grain was 0.5% lower under these conditions, and there were also small declines in protein content and free amino acids. The researchers used gas chromatography-mass spectrometry to analyze metabolic changes in the grains at different developmental stages. Among other changes, elevated CO2 altered the levels of certain nitrogen-containing amino acids during grain formation and at maturity. Although the metabolic changes they detected had modest impacts on final grain quality, the effects could be amplified by other changes in a plant's environment, such as limited nitrogen availability or drought conditions, the researchers say.

Journal Reference:

David Soba, Sinda Ben Mariem, Teresa Fuertes-Mendizábal, Ana María Méndez-Espinoza, Françoise Gilard, Carmen González-Murua, Juan J. Irigoyen, Guillaume Tcherkez, Iker Aranjuelo. Metabolic Effects of Elevated CO2 on Wheat Grain Development and Composition. Journal of Agricultural and Food Chemistry, 2019; DOI: 10.1021/acs.jafc.9b01594

THE SORGHUM HYBRID THAT HAS A CRACK IN TOUGH CONDITIONS.

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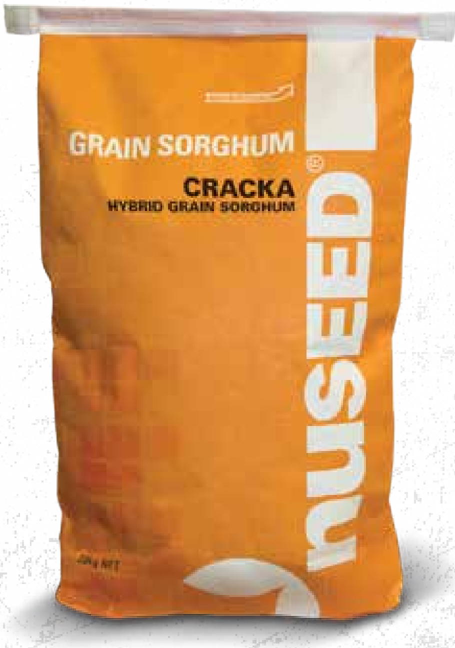

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HEAT, SALT, DROUGHT: THIS BARLEY CAN WITHSTAND POOR ENVIRONMENTAL CONDITIONS

Research for the benefit of food security: A new line of barley achieves good crop yields even under poor environmental conditions. It has been bred by a research team from Martin Luther University Halle-Wittenberg (MLU), which crossed a common variety with various types of wild barley. The researchers then planted the new lines of barley in five very different locations around the world, observed the growth of the plants and analysed their genetic make-up. As the team reports in "Scientific Reports," some of the plants were not only more resistant to heat and drought, but in many cases achieve higher yields than local varieties.

Barley, along with wheat and rice, is one of the most important cereals for human nutrition. "The demand for food is increasing worldwide, which is why the cultivation of these cereals must generate reliable crop yields. However, climate change is taking its toll on cultivation conditions worldwide and plants have to be fertilized and irrigated more frequently," says plant scientist Professor Klaus Pillen from MLU. His research team is studying how to improve common cereal varieties for years. Their approach is to cross certain industrially used barley varieties with wild barley. "Wild barley has adapted to adverse environmental conditions over millions of years. It still has a rich biodiversity today," explains Klaus. The idea is to combine the advantageous properties of both cereals.

For the study, the research team crossed a typical barley variety with 25 types of wild barley. This resulted in 48 genetically different plant lines, which the research team planted at five very different locations around the world: Dundee (UK), Halle (Germany), Al Karak (Jordan), Dubai (United Arab Emirates) and Adelaide (Australia). Each of these places has its own environmental conditions: Australia and Dubai suffer from very salty, dry soils, Al Karak and Dubai from heat and drought. In Germany and UK, fields always receive additional nitrogen fertilizer in order to increase crop yields. During the cultivation period, the scientists observed the growth of the plants under environmental stress and compared the results to native varieties from a control group. "We then selected plants from our cultivation that grew particularly well on site and examined their genetic material more closely," continues Klaus. The researchers wanted to draw conclusions about the interaction between genes, the environment and crop yields.

"Our study also shows that the timing of plant development is extremely important. This ensures maximum crop yields even under unfavourable environmental conditions," says Klaus.

By this he means, for example, the length of daylight, which varies according to latitude: the closer a place is to the equator, the shorter the duration of daily sunshine during spring and summer. This has a big impact on the development of the plants. "In northern Europe, it is more advantageous for plants to flower later. The closer you get to the equator, it's better for plants to develop much faster," explains Klaus. Based on genetic analysis of the plants, the team was also able to draw conclusions about the gene variants that cause this acceleration or delay in development.

Knowing which gene variants are advantageous for which geographical regions allows plants that are particularly well adapted to the local conditions to be crossed, bred and cultivated according to the modular principle. And this is all well worth the effort: even under adverse conditions, Halle's best barley produced up to 20 percent higher yields than native plants.

In follow-up projects, the research team would like to further investigate the genetic material in order to gain more detailed insights into the stress tolerance of plants. The findings from the new study can, in principle, also be applied to other cereal varieties, such as wheat and rice.

COMPREHENSIVE REVIEW OF THE FUTURE OF CRISPR TECHNOLOGY IN CROPS

CRISPR is often thought of as "molecular scissors" used for precision breeding to cut DNA so that a certain trait can be removed, replaced, or edited, but Yiping Qi, assistant professor in Plant Science & Landscape Architecture at the University of Maryland, is looking far beyond these traditional applications in his latest publication in Nature Plants. In this comprehensive review, Yiping and co-authors in his lab explore the current state of CRISPR in crops, and how scientists can use CRISPR to enhance traditional breeding techniques in nontraditional ways, with the goal of ensuring global food and nutritional security and feeding a growing population in the face of climate change, diseases, and pests.

With this new paper, Yiping highlights recent achievements in applying CRISPR to crop breeding and ways in which these tools have been combined with other breeding methods to achieve goals that may not have been possible in the past. He aims to give a glimpse of what CRISPR holds for the future, beyond the scope of basic gene editing.

"When people think of CRISPR, they think of genome editing, but in fact CRISPR is really a versatile system that allows you to home in on a lot of things to target, recruit, or promote certain aspects already in the DNA," says Yiping. "You can regulate activation or suppression of certain genes by using CRISPR not as a cutting tool, but instead as a binding tool to attract activators or repressors to induce traits."

Additionally, Yiping discusses the prospect of recruiting proteins that can help to visualize DNA sequences, and the potential for grouping desirable traits together in the genome. "I call this gene shuffling," says Yiping. "This is designed to move very important trait genes close to each other to physically and genetically link them so they always stick together in traditional crossbreeding, making it much easier to select for crops with all the traits you want."

These are just some of the examples of future directions Yiping hopes to cultivate and draw more attention to with this paper. "I hope this review [in Nature Plants] will open eyes to show that there is a lot to be offered by CRISPR, going beyond the current status of genome editing, but also outside of just editing to see where the whole field can lead down the road."

This includes the process of taking CRISPR applications in animals and humans and applying them to crops in ways that haven't been done before. For example, CRISPR technology has already enhanced screenings for genes and traits in human health by using a library of tens of thousands of guide molecules that are tailored for targeting selected gene sets at the genome scale. This system could be potentially used in plants to screen for

traits that contribute to disease and pest resistance, resiliency, and crop yield. "This not only helps with breeding, but also helps categorize gene functioning much more easily," says Yiping. "Mostly, these studies have been done in human cells, and crops are lagging behind. I see that as one future aspect of where plant science can harness some of these different applications, and my lab has already been doing some of this work."

Yiping's lab has published multiple original research papers this year that highlight some of the differences for CRISPR applications in human and plant cells. Earlier this year in Molecular Plant, Yiping, his graduate student, interns, and collaborators published findings testing the targeting scope and specificity of multiple CRISPR Cas9 variants. Yiping's team sought to prove or disprove claims made in humans about the fidelity and specificity of these tools in rice. "Not all claims that are made for CRISPR functionality in humans and animals are going to be true or applicable in plants, so we are looking at what works and what we can do to optimize these tools for crops."

Another recent paper in BMC Biology as part of a collaborative research effort investigated temperature as a method of improving efficiency of CRISPR Cas12a genome editing in rice, maize, and Arabidopsis, which was found to need higher than ambient temperatures to boost editing efficiency. "Human cells are always maintained at higher temperature which may be optimal for CRISPR to work, but is pretty hot for plants," says Yiping. "We have to explore how that temperature plays a role for CRISPR applications in other species."

Yiping also published the first ever book dedicated entirely to Plant Genome Editing with CRISPR Systems, highlighting cutting-edge methods and protocols for working with CRISPR in a variety of crops.

"This book is really gathering together specific applications for many different plant systems, such as rice, maize, soybeans, tomatoes, potatoes, lettuce, carrots - you name it - so that people working in their own plant of interest may find some chapters quite relevant. It is designed as a protocol book for use in the lab, so that anybody new to the field should be able to figure out how to work with CRISPR in their particular plant." Yiping was contacted by the publisher in the United Kingdom, Humana Press, to produce and edit the book. It was released earlier this year as part of the Methods in Molecular Biology book series, a prominent and respected series in the field.

"How to feed the world down the road - that's what motivates me every day to come to work," says Yiping. "We will have 10 billion people by 2050, and how can we sustain crop improvement to feed more people sustainably with climate change and less land? I really think that technology should play a big role in that."

Journal Reference:

Yiping Qi et al. The emerging and uncultivated potential of CRISPR technology in plant science. Nature Plants, 2019
DOI: 10.1038/s41477-019-0461-5

GETTING READY TO PROTECT YOUR VALUABLE 2019 GRAIN CROP

With grain-storage pests least mobile during the colder months, it's the ideal time of year to be cleaning out and treating grain -handling equipment and storage to reduce insect numbers ahead of spring harvest.

It's also a good time to ensure already-stored grain remains protected and free of insect pests.

Rabobank forecasters predict Australian grain prices will remain in the higher range due to forecast lower production and already-depleted local stocks.

So growers who are still holding stored grain - or who had the opportunity to plant winter cereals - will be looking to protect and retain the value of their precious crop during harvest and in storage, according to Barmac business manager Chris Ramsey.

"As the exclusive Australian supplier of the Methograin grain protectant range, Barmac has the solution for treatment of both storage and handling equipment with Methograin Fenitrothion 1000, and stored cereal grain with the Methograin IGR Grain Protection Pack."

He said the dry start to the 2019 winter cropping season was the third consecutive sub-optimal planting window for important cropping regions in Australia's eastern states, with lowest-on-record soil moisture, depleted catchments and no widespread autumn break in most cropping areas.

"However a high rate of dry sowing across the country and opportunistic use of storm rainfall saw a small increase in area planted. Welcome May rains in some eastern districts brought critical soil moisture, and some generous late rainfall in June in southern areas offered renewed hope to crop-growers in WA, SA, Victoria and southern NSW."

Preparing storage, harvesting and handling equipment ahead of harvest

Chris said that on properties expecting to harvest, now is the time to ensure storages and equipment used to harvest and handle grain are clean and free of insect pests.

