ScionConnections

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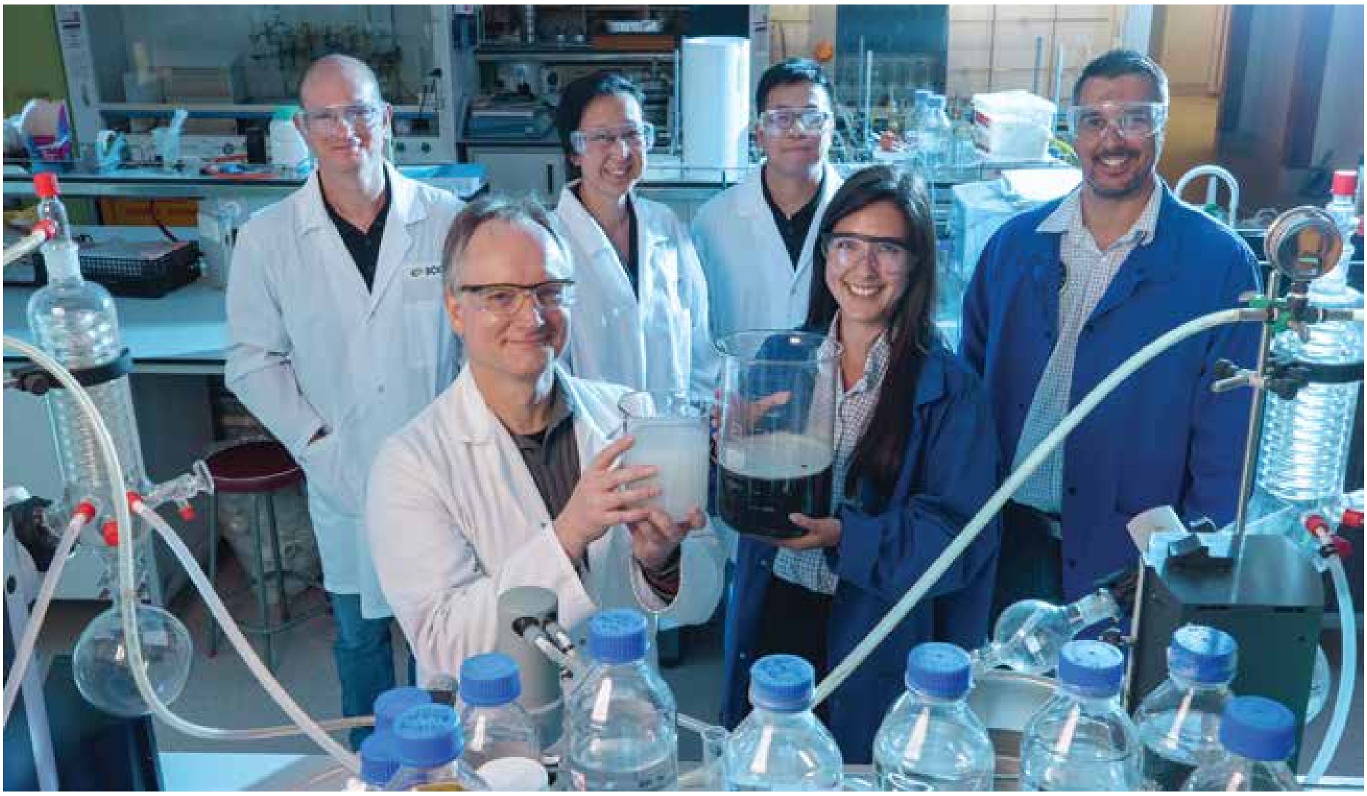


Front row from left: Dr Stefan Hill, Dr Melodie Lindsay. Back row from left: Sean Taylor, Dr Marie-Joo Le Guen, Dr Yi Chen and Tane Bradley.

Innovating with seaweed

A project to reveal the hidden properties of seaweed cellulose is starting to gel.

Seaweeds have unique natural properties. For example, the cellulose in seaweed forms chains that are long and wide – up to four times wider than land-based plants. Cellulose is a structural component in the primary cell wall of green plants and is the most common organic polymer on Earth.

Drs Stefan Hill and Marie-Joo Le Guen are leading a project, in partnership with AgriSea New Zealand Seaweed Ltd, to understand the functional properties of celluloses from selected seaweed species and how they could be developed to replace fossil fuel-based products.

Properties

A number of seaweed species have been selected based on their properties, including the commonly found and under-utilised *Undaria pinnatifida* and the commercially developed *Ecklonia radiata*. The seaweed samples were processed using green chemistry principles and a proprietary method based on Scion's expertise in pulp and paper research.

Nanocellulose chains extracted from the seaweed samples were characterised using solid state nuclear magnetic resonance (NMR) and mechanical testing at Scion, and x-ray diffraction at the Australian Synchrotron. The seaweed cellulose has also been incorporated into paper and plastic composites to evaluate its thermal properties; examples of these items have been sent to a commercial laboratory (Bethel) in Japan to test how well they conduct heat. The results show seaweed nanocellulose to be significantly more effective at transferring heat compared to tree-based nanocellulose.

Products from seaweed

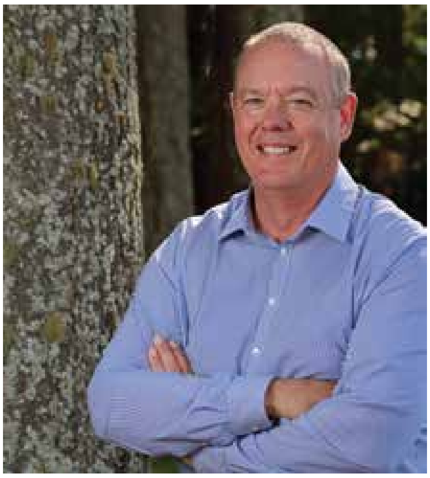
The nanocellulose from both *U. pinnatifida* and *E. radiata* has been used to make hydrogels. Hydrogels are often formed by cross-linked petroleum-based polymers absorbing vast amounts of water (up to 100 times their own weight) and swelling to form a jelly-like substance.

Seaweed nanocellulose can be used to replace petroleum-based polymers in a range of hydrogel products, this includes burn wound dressings, biomedical engineering applications, drug delivery, cosmetics, and in agriculture supporting plant health.

The hydrogels formed by the two seaweeds have displayed properties that distinguish them from nanocellulose hydrogels made from terrestrial plant cellulose.

(Continued on page 7)

Building back better with a biopilot boost



If companies had Christmas wishes, top of Scion's wish list would be tangible support for a National Bioproduct Innovation and Pilot Centre. As readers of my editorials will know, I have long advocated for such a biopilot facility.

Scion's mission is to drive innovation and growth in the forestry and bioproducts sectors. Achieving this is hampered by a missing critical piece of infrastructure - a biopilot plant. Why is this so important? A biopilot plant in New Zealand is vital to locking in the scaleable innovation these sectors need to help tackle climate change and ultimately benefit our country.

Such infrastructure fits into the Government's big picture around the mission for New Zealand to 'build back better'.

With the world moving increasingly towards a circular bioeconomy, New Zealand faces one of the largest opportunities ever to build a better future. We estimate this opportunity to be $30 billion per annum in 10 years.

The traditional petrochemical and fossil fuel economy has never afforded New Zealand real natural competitive advantage. However, in this promising new future world, our country has significant advantages: our clean green image, our ability to be among the world's most efficient and sustainable growers in forestry, agriculture and horticulture, our strong expertise in science and applied science in these areas and our partnership approach to heed a Te Ao Māori world view.

A sure way to tap into this circular bioeconomy opportunity is to provide a biopilot bridge between science and commercial operations. Biopilot plants contain specialised equipment beyond lab scale to test and de-risk new product innovations and work out how to scale up new products to commercially viable levels. Biopilot plants operate as open-access research and demonstration facilities enabling new and existing businesses to advance, prove, scale-up and decrease financial risk for innovative products.

A national biopilot plant's key value is the multiplier effect it will have by unlocking new biobased manufacturing opportunities and jobs for forestry and manufacturing in New Zealand. Establishing this scale up facility will bring initial jobs in construction and operation, while the investment will continue to pay off long into the future as it moves forestry and other regional agricultural biomass resources up the value chain with new products, new companies and new jobs. Based on international examples, a biopilot plant could create over 10,000 new jobs and increase the original value of the log or waste stream by up to 1000 times.

Around the world, biopilot plants are necessary scale-up infrastructure, well and truly accepted as essential to get science and technology adopted by industry, new businesses and investors. It's time leaders in New Zealand take note and look to investing in providing this bridge to bringing innovative products to market.