"This includes headers, augers, field bins, truck bins; silos, sheds, hardstands, hoppers and silo-support structures - plus feed mills, feed troughs, and used sacks."

Good handling and storage hygiene will play a major role in the efficacy of protectants applied to any fresh grain harvested this year.

"Protectant treatments applied to this year's cereal grain as it goes into storage will only protect this year's treated grain. Any remaining stored grain from last season, which may have run out of protectant, could now be a potential source of infestation for newly-harvested grain."

He said just one bag's worth of infected grain could produce a million insects a year, which then fly or walk to other stored grain and start new infestations.

"A trial in Queensland also revealed the presence of more than 1000 lesser grain borers in the first 40 litres of grain through a harvester at the start of harvest, even though the machine was considered reasonably clean at the end of the previous season."

He advised that once storage facilities and all equipment had been thoroughly cleaned out, Barmac's contact insecticide Methograin Fenitrothion 1000 could be applied as a structural treatment to kill pests in any remaining residues. (In WA, Methograin grain protectants can only be used by bulk handlers).

"Applied at 10mL/L water, 1L of dilute spray treats approximately 20 m2 of walls and floor surfaces. Other structural areas should be treated as well as machinery, transport vehicles and areas around storage facilities that may have grain residues present."

Protecting precious stocks of already-stored grain and the coming harvest

Chris said good hygiene in already-stored grain should continue with regular inspection - at least monthly in winter and fortnightly in warmer months - taking samples to detect any live insects and treating infested grain with a protectant.

"Barmac provides a simple protective solution to ensure exact dosage of an insect growth regulator (S-methoprene) and a contact insecticide - a well-known combination trusted by Australian grain growers.

"Our Methograin IGR Grain Protection Pack is a combi-pack of both contact insecticide and insect growth regulator sufficient to treat 50 tonnes of grain. It contains a 300-ml can of Methograin Fenitrothion 1000 insecticide and a 1-litre can of Methograin IGR Grain Protectant.

"Tipping the contents of these two cans into a 50-litre drum of good, clean water (rainwater is best) is sufficient to treat 50 tonnes of grain with exactly the prescribed amount of protectant as the 2019 harvest goes into storage, or on existing stores of grain.

"Methograin IGR Grain Protection Pack, used as directed (only by bulk handlers in WA), will protect uninfested grain against infestation by 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."

He said even though the pack - when used at the 6ppm Fenitrothion rate - has a withholding period (WHP) of only 24 hours (13 weeks for 12ppm Fenitrothion rate), growers should always check with potential buyers before using any treatment.

SOIL PORE STRUCTURE IS KEY TO CARBON STORAGE

Alexandra Kravchenko, Michigan State University professor in the Department of Plant, Soil and Microbial Sciences, and several of her colleagues recently discovered a new mechanism determining how carbon is stored in soils that could improve the climate resilience of cropping systems and also reduce their carbon footprints.

The findings, published in July in the scientific journal Nature Communications, reveal the importance of soil pore structure for stimulating soil carbon accumulation and protection.

"Understanding how carbon is stored in soils is important for thinking about solutions for climate change," said Phil Robertson, University Distinguished Professor of Plant, Soil and Microbial Sciences, and a co-author of the study. "It's also pretty important for ways to think about soil fertility and therefore, crop production."

The study was conducted through the MSU Great Lakes Bioenergy Research Center, funded by the U.S. Department of Energy, and the Kellogg Biological Station Long-term Ecological Research program funded by the National Science Foundation, or NSF, and it was supported by NSF's Division of Earth Sciences.

Over a period of nine years, researchers studied five different cropping systems in a replicated field experiment in southwest Michigan. Of the five cropping systems, only the two with high plant diversity resulted in higher levels of soil carbon. Alexandra and her colleagues used X-ray micro-tomography and micro-scale enzyme mapping to show how pore structures affect microbial activity and carbon protection in these systems, and how plant diversity then impacts the development of soil pores conducive to greater carbon storage.

John Schade, from the NSF Division of Environmental Biology, said the results may transform the understanding of how carbon and climate can interact in plant and soil microbial communities.

"This is a clear demonstration of a unique mechanism by which biological communities can alter the environment, with fundamental consequences for carbon cycling," John said.

"One thing that scientists always tend to assume is that the places where the new carbon enters the soil are also the places where it is processed by microbes and is subsequently stored and protected," Alexandra said. "What we have found is that in order to be protected, the carbon has to move; it cannot be protected in the same place where it enters."

Scientists have traditionally believed soil aggregates, clusters of soil particles, were the principal locations for stable carbon storage.

Recent evidence, however, shows that most stable carbon appears to be the result of microbes producing organic compounds that are then adsorbed onto soil mineral particles. The research further reveals that soil pores created by root systems provide an ideal habitat where this can occur.

Of particular importance are soils from ecosystems with higher plant diversity. Soils from restored prairie ecosystems, with many different plant species, had many more pores of the right size for stable carbon storage than did a pure stand of switchgrass.

"What we found in native prairie, probably because of all the interactions between the roots of diverse species, is that the entire soil matrix is covered with a network of pores," Alexandra said. "Thus, the distance between the locations where the carbon input occurs, and the mineral surfaces on which it can be protected is very short.

"So, a lot of carbon is being gained by the soil. In monoculture switchgrass the pore network was much weaker, so the microbial metabolites had a much longer way to travel to the protective mineral surfaces," explained Alexandra.

Phil said the research may prompt farmers to focus on plant diversity when attempting to increase soil carbon storage.

"We used to think the main way to put more carbon in soil is to have plants produce more biomass either as roots or as residue left on the soil surface to decompose," Phil said.

"What this research points out is that there are smarter ways of storing carbon than such brute force approaches. If we can design or breed crops with rooting characteristics that favor this kind of soil porosity and therefore that favor soil carbon stabilization, that would be a pretty smart way to design systems that can build carbon faster."

Nick Haddad, director of the Kellogg Biological Station Long-term Ecological Research program, said research that builds from these findings will continue to discover ways to improve the sustainability of agricultural ecosystems and landscapes.

"Long-term research shows surprising ways that a diversity of plants can benefit the microbes needed for a resilient agricultural system," Nick added.

Journal Reference:

A. N. Kravchenko, A. K. Guber, B. S. Razavi, J. Koestel, M. Y. Quigley, G. P. Robertson, Y. Kuzyakov. Microbial spatial footprint as a driver of soil carbon stabilization. Nature Communications, 2019; 10 (1) DOI: 10.1038/s41467-019-11057-4

SMART IRRIGATION MODEL PREDICTS RAINFALL TO CONSERVE WATER

Fresh water isn't unlimited. Rainfall isn't predictable. And plants aren't always thirsty.

Just 3 percent of the world's water is drinkable, and more than 70 percent of that fresh water is used for agriculture. Unnecessary irrigation wastes huge amounts of water - some crops are watered twice as much as they need - and contributes to the pollution of aquifers, lakes and oceans.

A predictive model combining information about plant physiology, real-time soil conditions and weather forecasts can help make more informed decisions about when and how much to irrigate. This could save 40 percent of the water consumed by more traditional methods, according to new Cornell University research.

> **"If you have a framework to connect all these excellent sources of big data and machine learning, we can make agriculture smart," said Fengqi You, energy systems engineering professor.**

You is the senior author of "Robust Model Predictive Control of Irrigation Systems With Active Uncertainty Learning and Data Analytics," which published in IEEE Transactions on Control Systems Technology. The paper was co-authored with Abraham Stroock, professor of chemical and biomolecular engineering, who is working on water conservation strategies with apple farmers in New York state and almond, apple and grape growers in drought-ridden regions of the West Coast.

"These crops, when grown in the semi-arid, semi-desert environment of California's Central Valley, are huge consumers of water - one gallon of water per almond," Abraham said. "So there's a real opportunity to improve the way we manage water in these contexts."

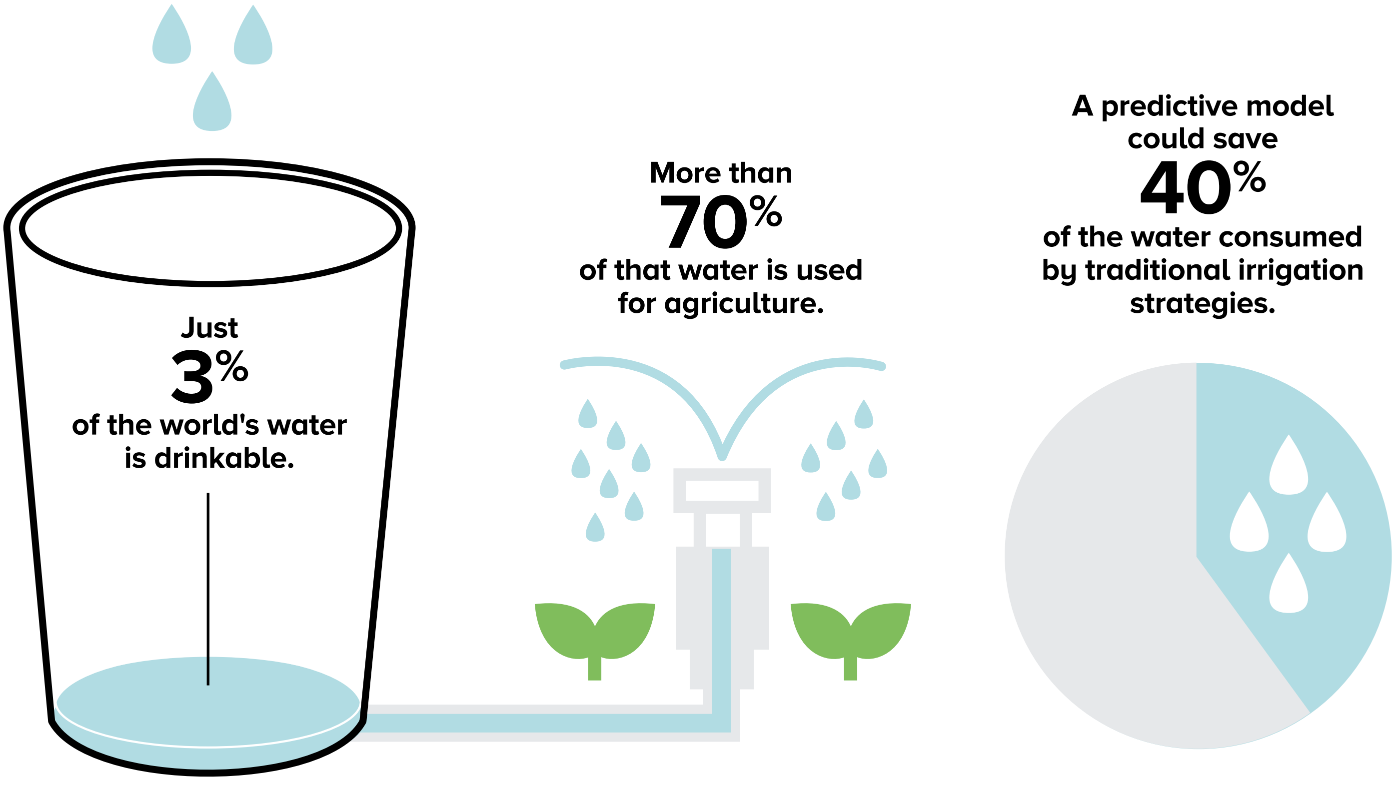
Controlling plant moisture precisely could also improve the quality of sensitive specialty crops such as wine grapes, he said.