I am heartened by the support Scion has received from 37 high-profile companies and organisations who were signatories to a Scion proposal for a National Bioproduct Innovation and Pilot Centre at Te Papa Tipu Innovation Park in Rotorua. That's the first step.

If you believe that New Zealand needs to have a biopilot plant as a national asset that will grow a whole new primary industry, please let me know.

Meri Kirihimete

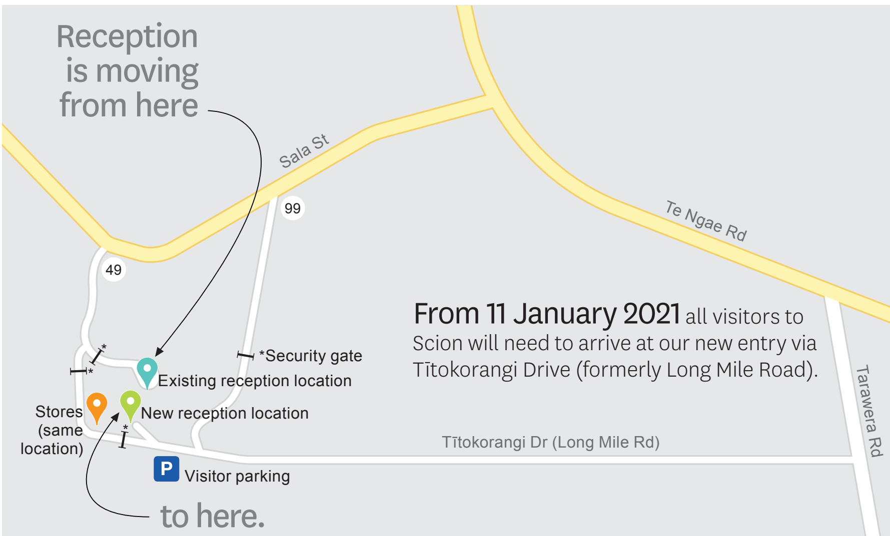
Dr Julian Elder
Chief Executive

FOR FURTHER INFORMATION
contact Dr Julian Elder at
julian.elder@scionresearch.com

On the move...

Our offices will close for the year on 24 December and re-open on 11 January when Scion reception (Rotorua) will move into our new building 'Te Whare Nui o Tuteata'. All visitors to Scion will need to arrive via the entrance at the end of Tītokorangi Drive (Long Mile Road).

The Scion Board and staff wish all our clients, partners and colleagues the very best for the festive season. We look forward to working with you again in 2021.



Controlling wilding pines

New Zealand is undertaking one of the largest wilding pine control programmes in the world.

The spread of wilding pines threatens the ecology and economy of indigenous grasslands, scrublands and forests, especially in the South Island high country. Wilding pines are self-sown conifers originating from early forestry, shelterbelt and farm plantings. Around two million hectares in New Zealand are estimated to be infested.

The goal of wilding pine management is to limit future spread and reduce the extent of current infestations. Over the next decade, control operations will be carried out over large areas with various densities of wilding pines with over $100 million already allocated towards achieving this goal. The most efficient operational tool that New Zealand currently has to control dense wilding conifer infestations is aerial spraying of the 'TDPA' brew, which combines the herbicides Triclopyr, Dicamba, Picloram, and Aminopyralid into a single mixture at relatively high concentrations.

Herbicide persistence

Scion researchers have looked at the persistence of Triclopyr, Dicamba and Dicloram in soil, forest floor litter, sediment and water. They looked at three sites located in the Mackenzie Basin, Southland and the Hawke's Bay following aerial spraying with TDPA. The goal was to quantify the amounts of herbicide present in the environment and the degradation over time to determine long-term impacts following application. Three sites sprayed as part of the National Wilding Conifer Control Programme between January 2018 and February 2019 were included in the trial set.

Their work showed that after two years, levels of Triclopyr, Picloram and Dicamba were below detection limits in soils. However, herbicides were detectable in the forest floor litter layer (mainly discarded needles) at all sites after two years. The general conclusion was that the levels of herbicides were below the thresholds that would be considered toxic to terrestrial fauna.

The highest concentrations of herbicides in water were detected on the day of spraying or following the first rainfall after spraying. Threshold standards were exceeded at one site after rainfall 13 days after spraying. A more intensive monitoring programme is required to determine whether these temporary fluctuations in herbicide concentrations had the potential to affect freshwater ecosystems.