The researchers' method uses historical weather data and machine learning to assess the uncertainty of the real-time weather forecast, as well as the uncertainty of how much water will be lost to the atmosphere from leaves and soil. This is combined with a physical model describing variations in the soil moisture.

Integrating these approaches, they found, makes watering decisions much more precise.

Part of the challenge of the research is identifying the best method for each crop, and determining the costs and benefits of switching to an automated system from a human-operated one. Because apple trees are relatively small and respond quickly to changes in precipitation, they may not require weeks or months of weather data. Almond trees, which tend to be larger and slower to adapt, benefit from longer-term predictions.

"We need to assess the right level of complexity for a control strategy, and the fanciest might not make the most sense," Abraham said. "The experts with their hands on the valves are pretty good. We have to make sure that if we're going to propose that somebody invest in new technology, we've got to be better than those experts."



A predictive model combining information about plant physiology, real-time soil conditions and weather forecasts can save 40% of the water consumed by traditional irrigation strategies, according to new Cornell research. Image Credit: Cornell University

SCIENTISTS MAKE FUNDAMENTAL DISCOVERY TO CREATING BETTER CROPS

A team of scientists led by the Department of Energy's Oak Ridge National Laboratory have discovered the specific gene that controls an important symbiotic relationship between plants and soil fungi, and successfully facilitated the symbiosis in a plant that typically resists it.

The discovery could lead to the development of bioenergy and food crops that can withstand harsh growing conditions, resist pathogens and pests, require less chemical fertilizer and produce larger and more plentiful plants per acre.

Scientists in recent years have developed a deeper understanding of the complex relationship plants have with mycorrhizal fungi. When they are united, the fungi form a sheath around plant roots with remarkable benefits. The fungal structure extends far from the plant host, increasing nutrient uptake and even communicating with other plants to "warn" of spreading pathogens and pests. In return, plants feed carbon to the fungus, which encourages its growth.

These mycorrhizal symbioses are believed to have supported the ancient colonization of land by plants, enabling successful ecosystems such as vast forests and prairies. An estimated 80% of plant species have mycorrhizal fungi associated with their roots.

"If we can understand the molecular mechanism that controls the relationship between plants and beneficial fungi, then we can start using this symbiosis to acquire specific conditions in plants such as resistance to drought, pathogens, improving nitrogen and nutrition uptake and more," said ORNL molecular geneticist Jessy Labbe. "The resulting plants would grow larger and need less water and fertilizer, for instance."

Finding the genetic triggers in a plant that allow the symbiosis to occur has been one of the most challenging topics in the plant field. The discovery, described in Nature Plants, came after 10 years of research at ORNL and partner institutions exploring ways to produce better bioenergy feedstock crops such as Populus, or the poplar tree. The work was accomplished by improvements over the past decade in genomic sequencing, quantitative genetics and high-performance computing, combined with experimental biology.

The scientists were studying the symbiosis formed by certain species of Populus and the fungus Laccaria bicolour (L. bicolour). The team used supercomputing resources at the Oak Ridge Leadership Computing Facility, a DOE Office of Science user facility at ORNL, along with genome sequences produced at the DOE Joint Genome Institute, a DOE Office of Science user facility at Lawrence Berkeley National Laboratory, to narrow down the search to a particular receptor protein, PtLecRLK1. Once they had identified the likely candidate gene, the researchers took to the lab to validate their findings.

"Experimental validation is the key to this discovery as genetic mapping revealed statistical associations between the symbiosis and this gene, but experimental validations provided a definitive answer that it is this particular gene that controls the symbiosis," said ORNL plant molecular biologist Jay Chen.

The researchers chose Arabidopsis, a plant that traditionally does not interact with the fungus L. bicolour, and even considers it a threat, for their experiments. They created an engineered version of the plant that expresses the PtLecRLK1 protein, and then inoculated the plants with the fungus. The fungus L. bicolour completely enveloped the plant's root tips, forming a fungal sheath indicative of symbiote formation.

"We showed that we can convert a non-host into a host of this symbiont," said ORNL quantitative geneticist Wellington Muchero. "If we can make Arabidopsis interact with this fungus, then we believe we can make other biofuel crops like switchgrass, or food crops like corn also interact and confer the exact same benefits. It opens up all sorts of opportunities in diverse plant systems. Surprisingly, one gene is all you need."

Scientists from the University of Wisconsin-Madison, the Universite de Lorraine in France, and the HudsonAlpha Institute for Biotechnology in Alabama also contributed to the project. The work was supported by DOE's Office of Science, DOE's Center for Bioenergy Innovation (CBI) and its predecessor the BioEnergy Science Center (BESC). One of CBI's key goals is to create sustainable biomass feedstock crops using plant genomics and engineering. Both BESC and CBI have developed experimental and computational approaches that accelerate the identification of gene function in plants.

"This is a remarkable achievement that could lead to the development of bioenergy crops with the ability to survive and thrive on marginal, non-agricultural lands," said CBI director Jerry Tuskan. "We could target as much as 20-40 million acres of marginal land with hardy bioenergy crops that need less water, boosting the prospects for successful rural, biobased economies supplying sustainable alternatives for gasoline and industrial feedstocks."

Laccaria bicolour is fruiting above ground and colonizing the Populus deltoides plant root system below ground in a greenhouse setting. Photo Credit: Jessy Labbe/Oak Ridge National Laboratory, U.S. Dept. of Energy

TESTING AVAILABLE FOR INSECTICIDE RESISTANCE IN REDLEGGED EARTH MITE

Western Australian grain growers who notice high numbers of redlegged earth mites (RLEM) in sprayed canola and cereal crops are now able to test for chemical resistance.

RLEM (Halotydeus destructor) is an important pest of germinating crops and pastures across Western Australia, with canola, lupins, and legume seedlings the most susceptible to attack by the mites.

The Department of Primary Industries and Regional Development is again making available a screening service to growers and advisers to test for insecticide resistance in RLEM, following previous screening in 2017.

The free-of-charge service, made possible with investment by the Grains Research and Development Corporation (GRDC), is led by The University of Melbourne, in collaboration with cesar, the department, and CSIRO.

Department research officer Svetlana Micic said RLEM resistance to synthetic pyrethroids, including bifenthrin and alpha-cypermethrin, was becoming widespread across the Western Australian grainbelt.

“Localised resistance to organophosphate omethoate has also been discovered on multiple properties,” Svetlana said. “While insecticide options are limited, it is vital to minimise chemical use and rotate chemical groups to reduce the spread of insecticide resistance."

"Growers are advised to use different chemical groups across successive spray windows (on multiple generations of RLEM), to help reduce resistance to a particular chemical group.”

Department research officer Dusty Severtson said high numbers of redlegged earth mites were being found in canola and cereal crops in northern and central grain growing areas.

“Growers and consultants are encouraged to be aware of the large number of RLEM being found in crops that have already been sprayed,” Dusty said. “Clover pastures are also at risk.”

Dusty encouraged growers and consultants to monitor RLEM to prevent significant damage in a short period, the death of plants and stunting of surviving plant growth.

Growers who notice a chemical control failure should not re-spray the paddock during the same season using the same product, unless insecticide resistance has been ruled out.

The calibration of spray rigs and other causes should then be investigated and resolved.

Growers who find RLEM that survive registered rates of insecticide treatments are encouraged to arrange for resistance testing to be conducted by contacting Svetlana on **svetlana.micic@dpird.wa.gov.au,** or **+61 (0)8 9892 8591.**

The RLEM Resistance Management Strategy can be found on the GRDC website at **grdc.com.au**

Redlegged earth mite (RLEM) has been a major pest of pastures, crops and vegetables in winter rainfall areas of southern Australia since its introduction from South Africa in 1917. It causes an estimated $200 million annual loss in production. Photo credit: CSIRO

Western Australian grain growers who suspect insecticide resistance in redlegged earth mite (RLEM) are encouraged to screen for resistance via a free service. Photo credit: CSIRO

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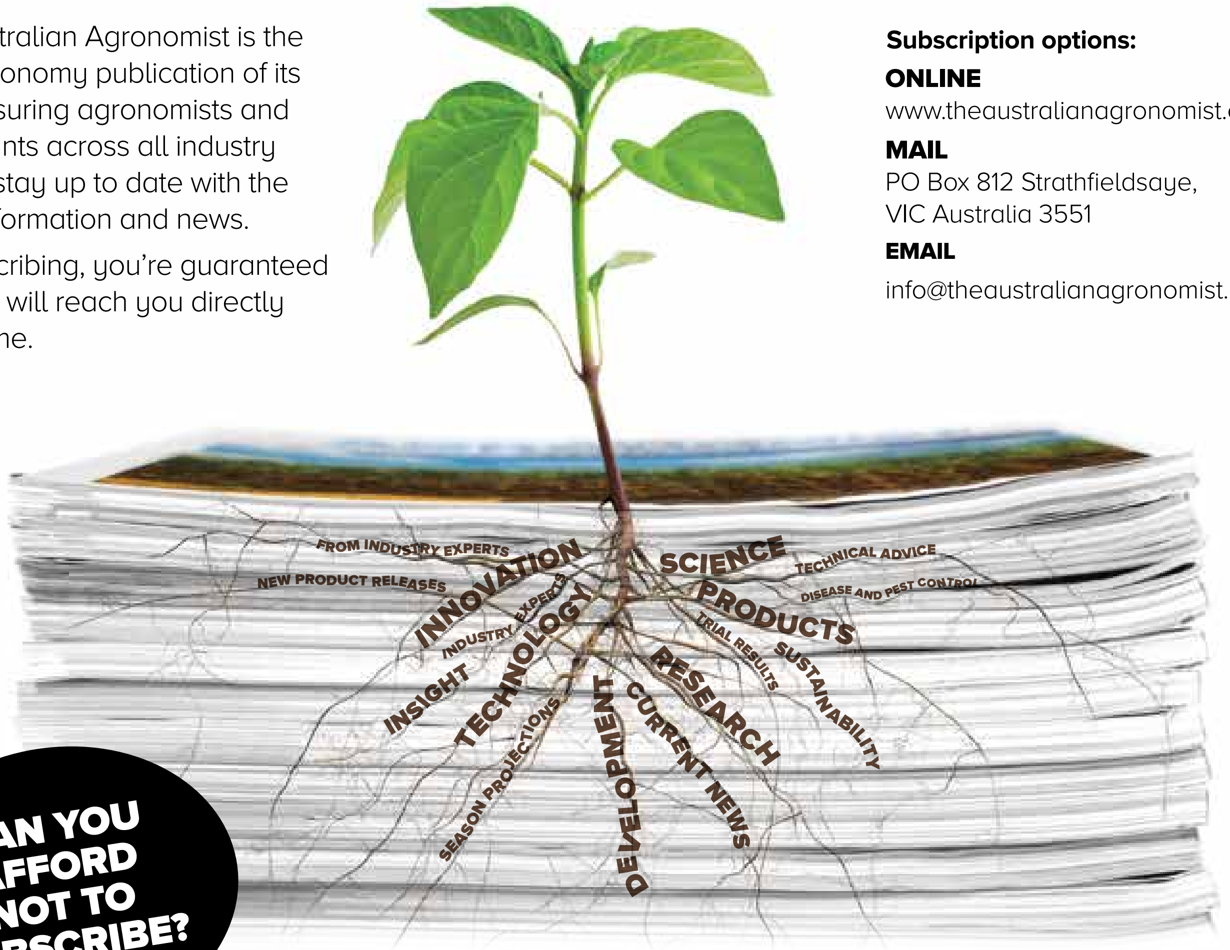

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WORM PHEROMONES PROTECT MAJOR CROPS

Protecting crops from pests and pathogens without using toxic pesticides has been a longtime goal of farmers. Researchers at Boyce Thompson Institute have found that compounds from an unlikely source - microscopic soil roundworms - could achieve this aim.

As described in research published in the May 2019 issue of Journal of Phytopathology, these compounds helped protect major crops from various pathogens, and thus have potential to save billions of dollars and increase agricultural sustainability around the world.

Led by BTI Senior Research Associate Murli Manohar, a team around Professors Daniel Klessig and Frank Schroeder investigated the effects of a roundworm metabolite called ascr#18 on plant health.

Ascr#18 is a member of the ascaroside family of pheromones, which are produced by many soil-dwelling species of roundworms for chemical communication.

The researchers treated soybean (Glycine max), rice (Oryza sativa), wheat (Triticum aestivum) and maize (Zea mays) plants with small amounts of ascr#18, and then infected the plants with a virus, bacteria, fungus or oocmycete.

When examined several days later, the ascr#18-treated plants were significantly more resistant to the pathogens compared with untreated plants.

“Plant roots are constantly exposed to roundworms in the soil, so it makes sense that plants have evolved to sense the pest and prime their immune systems in anticipation of being attacked,” says Schroeder.

Because they boost plants’ immune systems instead of killing pests and pathogens, ascarosides are not pesticides. As a result, they are likely to be much safer than many current means of pest and pathogen control.

“Ascarosides are natural compounds that appear to be safe to plants, animals, humans and the environment,” says Daniel. “I believe they could thus provide plants more environmentally friendly protection against pests and pathogens.”

In previous work, Daniel and Frank demonstrated that ascr#18 and other ascarosides increased resistance against pest and pathogens in tomato, potato, barley and Arabidopsis.

“By expanding the work to major crops, and concentrating on their most significant pathogens, this study establishes the potential for ascarosides to enhance agriculture production worldwide,” says Daniel.

Indeed, rice is the world’s most important staple food for nearly half of the global population. Ascr#18 provided protection against Xanthomonas oryzae pv. oryzae, a bacterium that causes yield losses of 10-50% in Asian countries.

Wheat is close behind rice in importance as a food staple, and ascr#18 protected it against Zymoseptoria tritici, a fungus that is one of the most severe foliar diseases of the crop.

Maize is the most widely grown grain crop throughout the Americas with great importance for food, biofuel and animal feed. Ascr#18 provided protection against Cochliobolus heterostrophus, a fungal pathogen that causes southern corn leaf blight.

Soybean is a major high-protein, oil-rich seed crop used as a food source for humans and animals. Ascr#18 protected soybeans against Phytophthora sojae, an oomycete that can kill infected plants in days, as well as the bacterial pathogen Pseudomonas syringae pv glycinea and Soybean Mosaic Virus.

Extremely small concentrations of ascarosides are sufficient to provide plants with resistance against pathogens. Interestingly, the optimal concentration appears to be dependent on the plant species and not the pathogen.

The researchers believe the reason that different plant species have different optimal dosages is likely related to the plant cell’s receptors for ascr#18. Different plant species may express different amounts of ascr#18 receptors, and receptors may have varying affinities for ascarosides. Such differences would affect the amount of ascr#18 needed to trigger the plant’s immune systems.

The group is now working to determine the molecular mechanisms of how ascarosides prime the plant’s immune systems.

These discoveries are being commercialized by a BTI and Cornell University-based startup company, Ascribe Bioscience, as a family of crop protection products named PhytalixTM.

“This work is a great example of how the Institute is leveraging our technology through new start-up ventures, an important strategic initiative at BTI,” says Paul Debbie, BTI’s Director of New Business Development. “The Institute is proud of the opportunity to develop innovative technology in partnership with a new company that is having a positive economic impact here in our local community and for New York State.”

In addition to their BTI positions, Daniel is an adjunct professor in Cornell’s Department of Plant Pathology and Plant-Microbe Biology and Frank is a professor in Cornell’s Department of Chemistry and Chemical Biology.

Collaborators included researchers at Cornell, University of Kentucky, Justus Liebig University in Germany, University of California, Davis, and Colourado State University.

NEW, PORTABLE TECH SNIFFS OUT PLANT DISEASE IN THE FIELD

NEW TECH

Researchers at North Carolina State University have developed portable technology that allows farmers to identify plant diseases in the field. The handheld device, which is plugged into a smartphone, works by sampling the airborne volatile organic compounds (VOCs) that plants release through their leaves.

"All plants release VOCs as they 'breathe,' but the type and concentration of those VOCs changes when a plant is diseased," says Qingshan Wei, an assistant professor of chemical and biomolecular engineering and corresponding author of a paper on the work. "Each disease has its own signature profile of VOCs. So, by measuring the type and concentration of VOCs being released by the plant, you can determine whether a plant is diseased and - if it is diseased - which disease it has.

"Our contribution here is the creation of a device that can be plugged into a smartphone and used to make those VOC measurements quickly in the field," says Qingshan, who is also a faculty member in NC State's Emerging Plant Disease and Global Food Security cluster.

Current disease identification techniques rely on molecular assays, which take hours to perform and - most importantly - have to be done in a lab. Getting a sample to the lab, where the sample may have to wait to be tested, can delay disease identification by days or weeks.

"Our technology will help farmers identify diseases more quickly, so they can limit the spread of the disease and related crop damage," says Jean Ristaino, William Neal Reynolds Distinguished Professor of Plant Pathology at NC State, co-author of the paper and director of the cluster. "We are now ready to scale up the technology."

Here's how the technology works. If a farmer suspects that a plant may be diseased, he or she can take a leaf from the relevant plant and place it in a test tube. The test tube is then capped for at least 15 minutes to allow the relevant VOCs to accumulate. After this incubation period, the cap is removed and the farmer uses a narrow, plastic tube to pump the VOC-laden air into a "reader" device connected to a smartphone.

The air is pumped into a chamber in the reader that contains a paper strip. The paper is embedded with an array of chemical reagents that change colour when they come into contact with a specific chemical group. By evaluating the resulting colour pattern on the strip, users can determine the nature of any plant disease that may be affecting the plant.

"For this technology to work, we had to develop reagents that could be embedded in the paper strips," says Zheng Li, a postdoctoral researcher at NC State and first author of the paper. "About half of the reagents were off-the-shelf organic dyes, but the other half were gold nanoparticles that we functionalised to respond to specific chemical groups. These functionalised nanoparticles allow us to be more precise in detecting various types of VOCs."

"We also had to design and build the reader device, since there is nothing like it on the market," says Qingshan.

In proof-of-concept testing, the researchers demonstrated the device's ability to detect and classify 10 plant VOCs down to the parts-per-million level. They were able to detect the late blight pathogen that caused the Irish famine two days after tomato plants were inoculated with the pathogen. Researchers could also distinguish tomato late blight from two other important fungal pathogens that produce similar symptoms on tomato leaves. In addition, the researchers showed they could detect the pathogen Phytophthora infestans in tomato leaves with greater than 95% accuracy.

"We've shown that the technology works," Qingshan says. "There are two areas where we could make it even better. First, we would like to automate the pattern analysis using software for the smartphone, which would make it easier for farmers to make disease determinations.

"Second, we envision the development of customized reader strips that are designed to measure the VOCs associated with other diseases specific to a given crop. Different crops in different regions face different threats, and we could develop paper strips that are tailored to address those specific concerns.

"This kind of innovation is an integral part of the goals of the NC State Plant Sciences Initiative, which aims to develop new technologies that will improve food production through interdisciplinary science," Qingshan says.

Journal Reference:

Zheng Li, Rajesh Paul, Taleb Ba Tis, Amanda C. Saville, Jeana C. Hansel, Tao Yu, Jean B. Ristaino, Qingshan Wei. Non-invasive plant disease diagnostics enabled by smartphone-based fingerprinting of leaf volatiles. Nature Plants, 2019; DOI: 10.1038/s41477-019-0476-y

SOIL MOISTURE MONITORING - PASTURES

Agriculture Victoria has installed several soil moisture probes on a range of soil and pasture types across Victoria.

Soil moisture probes have helped with making early decisions in the cropping industry for some time with monthly analysis produced as a newsletter by Dale Boyd.

The probes are capacitance probes that are 80 centimetres long with 8 internal sensors to provide soil water content values and temperature every 10 centimetres.

This will collect information on water infiltration after rain events and plants using water as they grow dry matter (particularly in the absence of rain).

After installation, the sensors at the monitoring points go through a field calibration process to determine important knowledge of how much water the soil can hold. Identifying the field capacity of the soil during wet periods and the wilting point in spring/summer where the pasture can not extract any more water are the critical interpretations points of the data collection. Most sites now show the soil water holding capacity percentage at any point of they year so that the season can be analysed to assist with informed strategic decisions. Seasonal outlook with this soil moisture data will provide some guidance on the length of the season and pasture production.

Different soil types at each site means they cannot be directly compared to other sites and are best assessed individually.

All sites are currently useful to show relative movement/use of moisture down the profile for soil types/plant species.

Dale Boyd's newsletters can be read online on the Agriculture Victoria website: http://agriculture.vic.gov.au/agriculture/weather-and-climate/soil-moisture-monitoring-pastures

Location of soil moisture probes on grazing sites (pastures)

Soil moisture monitoring probe setup.

SCIENTISTS PROPOSE ENVIRONMENTALLY FRIENDLY CONTROL PRACTICES FOR HARMFUL TOMATO DISEASE

Tomato yellow leaf curl disease (TYLCD) caused by tomato yellow leaf curl virus-like viruses is the most destructive disease of tomato, causing severe damage to crops worldwide and resulting in high economic losses. To combat this disease, many farmers opt for intensive application of insecticides. However, this practice is frequently ineffective and has a negative impact on the environment and human health.