Revegetation

The research showed that the persistence of herbicides in the forest floor litter had the potential to affect woody vegetation regeneration beneath controlled wilding stands. The researchers collected soil and forest floor litter from the sprayed Mackenzie Basin site and a nearby untreated site, one, six and 16 months after spraying. Subsequently they assessed germination rates of *Pinus contorta* (lodgepole pine, the most common wilding species) and indigenous plant seeds in the collected samples. Overall, they observed very poor germination rates for the *P. contorta*, including abnormal growth for those that did germinate, a typical indication of herbicide phytotoxicity. Even 16 months after spraying, the levels of herbicide were still high enough to cause needle curling, root deformities and lower seedling biomass in lodgepole pine.

The indigenous plants also fared poorly. By 16 months post-spraying, herbicide levels had dropped enough to not affect the germination or mortality of native seedlings, but some symptoms of toxicity could still be seen in mānuka and twiggy coprosma plants.

The effects of residual herbicides in the decomposing needle litter could limit the resurgence of *P. contorta* for at least 16 months after spraying. However, this also has consequences for seeding or planting with natives as a restorative practice. To improve the chances of successful revegetation, it is suggested that restoration be delayed until at least two years after application of the TDPA brew.

Reversing the spread

Understanding the long-term effect of using herbicides in the environment is important to validate and inform best practice and to retain the licence to operate for chemical control of wildings. It also helps with developing management plans to prevent re-infestations, which include revegetation, ensuring the initial investment in control is not wasted and that ecosystems and landscapes are protected.

This work has been funded by the New Zealand Wilding Conifer Control Group and through the Sustainable Farming Fund, Ministry for Primary Industries.

FOR FURTHER INFORMATION on our wilding conifer control research, contact Dr Carol Rolando at carol.rolando@scionresearch.com or Dr Thomas Paul at thomas.paul@scionresearch.com

Dr Peter Beets, Loretta Garrett and Dr Simeon Smaill in Puruki Forest, Scion's most researched and productive forest.

Feeding our forests: Better planted forest nutrition

Soil nutrients play a critical part in healthy forest growth. Each nutrient has a role regulating the production and decomposition in all terrestrial ecosystems and in delivering the flow of ecosystem services from our planted forests.

Organisms living in the soil are responsible for maintaining and modulating forest productivity and health by contributing to soil development, cycling organic matter and nutrients from a plant and soil microbial perspective. In the future, forest nutrition science will be focused on understanding the importance of plant and soil microbiomes working together to ensure a sustainable supply of nutrients for trees.

Research is now focusing on forest nutrition at the ecosystem level and how the balance of energy and vital nutritional elements influence living systems. Nutrients range from elements like nitrogen, which are required in the greatest proportions (macronutrients) to those that are essential but in small quantities, such as boron (micronutrients).

> Research suggests that optimising the availability of specific micronutrients could improve plant water use efficiency, growth and development, and enhance tolerance to abiotic and biotic stresses.

We need to consider nutrient availability and balance at the ecosystem level and the site-specific requirements to optimise forest nutrition. Fertiliser addition is one tool for supporting increased forest growth. However, forest managers need more information to develop site-specific nutrient management plans that will enhance forest productivity and deliver multiple ecosystem benefits.

The potential of micronutrients

Micronutrients are essential nutrients used by plants and microbes in very small amounts. They are key components of complex compounds (e.g., cofactors of enzymes) that regulate metabolism and growth at a cellular level. An example is molybdenum, which is essential for biological nitrogen fixation.

Scion researchers are exploring the potential of specific micronutrients to boost forest productivity, sustainability and resilience. Research suggests that optimising the availability of specific micronutrients could improve plant water use efficiency, growth and development, and enhance tolerance to abiotic and biotic stresses. Micronutrients are also critically important for soil microorganisms in relation to microbial abundance, biodiversity and ecosystem multifunctionality.

Planning is underway to look at some effects of boron, molybdenum, manganese and zinc treatment options. The initial focus will be on how these micronutrients interact with the plant microbiome to regulate processes and ecosystem functions at a lab-scale. This will be followed by investigating how seedlings grown under stress benefit from selected micronutrients, before installing field trials in spring 2021.

Balanced nutritional approach

Site-specific nutrient treatments have been applied recently to nine mid-rotation radiata pine field trials from Northland to Otago and compared to a control and a conventional nitrogen-only treatment. After applying fertilisers tailored to a site for three years, an average volume gain of 2.2% per year has been seen, relative to controls. Over a full rotation, significant volume gains can be made, highlighting the importance of considering possible co-limiting nutrients, rather than focusing exclusively on nitrogen.