Alternatively, some farmers plant TYLCD-resistant tomato varieties, but these hybrid varieties are often tasteless and a poor comparison to the robust flavor of traditional tomatoes. As a result, there is a demand for effective and environmentally friendly control measures to prevent continuing widespread damage of TYLCD, as well as other plant viruses.

To answer this demand, a team of scientists at the Spanish Council of Scientific Research (IHSM UMA-CSIC) conducted field and greenhouse trials for three consecutive years and found two environmentally friendly control alternatives to insecticides.

First, they discovered that protecting tomato crops with UV-blocking plastics led to reduced TYLCD damage. Secondly, they found that the application of a salicylic acid analogue to strengthen tomato plant defenses was also effective in reducing TYLCD-associated losses.

For the most effective results, the team recommends that farmers combine both control practices. These practices are proposed for commercial use in open field or on protected tomato crops. These findings also suggest the possibility for future discovery of environmentally friendly virus control strategies.

Journal Reference:

Francisco Monci, Susana García-Andrés, Sonia Sánchez-Campos, Rafael Fernández-Muñoz, Juan Antonio Díaz-Pendón, Enrique Moriones. Use of Systemic Acquired Resistance and Whitefly Optical Barriers to Reduce Tomato Yellow Leaf Curl Disease Damage to Tomato Crops. Plant Disease, 2019; 103 (6): 1181 DOI: 10.1094/PDIS-06-18-1069-RE

ASK A WEEDSMART EXPERT

WITH BHAGIRATH CHAUHAN, WEEDS RESEARCHER, QAA

What's the best way to manage annual ryegrass in chickpea crops?

Annual ryegrass is becoming increasingly prevalent in the northern cropping region, and many populations already have a high level of resistance to the major Group B and Group A herbicides registered for use in chickpea crops.

To keep this important crop as a viable option, growers are looking for ways to add non-chemical in-crop options to an integrated weed control program to prevent a yield-limiting blow out in ryegrass populations.

The principles of crop competition are fairly well known but making the necessary changes to planting gear can be daunting, so it is important to know that any changes will achieve the desired effect.

To assist growers to better implement crop competition in chickpeas, A/Professor Bhagirath Chauhan, principal research fellow and weed team leader, QAAFI, UQ looked at the effect of narrow rows, variety and early weed control to assess which is the most powerful suppressant of annual ryegrass.

"In a weed-free environment, it has been shown that narrow-sown chickpeas will produce higher yield, so we wanted to see if narrow sowing also suppresses weed growth and seed set," says Bhagirath. "We also wanted to understand whether a more-prostrate variety like PBA Seamer would suppress more weeds than the more-erect PBA HatTrick. The third aspect we considered was the effect of weed infestation at different growth stages of the crop."

The results were pretty conclusive: PBA Seamer sown at 25 cm and kept weed-free for at least the first three weeks after planting is a winning combination for ryegrass control.

What is the best way to reduce ryegrass growth and seed set?

Short answer: Narrowing the row spacing and ensuring good early weed control are the most effective tactics in chickpeas.

Longer answer: Plant architecture made some difference, but only in very weedy conditions. Narrowing row spacing from 75 cm to 25 cm reduced weed biomass by 16 per cent and reduced seed set by 26 per cent.

Keeping the crop weed-free for at least three weeks had the biggest effect, driving down weed biomass at the end of the season by 52 per cent and weed seed set by 48 per cent. This shows that, once established, chickpea can hold its own against weeds that emerge later in the season.

Can more competitive crops also produce higher grain yield?

Short answer: Yes. If you can't do narrower rows then put an emphasis on early weed control.

Longer answer: Averaged across both cultivars and all weed infestation periods, sowing chickpeas on 25 cm row spacing (same seeding rate) produced 20 per cent more grain than sowing on 75 cm row spacing. This is most likely due to the crop plants being more evenly spaced and able to better exploit the available soil and light resources.

This research was conducted across two growing seasons

QAAFI weeds researcher Baghirath Chauhan has completed several studies to investigate ways to make pulse crops, including chickpeas and mungbeans, more competitive against weeds.

and demonstrated that controlling annual ryegrass for the first three weeks after planting increased crop yield by a whopping 200 per cent compared to the season-long weedy scenario. Annual ryegrass that emerges 6 weeks or more after planting does not impact on chickpea yield, but if allowed to set seed, can contribute to the weed seed bank present at seeding the following year.

Is annual ryegrass a serious weed in chickpea?

Short answer: Yes, annual ryegrass is a yield limiting weed and is adapting to farming systems further north than its traditional range.

Longer answer: Averaged over row spacing and cultivar, the penalty attributable to annual ryegrass was 1.2 t/ha less grain yield between the weed-free plots (1.8 t/ha) and the season-long weedy plots (0.6 t/ha). Without any competition, season-long weedy plots produced more than 129 annual ryegrass seed spikes per m2.

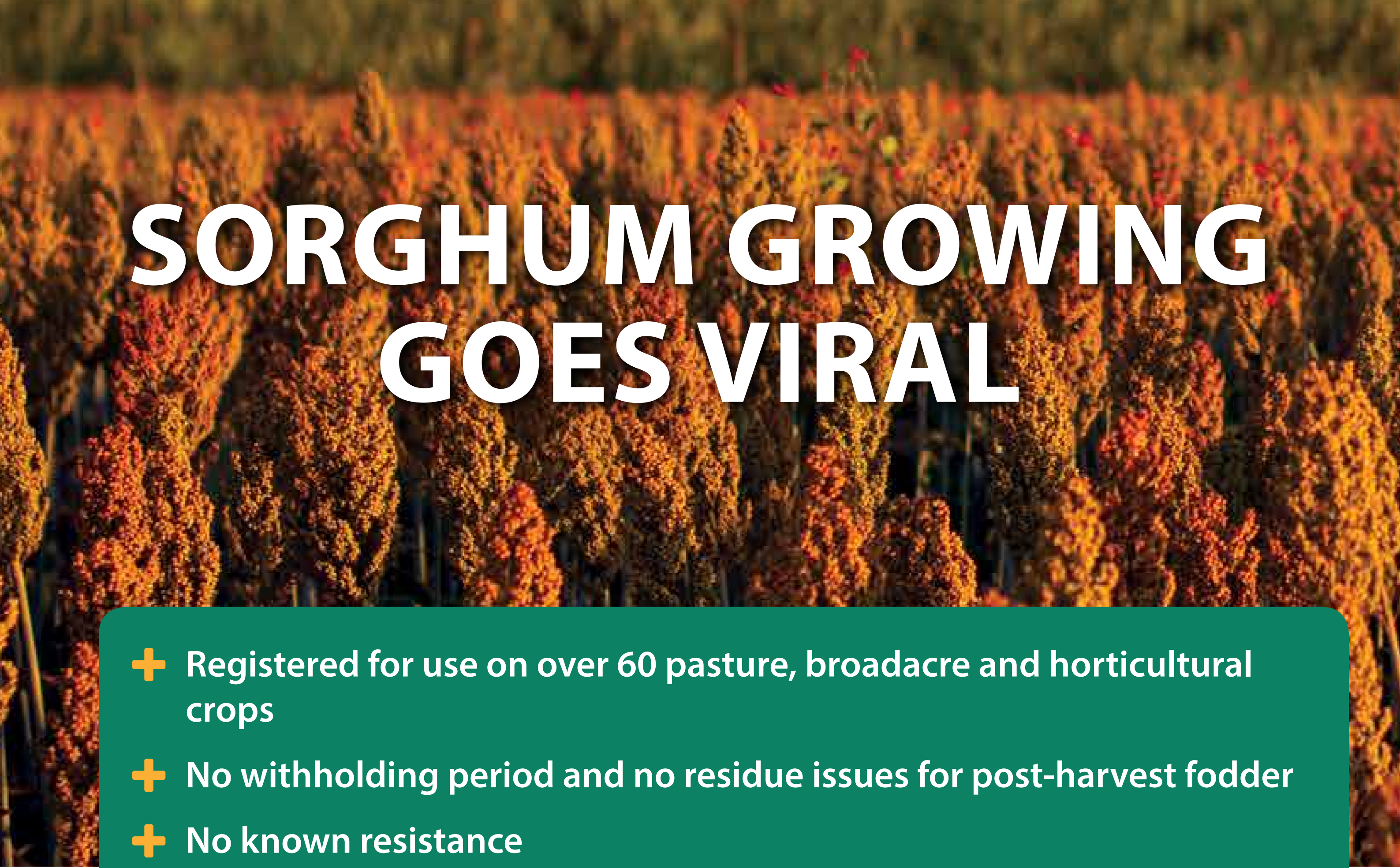
By planting PBA Seamer at 25 cm row spacing and keeping the crop weed-free for three weeks, the number of annual ryegrass spikes is reduced to just 8 per m2.

How can I achieve this early weed control?

Short answer: Start the year ahead in the paddocks you plan to grow chickpeas and do everything possible to reduce the ryegrass seed bank using effective herbicides, weed seed burial, competitive cereals and harvest weed seed control tactics or hay-making. Back this up with registered pre-emergents for chickpea and as many non-herbicide tactics in-crop as possible.

Longer answer: Annual ryegrass is a master at evolving herbicide resistance. In southern regions it has evolved resistance to the registered in-crop herbicides for chickpeas. This will also occur in the northern region if steps are not taken to preserve the efficacy of Group A post-emergent chemistry across the crop sequence.

An over-reliance on pre-emergent herbicide use will also select for herbicide resistance, just as it has for post-emergent herbicides. To minimise this risk, it is important to use a diverse range of weed management tactics in-crop, such as crop competition, inter-row cultivation or chipping, to remove survivor weeds before they set seed. Where possible, rotate registered pre-emergent herbicide modes of action groups J, D and K between years and consider mixing pre-emergent modes of action groups where permitted, always at full label rates for all active components of the mix. Always read and follow label instructions.



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3rd	4 - 8	Medium (small)	8 - 13		✓
4th	8 - 11	Medium (large)	14 - 23		✗
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	LARVAE / HEAD						
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$250	$7.20	$14.40	$21.60	$36.00	$50.40	$72.00	$144.00
$300	$8.64	$17.28	$25.92	$43.20	$60.48	$86.40	$172.80
$350	$10.08	$20.16	$30.24	$50.40	$70.56	$100.80	$201.60
$400	$11.52	$23.04	$34.56	$57.60	$80.64	$115.20	$230.40

*12 heads/m, 1m row spacing. Source QDAF.

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WHERE

C = Cost of control ($/ha)
R = Row spacing (cm)
V = Value of crop ($/t)
N = Number of heads/m row
2.4 = weight of sorghum (grams) lost/larvae

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COMPOST VITAL TO SEQUESTERING CARBON IN THE SOIL

By moving beyond the surface level and literally digging deep, scientists at the University of California, Davis, found that compost is a key to storing carbon in semi-arid cropland soils, a strategy for offsetting CO_2 emissions.

For their 19-year study, published in the journal Global Change Biology, scientists dug roughly 6 feet down to compare soil carbon changes in conventional, cover-cropped and compost-added plots of corn-tomato and wheat-fallow cropping systems.