Predicting nutrient demand and growth response

Scion has developed a model called the Nutrient Balance Model (NuBalM), which predicts the demand for nitrogen and phosphorus from a site over a rotation of radiata pine forest. NuBalM models tree biomass and forest floor nitrogen and phosphorus stocks. It can be used to understand the nutrient gap required to meet a target productivity goal when the nutrient demand is highest. This information can then be used to help develop nutrient management plans and site-specific precise management interventions, such as the timing of applications of fertiliser.

The forest industry wants to know if and when a site will respond to fertiliser addition. Scion scientists have found that, with the addition of 200 kg/ha of nitrogen, there is a highly variable productivity response, both positive and negative. However, on average a forest is most likely to respond one to three years after fertiliser addition.

Researchers have also calculated a nitrogen enrichment factor by testing archived soil and foliage samples from past trials for levels of “light” nitrogen and “heavy” nitrogen, or natural isotopes. This information, along with site specific environmental data, tree age and measurements of tree growth, were analysed by machine learning software. Results showed the best growth response to nitrogen applications came from targeting young trees that have the freedom to grow (3 to 15 years old) and sites with more negative enrichment factors, where nitrogen is hard for plants to access.

Measuring nutrients more efficiently and in greater detail

Forest managers need information on their forest nutrition to optimise and support long-term sustainable productivity. Scion scientists are using two complementary approaches to develop quick, cheap and reliable analytical methods to supply this.

The first method is based on mid-infrared spectroscopy of soil and foliage samples. This lab-based method is a quick and cost-effective way to detect and quantify many different properties with one scan, including major minerals and soil pH.

The second method showing promise is remote collection of detailed hyperspectral data from trees. Strong relationships exist between spectral indices and photosynthesis, and photosynthesis is affected by nitrogen and phosphorus levels. Preliminary work using small radiata pine in pots has shown hyperspectral data can predict when nitrogen and phosphorus levels are growth limiting. This work is being scaled up to collect data from already established field trials.

Conclusion

Recent research into forest nutrition is producing results that have already led to new management recommendations for increasing forest productivity. Current and future research across the wide bounds of forest nutrition will maintain a productivity focus, plus improved understanding of nutritional ecology – the relationships between plant and soil microbiomes for productive healthy forest ecosystems. New research is underway in the Resilient Forests Programme, which aims to deliver the healthy, hardy and productive planted forests New Zealand needs. The New Zealand forest industry can look forward to strong and healthy, next generation planted forests that continue to bring “prosperity from trees”.

The Resilient Forests Programme runs from October 2019 to September 2021 and is supported by the Strategic Science Investment Fund and Forest Growers Levy Trust.

FOR FURTHER INFORMATION on this work contact Dr Peter Clinton at peter.clinton@scionresearch.com

Studying microplastics in the Kaituna River catchment has taught students from three local schools about the effects of plastic waste.

Microplastic sampling from lake to sea

Students from Mokoia Intermediate, Whangamarino and Maketu Schools in the Bay of Plenty have something in common. They are all close to water bodies that take freshwater from Lake Rotorua to the sea, and they all took part in a Scion-led project working to study microplastics in the Kaituna catchment.

Awareness of New Zealand's microplastic pollution issues is growing, helped along by biomaterial researchers Dr Meeta Patel, Dr Kate Parker and Jamie Bridson. They observed New Zealand's microplastics problem first-hand when sampling the sand and soil around Auckland waterways. The findings spurred them into further action and led to this project examining the microplastics present in our Bay of Plenty backyard.

Sampling soil and sand

The project began with Scion's microplastic experts Meeta, Jamie and Kate visiting each school. Students then took to the field to sample a section of sand.

Mokoia Intermediate School sampled the beach on the eastern edge of Lake Rotorua at Hannah's Bay. Downstream, a few kilometres away on the banks of the Kaituna River (outlet for Lake Rotorua) is where Whangamarino School carried out their sampling. Maketu School, at the end of the river's journey, took samples at Maketu beach.

> "Most of our students know about microplastics from school or home. Now they know much more and what they can do to make a difference." Krystal Stevenson, science teacher.

The next step was finding out what their samples held. Students used sieves to separate microplastics from the sand, and then applied a simple density separation method to identify what kinds of plastic they found. Their bounty included the most common types of plastic (PP, PE, PS and PET.) After analysing the microplastic samples, students wrote reports and gave presentations on what they found.

Teachers and students

On sampling day, Mokoia student Lachie Hoggard admitted that it's easy to forget rubbish you can't see. He was inspired to take action and recommended that people should try to buy food with more ecofriendly packaging and remember to bring their own bags to the supermarket.

Krystal Stevenson, science teacher at Mokoia Intermediate School, said that students gained a lot from this approach and from learning outside the classroom. "Most of our students know about microplastics from school or home. Now they know much more and what they can do to make a difference."

The project was also fortunate to have support from Tatau Pounamu, a community-led organisation running environmental, health and wellbeing initiatives in Rotorua's eastern suburbs. Tireni Ratema, Pou Tāhu at Tatau Pounamu, helped Mokoia students with sampling and provided a cultural lens to the project. "Strengthening the student's sense of identity and connection to the whenua is important,' says Tireni. "With that knowledge, our tamariki will be better equipped to navigate the future. A connection to land gives you substance, defines your uniqueness and provides a roadmap for wellbeing."

At the end of the day

Meeta says, "Microplastics have been found everywhere from Antarctica to the deepest trenches of the Pacific Ocean[1] so we weren't surprised to find them in the Kaituna catchment. By talking to our students about the issues, we've raised their awareness of how microplastics get into waterways and the damage they can cause.

"For the kids, it's empowering. They understand that through their strong sense of katiakitanga (stewardship) for their lakes and rivers, they're helping to look after the people and environment downstream."

This project was supported by the Ministry of Business, Innovation and Employment's Unlocking Curious Minds fund.

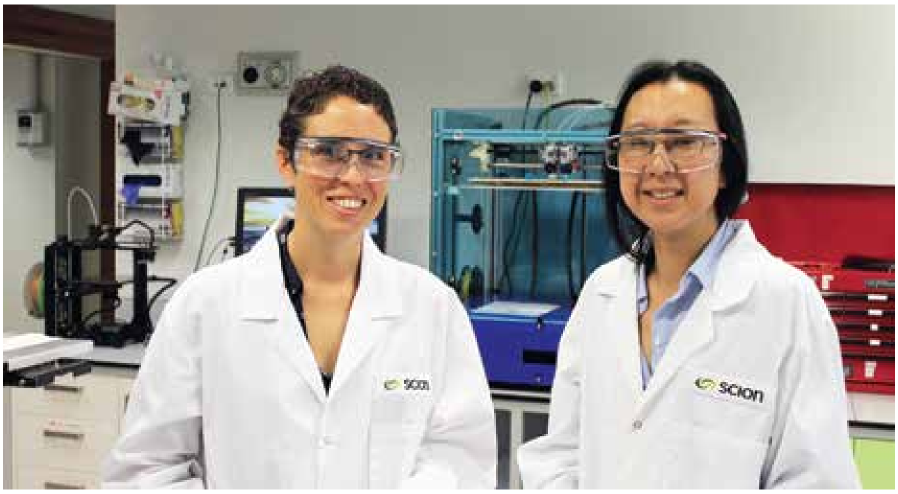
FOR FURTHER INFORMATION on the project contact Meeta Patel at meeta.patel@scionresearch.com

[1] https://www.bbc.com/news/science-environment-48230157

Marie Skłodowska-Curie grantee comes to Scion

Dr Claire Mayer has arrived in New Zealand ready to begin a two-year research programme to explore the use of plant material in 4D printing.

Claire works for France's National Research Institute for Agriculture, Food and Environment (INRAe) and was awarded a Marie Skłodowska-Curie (MSC) fellowship in 2020. MSC fellowships are regarded as one of the most prestigious and highly competitive grant programmes in the world. The fellowship is supporting Claire to work at Scion for two years.



Dr Claire Mayer and Dr Marie-Joo Le Guen will be using plant-based resources in new materials that can change with their environment.

4D printing with plant material

While at Scion, Claire will be researching plant biomass to explore the qualities it could bring to a material when used to replace fossil-fuel components.

Claire explains, "In woody plant biomass, the functional elements are buried within plant tissues but milling or grinding plant material to ultrafine powders could bring hidden qualities to the surface and allow plant material to be used in advanced 3D printing technologies. We specifically want to understand if we can use plant powder to bring new qualities that we can use to design smart materials for 4D printing (where printed material changes in relation to environmental stimuli).