They found that:

- Conventional soils neither release nor store much carbon. - Cover cropping conventional soils, while increasing carbon in the surface 12 inches, can actually lose significant amounts of carbon below that depth.
- When both compost and cover crops were added in the organic-certified system, soil carbon content increased 12.6 percent over the length of the study, or about 0.07 percent annually. That's more than the international "4 per 1000" initiative, which calls for an increase of 0.04 percent of soil carbon per year. It is also far more carbon stored than would be calculated if only the surface layer was measured.

"If we take the time and energy to look a little deeper, there's always more to the story," said co-first author Jessica Chiartas, a Ph.D. student with the UC Davis land, air and water resources department. "The soil represents a huge mass of natural resource under our feet. If we're only thinking about farming the surface of it, we're missing an opportunity. Carbon is like a second crop."

Cover crops, compost and the carbon market

Nationwide, many studies that investigated carbon change in the top foot of soil found that cover-cropped systems store carbon. The UC Davis study also found gains in the surface but, deeper down, enough carbon was released from cover-cropped systems that it resulted in an overall net loss.

"There are other benefits to cover crops that farmers may still enjoy, but in our systems, storing carbon is not necessarily one of them," said co-first author Nicole Tautges, a cropping systems scientist with the UC Davis Agricultural Sustainability Institute. "We'd make more progress by incentivizing compost."

The researchers did not compare composted systems without cover crops, but suspect the compost helped sequester carbon despite the cover crop, a notion they intend to investigate further.

Microbes need a balanced diet

Carbon has to filter through soil microbes to create stabilized forms of carbon in soil. Compost provides not only carbon but also additional vital nutrients for those microbes to function effectively.

"One reason we keep losing organic matter from soils is that our focus is on feeding the plant, and we forget the needs of others who provide important services in soil like building organic carbon," said senior author Kate Scow, director of the UC Davis Russell Ranch Sustainable Agriculture Facility. "We need to feed the soil, too".

Having a balanced diet can make the difference between how much carbon stays in the soil versus how much is released as carbon dioxide, Scow said. When their diet is out of balance, microbes seek out missing nutrients, mining them from existing soil organic matter. This results in the loss rather than gain of carbon. The authors think that deep in the soil, cover-crop roots provided carbon but not the other nutrients needed to stabilize it.

Sequestering Carbon in arid climates

The study was conducted in California's northern Central Valley at the Russell Ranch Sustainable Agriculture Facility, part of the Agricultural Sustainability Institute at UC Davis. The results indicate that semi-arid Mediterranean climates like the study site may be capable of storing far more carbon in the soil than once thought possible.

"This work coming out of Russell Ranch at UC Davis is very timely as the state invests in programs to sequester carbon in soils," said Secretary Karen Ross of the California Department of Food and Agriculture. "Carbon sequestration in soils through the addition of compost is a key practice in our Healthy Soils Program and we are delighted that the science and policy efforts are aligning and supporting each other."

The results also indicate an opportunity for compost to provide multiple, interconnected benefits to farmers and the environment by improving soils, offsetting greenhouse gas emissions, and transforming animal and food wastes into a valuable product the soil needs.

RESEARCHERS DISH UP DIGITAL AVOCADO

It's an ancient fruit, but the avocado has been brought into the new millennium with the publication of its draft genome, which may be the key to improvements in future crops.

University of Queensland Centre for Horticultural Science's Professor Neena Mitter, along with colleagues Dr Alice Hayward and Stephen Fletcher collaborated on the international research led by Professor Luis Herrera-Estrella that recently published the first draft sequencing of the Hass variety genome.

Neena said the avocado had around 25,000 protein-coding genes - roughly the same as humans.

"There is a lot of genetic variation in avocado, and this new genetic information, coupled with advances in big data means there's huge potential for future crop improvement and breeding that we can now tap into," Neena said.

University of Queensland researchers in the Hort Innovation National Tree Genomics Program will now complete the final assembly of the genome.

"Unlocking the avocado genome will help us better target management practices by understanding the genetic controls for biological processes that influence commercially important traits," she said.

Hort Innovation's R&D Manager Dr Vino Rajandran said having a detailed blueprint of the avocado genome would provide the Australian industry with an important tool to drive future productivity.

"It will give us new insights into improved tree architecture and flowering, and the intensification of orchards, which are priorities of our National Tree Genomics Program," Vino said.

Avocado can be traced back 65 million years to the beginning of the Cenozoic era and was a source of food for giant sloths and other large animals.

Alice said the genome draft also helped unravel how the fruit evolved.

"Avocado is an ancient flowering tree in the family that also includes cinnamon," Alice said.

"The genome data supports the idea that the avocado lineage split from other flowering plants around 150 million years ago."

As well as being valued for its buttery flavour and health qualities, avocado is an important crop of Mexico which produces around half the world's supply.

The University of Queensland team also provided sequence data for Velvick, a disease-tolerant rootstock that is widely sought-after in Australia for grafting new avocado trees.

"Avocados can be highly susceptible to diseases such as phytophthora root rot, so having this new understanding of avocado genetics will be important in combatting the disease, and also disease like black spot," Neena said.

Avocado is an economically important fruit crop with the global market predicted to reach US$23 billion by 2027.

The Australian component of this work was supported by Hort Innovation through a Science and Innovation Award and Minister's Award from ABARES (Australian Government Department of Agriculture).

THE PLANT MICROBIOME

BY DR. UWE STROEHER, PH.D. (MICROBIOLOGY) & R&D MANAGER, NEUTROG AUSTRALIA

IN A WORLD WITH A GROWING POPULATION AND A POTENTIALLY CHANGING ENVIRONMENT, FOOD SECURITY HAS BECOME A MAJOR AGRICULTURAL CHALLENGE. WE HAVE KNOWN FOR MANY YEARS THAT THERE IS A RANGE OF SOIL MICROBES WHICH CAN SIGNIFICANTLY ENHANCE PLANT HEALTH AND GROWTH, AS WELL AS POSITIVELY AFFECT CROP YIELD.

Unfortunately, until recently, the ability to decipher this plant-microbe interaction and to determine exactly which microbes are in the soil (or for that matter associated with the plant) has been difficult and extremely expensive. So why has it taken so long to be able to undertake these kinds of studies? There have been two major factors.

Firstly, traditional microbial studies are limited by the ability to grow various micro-organisms in a laboratory setting, so until now only ~2% of the potential soil bacteria and fungi can be cultured. We know even less about what they do, and how and when they are actually in the soil, or when they associate with plants.

Secondly, a major technical leap was required in order to examine the microbes using genomic sequencing. So we now find ourselves in a new age of meta genomics, where, thanks to Next Generation Sequencing, we have the ability to examine and piece together the whole range of DNA of micro-organisms that are found in the soil or associated with the plant. It is this association of plants with viruses, bacteria and fungi that constitutes the plant microbiome. Every tissue of the plant, whether it be leaves, roots or even seeds, interact in some way with various microbes, and in some cases micro-organisms (known as endophytes) are even internalised within plant tissue.

However, for ease of understanding, the plant microbiome is often split into two parts - the phyllosphere, which is the part above the ground - this describes the microbes associated with the stem, leaves, flowers, fruit and seeds of the plants. The second region is the rhizosphere, which represents the roots and the region surrounding the roots, where secretions from the plant can and will influence the microbes present in this area. (Fig 1)[1].

Over the last four to five years there has been an explosion of data on the plant microbiome. What we have learned is that the plant microbiome is likely to be the most diverse biome on the planet. As such, there is not a one-size-fits-all, although a core plant microbiome has been identified[1].

Therefore, every plant has its own unique set of micro-organisms, which is overlayed by the fact that the plant microbiome is not fixed, but is in continual flux. This flux or change can be due to environmental factors such as temperature, moisture, soil pH and even the nutritional status of the plant.

There are also means by which plants directly alter their microbiome. The most well studied is root secretions. In this way, plants can select and also discourage certain bacteria and fungi by secreting a range of sugars, organic acids, amino acids, phenolic compounds and plant growth factors - all of which alter the microbiome, in particular in the rhizosphere [2-3].

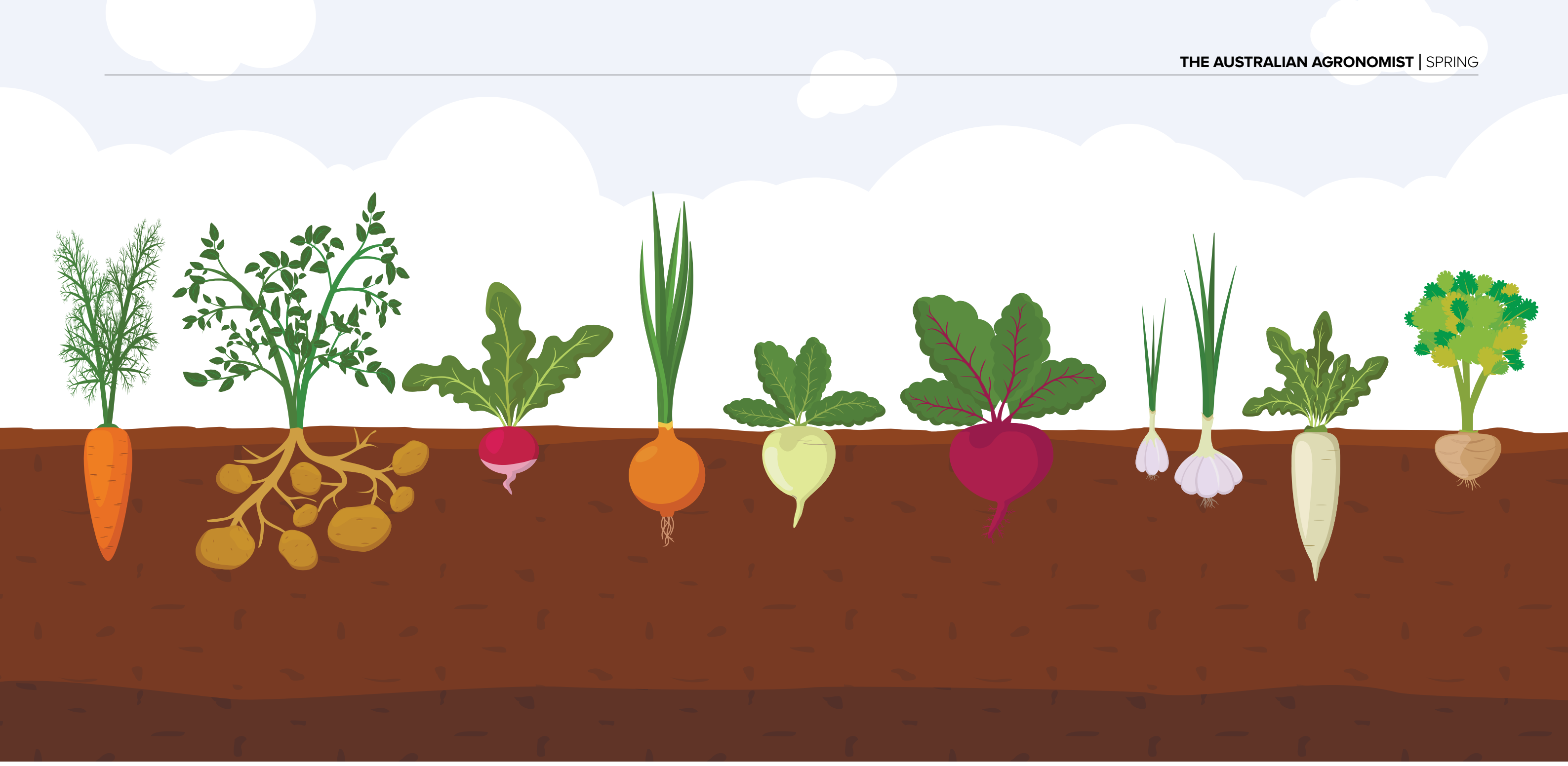
Although we can now identify which microbes are present and no longer have to rely on classical microbiology, we still struggle to assign very specific functions to the many bacteria, viruses and fungi which co-habitate with plants. So what has the ability to determine plant microbiome really given us? We know that higher levels of diversity in the plant microbiome appears to be associated with better outcomes, and that the loss of even low represented species can be detrimental[1].

Many of the beneficial effects seen from the association of plants with micro-organisms can now be more readily mapped to an organism with specific characteristics or genes, such as the gene for 1-aminocyclopropane-1-decarboxylase, which is capable of reducing the level of the stress hormone ethylene, thereby reducing the damage done by this hormone.

It is now also possible to accurately map broad functional groups and genes involved in certain metabolic pathways, and to determine their relative predominance[4]. For example, if we see numerous genes involved in nitrogen fixation, or if we find many genes involved in the production of plant growth factors such as auxins or cytokinin, then it is most likely that these soils will effectively fix nitrogen and enhance plant growth respectively due to the microbes present.

Alternatively, if we see the presence of certain pathogenic genes such as those involved in toxin production, we can then speculate that these soils are more prone to allow disease-causing organism to flourish, or that plants in these soils are more likely to show disease. Conversely, it is now also possible to look for the biological control agents against microbes that may represent pathogens.

The other obvious advantage is that it's now relatively easy to make a list of pathogens found, so if there is a dominance or high number of certain pathogens, this would highlight an issue prior to the disease showing up in the plants themselves (Fig2). Furthermore, the ability to unravel the plant microbiome has also allowed us to examine the difference between pathogen suppressive and permissive soils[5]. In suppressive soils, the pathogens are generally present in low numbers or have difficulty in establishing themselves. One characteristic feature of suppressive soils is that they have a higher diversity of microbes included in the rhizosphere[6]. A prime example is Take-All caused by the Gaeumannomyces graminis fungus, which, to some extent, can be controlled in suppressive soils by the build-up of fluorescent Pseudomonas spp[6].



So what is the future for the plant microbiome? The ability to compare productive to non-productive soils at a microbial level will be possible, which may lead to the development of microbial inoculants (such as Neutrog's GOGO Juice) to overcome issues in poorly performing soils. Additionally, the microbiome technology will subsequently allow the monitoring of the effect of any such inoculant on the plant's microbiome, and whether these products can elevate issues[1].

It will also be possible to monitor the impact that certain cropping or growing practices have on the microbiome of the plants and soil, thereby allowing farmers to potentially mitigate any effects prior to crop losses or yield reductions.

Further down the track we will have the ability to select plants capable of interacting and taking advantage of beneficial microbes. We know from plant microbiome studies that domesticated plants have a lowered capacity to interact with plant growth-promoting micro-organisms[7-8].

Neutrog are currently working together with Western Sydney University on a species of soil fungi called Trichoderma. Trichoderma is a known biological control agent which has the ability to effectively compete with plant pathogens, and can help to strengthen the overall defence of the plant. Neutrog have isolated a range of Trichoderma strains and are now testing their efficacy against a range of fungal plant pathogens on a number of economically important crops.

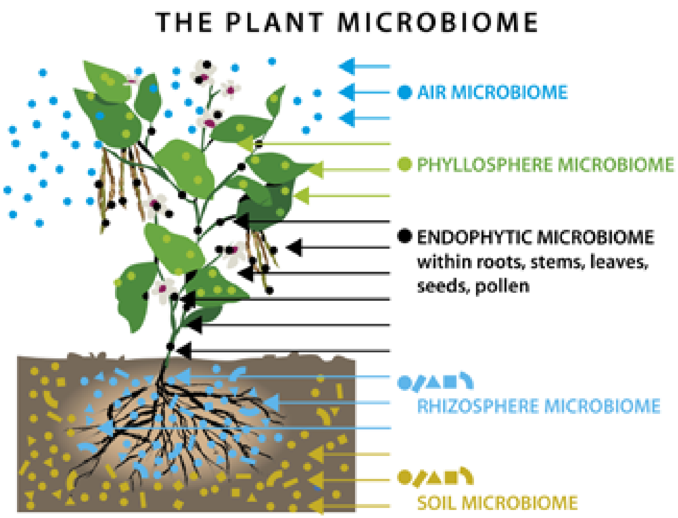


Fig 1. The Plant Microbiome

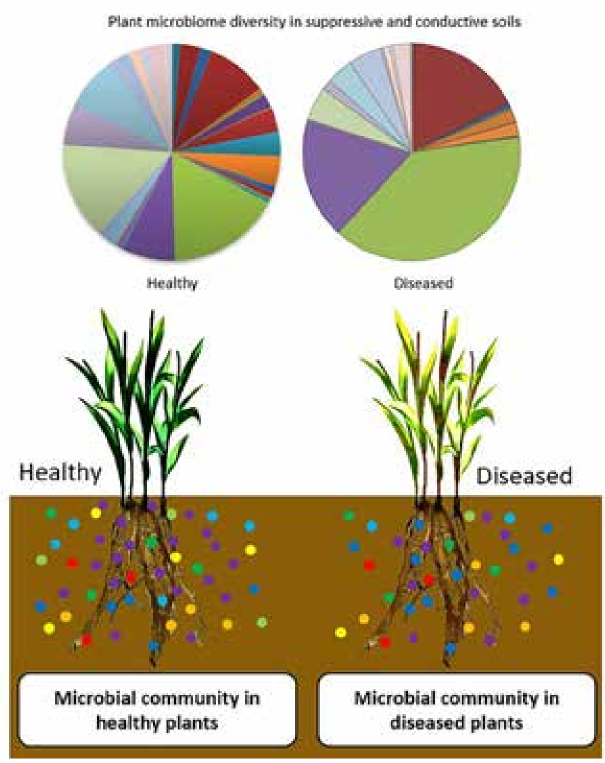


Fig 2. Figure kindly provided by Professor Brajesh Sigh and Galaxy Qiu from the Western Sydney University.

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NEW DEALERS FOR THE CROPSCAN 3300H ON COMBINE NIR ANALYSER

The CropScan 3300H On Combine NIR Analyser is the most dramatic development in Precision Agriculture in 20 years. No other piece of farming technology offers such a high return on investment, ie, 2-3 per year. With more than 300 systems now around the world, this Australian developed and manufactured technology is now available to Australian farmers through a much broader dealer network.

Several large John Deere, Claas and Massey Ferguson dealers have now signed up to offer the Cr3300H to their new and existing combine customers. These new dealers include Chesterfield Australia, Southern Queensland and New South Wales, Emmetts, Victoria and South Australia, Northern New South Wales and Ag Implements, Western Australia. Other dealers are in discussions to include the Cr3300H in their range.

Next Instruments has been manufacturing the CropScan range of NIR analysers for 20 years. The CropScan 3300H was introduced in 2013. Under a supply contract with CHNi, approximately 150 systems were installed on CASE and New Holland combines since 2016. However many John Deere and Claas users also installed system bought directly from Next Instruments. Now that there are more than 100 installations on John Deere, Claas and Massey Ferguson combines, there is obviously a demand for this technology coming from farmers. As such, Next Instruments has aggressively broadened its dealer network to expand the uptake of this exciting technology across all brands of combines.

For more information on the CropScan 3300H On Combine NIR Analyser, visit our web site: **www.nextinstruments.net** or view our video on Youtube: **https://youtu.be/cw9DZlqShks.**

Or contact us at **sales@nextinstruments.net**, Tel: **0427791283**, Twitter: **cropscan@cropscan**.

HIGH-TECH SUSTAINABLE PROTECTION FOR KEY AUSTRALIAN CROPS

The application of a revolutionary alternative to chemical fungicides to protect Australia's $5 trillion global food and agribusiness sector is being spearheaded by researchers at The University of Queensland.

UQ's Professor Neena Mitter said the team from the newly launched $17.5m Australian Research Council (ARC) Industrial Transformational Research Hub for Sustainable Crop Protection was building on UQ's BioClay technology to create a 'smart' form of biological crop protection.

"We will be bringing biological-based fungicides to Australian broadacre and horticultural crops, resulting in reduced chemical use, increased crop productivity, and improved sustainability across the supply chain," she said. "This technology involves topical application of RNA interference using clay particles as carriers.

"There is no genetic modification and the clay is completely biodegradable." Neena said that meant the BioClay would not result in chemical residues in food or run-off into waterways.

"Globally, an estimated 40 per cent of food grown is lost to crop pests and pathogens."

She said the fungal pathogens targeted by the Hub were selected in close consultation with Research and Development Corporations and industry partners.

"We will tackle issues such as fungicide resistance or targets where no effective control measures are currently available."

The Queensland Alliance for Agriculture and Food Innovation project involves staff from Australian Institute Bioengineering and Nanotechnology, School of Agriculture and Food Sciences, School of Chemistry and Molecular Biosciences, Sustainable Energy Futures, and Centre for Policy Futures.

"The Hub comprises an expert multidisciplinary team including science, commercial and policy experts, with the aim of increasing productivity, market access and enhanced environmental credentials of Australian food," Neena said.

Hub Partner Oganisations:

Nufarm Australia limited, DuluxGroup (Australia) Pty Ltd, Bioplatforms Australia Ltd, AusVeg Ltd, Grains Research & Development Corporation, Cotton Research & Development Corporation, Horticulture Innovation Australia Limited, Department of Agriculture and Fisheries Queensland, Department of Primary Industries - NSW, Australian Wine Research Institute, South Australian Research and Development Institute, Australian Grape and Wine Authority, Griffith University, Curtin University, La Trobe University, University of Tasmania, University of California, Riverside.

COULD BIOLOGICAL CLOCKS IN PLANTS SET THE TIME FOR CROP SPRAYING?

Plants can tell the time, and this affects their responses to certain herbicides used in agriculture according to new research led by the University of Bristol. The study, in collaboration with Syngenta, found that plant circadian rhythms regulate the sensitivity of plants to a widely used herbicide according to the time of day. The findings could benefit agriculture by reducing crop loss and improving harvests.

Just like human jet lag, plants have body clocks that are crucial for their life in a world that has day and night. Plant biological clocks make a crucial contribution to their growth and the responses of crops to their fluctuating environments.

Dr Antony Dodd, Senior Lecturer in the School of Biological Sciences and senior author of the paper, said

"This proof of concept research suggests that, in future, we might be able to refine the use of some chemicals that are used in agriculture by taking advantage of the biological clock in plants. Approaches of this type, combining biotechnology with precision agriculture, can provide economic and environmental benefits."

In a new paper, published in the journal Nature Communications, the researchers found that the death of plant tissue and slow-down in growth resulting from the herbicide glyphosate depends upon the time that the herbicide is applied and also the biological clock.

Crucially, the biological clock also led to a daily change in the minimum amount of herbicide that is needed to affect the plant, so less herbicide was needed at certain times of day. This provides an opportunity to reduce the quantity of herbicides used, saving farmers time, money and reducing environmental impacts.

In medicine, "chronotherapy" considers the body clock when deciding the best time to give a medicine or treatment. This new research suggests that a similar approach could be adopted for future agricultural practice, with crop treatments being applied at times that are most appropriate for certain species of weed or crop. By employing a form of agricultural chronotherapy might have a future role in the sustainable intensification of agriculture required to feed the growing population.

Journal Reference:

'Plant circadian rhythms regulate the effectiveness of a glyphosate-based herbicide' by Belbin FE, Hall GJ, Jackson AB, Schanschieff FE. Archibald G, Formstone C, Dodd AN in Nature Communications

WAGYU FARMER FINDS PERFECT SUMMER FEED OPTION

Shepparton dairy farmer Duncan Crawford has been fuelling his 800 Holsteins on corn silage from varieties PAC 606 and PAC 606IT for six seasons and he doesn't plan on changing the program anytime soon. Duncan said that's because it produces high quality, high yielding silage and the maturity is ideal.

"We've been growing PAC 606 and its replacement PAC 606IT for six seasons now under the two centre pivots," he said. "We can hit our target of 23 tonnes per hectare of dry matter most seasons and it's great for putting condition on the cows.

"Having a CRM of 114 also maximises the growing period, so it gives us a chance to grow a decent crop and then get early autumn growth after harvest.

"There are varieties with a shorter CRM available, but we find the 114 maximises yield and when it comes off, it's not so late we can't sow the winter crop."

Duncan runs 'Fenton Hall' with his wife Emily and father Ross, milking the 800 cows on a 60-unit rotary with auto draft. They also grow wheat for silage, Lucerne, perennial ryegrass, Italian ryegrass, and buy in grain to supplement the diet. Duncan said they run three 1000t earth bunkers at the property – one for pasture, one for Lucerne and one for corn.

"We aim to plant the corn in early November and harvest in March, so then we have feed in the bunkers to supplement the herd over winter."

Last season, the farmers stuck to that window, seeding 47ha of PAC 606IT on November 16 with chicken manure into a paddock out of Italian ryegrass that was strip tilled before sowing.

Duncan said it was a hot, dry season, with tight water allocations to go with it.

"It was a terribly dry, awful, hot summer season and it was a pretty tight year for water too. Luckily enough we filled our cobs."

Shepparton received 28mm in November, 37mm in December, 7mm in January, 7mm in February and 5mm in March – a growing season rainfall total almost half that of the annual median.

Each month's annual median temperature was also exceeded in that period, making it tough going for the corn. Despite all this, the family harvested the corn at the end of March and averaged 22t/ha DM from the 47ha block.

"Getting close to our usual 23t/ha DM target was pretty remarkable given how harsh the season was. In the best seasons we can get the 606it to push 26t/ha DM.

"The 606it having the IT gene also gives us the option to spray Lightning herbicide in-crop to tackle weeds."

The paddock has now been sown to wheat, which will go on to produce silage for the cows, and the Crawford's will sow their seventh season of PAC corn in November.

POTENTIAL FOR REDUCED METHANE FROM COWS

An international team of scientists has shown it is possible to breed cattle to reduce their methane emissions.

Published in the journal Science Advances, the researchers showed that the genetics of an individual cow strongly influenced the make-up of the microorganisms in its rumen (the first stomach in the digestive system of ruminant animals which include cattle and sheep).

"What we showed is that the level and type of methane-producing microbes in the cow is to a large extent controlled by the cow's genetic makeup," says one of the project's leaders and co-author Professor John Williams, from the University of Adelaide's School of Animal and Veterinary Sciences. "That means we could select for cattle which are less likely to have high levels of methane-producing bacteria in their rumen."

Cattle and other ruminants are significant producers of the greenhouse gas methane - contributing 37 per cent of the methane emissions resulting from human activity. A single cow on average produces between 70 and 120 kg of methane per year and, worldwide, there are about 1.5 billion cattle.

The study comes out of a project called RuminOmics, led by the Rowett Institute at the University of Aberdeen and involving the Parco Tecnologico Padano in Italy (where John used to work), the Ben-Gurion University of the Negev in Israel, and a number of other institutions in Europe and the US.

The researchers analysed the microbiomes from ruminal fluid samples of 1000 cows, along with measuring the cows' feed intake, milk production, methane production and other biochemical characteristics.

Although this study was carried out on dairy cows, the heritability of the types of microbes in the rumen should also apply to beef cattle.

"Previously we knew it was possible to reduce methane emissions by changing the diet," says John. "But changing the genetics is much more significant - in this way we can select for cows that permanently produce less methane."

John says breeding for low-methane cattle will, however, depend on selection priorities and how much it compromises selection for other desired characteristics such as meat quality, milk production or disease resistance.

"We now know it's possible to select for low methane production," he says. "But it depends on what else we are selecting for, and the weighting that is placed on methane - that's something that will be determined by industry or society pressures."

The researchers also found a correlation, although not as high, between the cows' microbiomes and the efficiency of milk production.

"We don't yet know, but if it turned out that low-methane production equated to greater efficiencies of production - which could turn out to be true given that energy is required to produce the methane - then that would be a win, win situation," John says.

Journal Reference:

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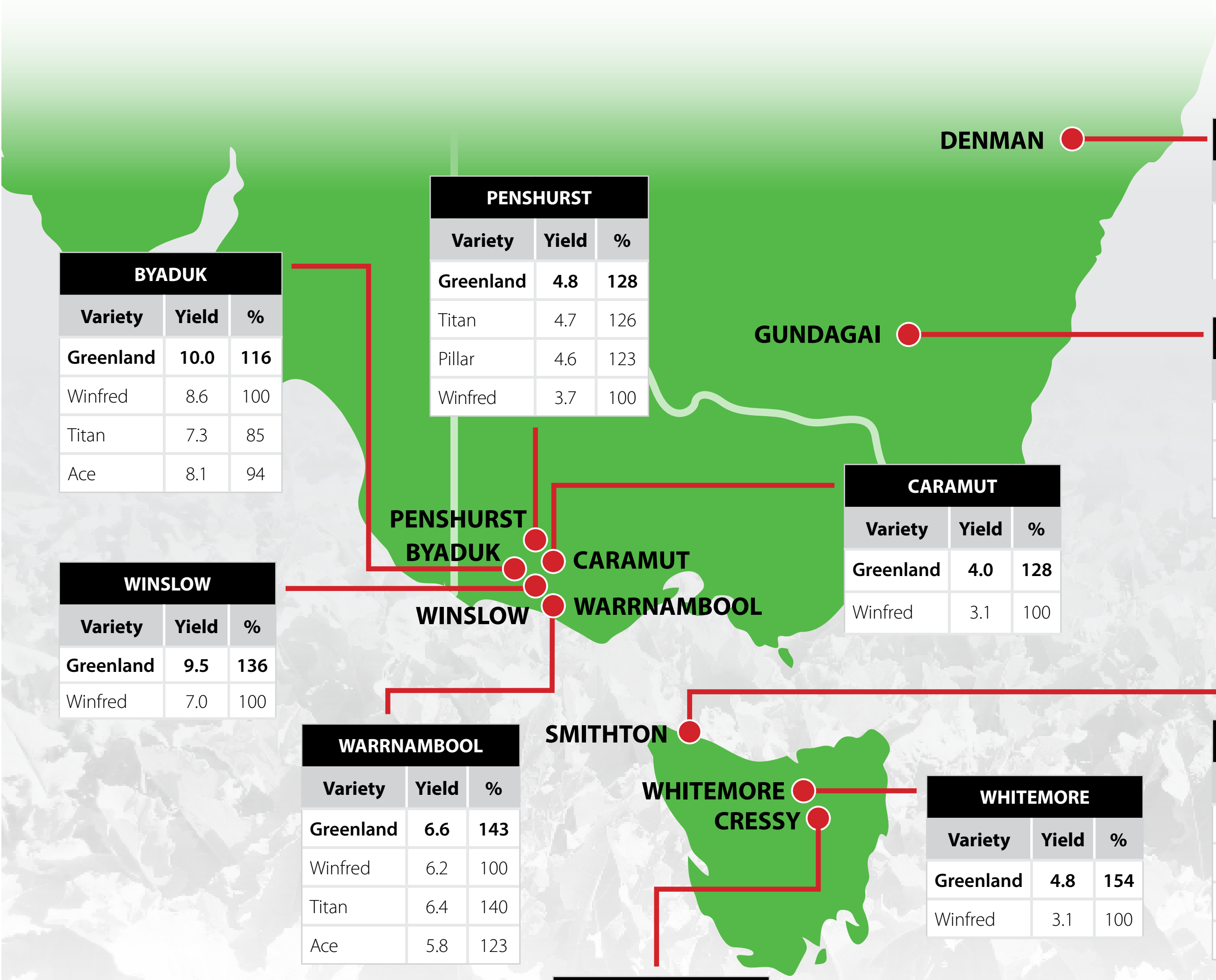

BYADUK

Variety	Yield	%
Greenland	**10.0**	**116**
Winfred	8.6	100
Titan	7.3	85
Ace	8.1	94

PENSHURST

Variety	Yield	%
Greenland	**4.8**	**128**
Titan	4.7	126
Pillar	4.6	123
Winfred	3.7	100

DENMAN

Variety	Yield	%
Greenland	**14.9**	**117**
Winfred	12.7	100

GUNDAGAI

Variety	Yield	%
Greenland	**10.0**	**115**
Winfred	8.7	100
Ace	8.4	96

CARAMUT

Variety	Yield	%
Greenland	**4.0**	**128**
Winfred	3.1	100

WINSLOW

Variety	Yield	%
Greenland	**9.5**	**136**
Winfred	7.0	100

WARRNAMBOOL

Variety	Yield	%
Greenland	**6.6**	**143**
Winfred	6.2	100
Titan	6.4	140
Ace	5.8	123

SMITHTON

Variety	Yield	%
Greenland	**9.2**	**147**
Winfred	6.2	100
Titan	6.3	101
Interval	8.3	133

WHITEMORE

Variety	Yield	%
Greenland	**4.8**	**154**
Winfred	3.1	100

CRESSY

Variety	Yield	%
Greenland	**6.6**	**112**
Winfred	5.9	100
Goliath	6.2	105

Yield = tDM/ha
% = % control Winfred

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