Research will test agricultural byproducts that are widely available in France and New Zealand, such as powders from rice husk, hemp core and flax shives (waste from processing flax and hemp) and pine bark. Scientists aim to create materials that react to the environment using treated plant biomass with new functionalities.

This research combines INRAe's experience milling plant biomass and Scion's knowledge of additive manufacturing.

Why Scion?

When asked why she chose to come to Scion, Claire says, "In Europe, Scion is renowned for its world class capability in biopolymer and biomass extrusion, characterisation and 3D/4D printing using biobased materials. Scion has the capabilities and expertise to characterise powder from biomass and bioproducts (solid-state NMR, confocal microscopy) which supplements the tools available in France. Together we can develop joint methodologies.

FOR FURTHER INFORMATION on this project contact Dr Claire Mayer at claire.mayer@scionresearch.com or Dr Marie-Joo Le Guen at mariejoo.leguen@scionresearch.com

Innovating with seaweed

(Continued from page 1)

Seaweed hydrogels have been made before, but never from species that are growing around New Zealand in sustainably harvestable quantities. The methods used to make the new nanocellulose hydrogels are also significantly cheaper than those currently in use.

Nanocellulose seaweed hydrogels offer not only a potential new revenue stream for New Zealand aquaculture but also access to new high-value onshore and export markets.

Project partner AgriSea New Zealand Seaweed Ltd is continuing the development of the nanocellulose hydrogels for their growing range of seaweed-based products, with Scion providing technical services to AgriSea as needed. Both partners are hugely excited to see this project move to commercialisation so soon.

The project impact leader Dr Marie-Joo Le Guen says, "This is an ideal example of our work here at Scion. Finding solutions to replace petrochemical-based products with renewable biobased products and providing a path for industry uptake.

"Working with an innovative company like AgriSea has been wonderful. Their appetite for exploration and desire to take on new challenges is invigorating."

More innovation on the horizon

The project team is now two years into their three-year project. They hope that the results from thermal conductivity testing will open another avenue of innovation for them to explore.

Stefan and his team have shown that seaweed nanocellulose crystals are able to transfer heat at a rate that is at least twice as fast as terrestrial plant-based nanocellulose. This opens potential for seaweed cellulose that could have a variety of uses in electronic applications in technology for passively cooling batteries in smart phones, for example, where fast and effective heat transfer is essential to extend their life.

The project received Smart Idea funding from the Ministry of Business, Innovation and Employment's 2018 Endeavour Fund.

FOR FURTHER INFORMATION on our seaweed research, contact Dr Stefan Hill at stefan.hill@scionresearch.com or Clare Bradley at clare@agrisea.co.nz

Tree microbiome research programme underway

Scion researchers have started a new programme to develop the first ever tree-root-microbiome model.

The programme 'The tree microbiome project: at the root of climate proofing forests' is a five-year research programme supported by the 2020 MBIE Endeavour Fund and the Forest Owners Association.

Programme leader Dr Steve A Wakelin says, "We have a solid understanding of the importance of tree-mycorrhizal (root fungus) associations to environmental adaptation, but the overwhelming majority of root-microbiome associations are still a mystery.

"We need a tree root microbiome model to develop and test how the microbes on, and in, a tree's tissues can influence its physical properties or phenotype."

The tree microbiome model will be developed for radiata pine, as it is a well-researched and commercially important species that is vital to New Zealand's economy.

'Internet of Things' for trees

The tree microbiome research programme has been encouraged by the large scientific advances made by the human microbiome research programme linking the human gut microbiome to health and wellbeing. Steve suggests that the same logic could apply to trees, i.e., the microbial communities that live on and in trees can have a profound effect on the tree's growth, physiology, health and ability to adapt to change.

Steve says, "We believe that the tree-root-microbiome can act as an environmental sensor that enables plants to interpret and respond to environmental stimuli."

The microbes that are intimately connected with the tree-root are a direct connection to the environment and can send the tree important information about the conditions to help the tree adapt as needed. For example, microbes sensing a lack of water in the soil use that information to adapt wood formation rates.

Outcomes

The work undertaken in this programme will create new insights and stimulate more research into the tree-root-microbiome. In the long-term, this could lead to a forest microbiome specifically managed to increase tree productivity and resilience to climate change, increase resistance to disease and understand and control tree physiology and wood formation processes.

Steve concludes, "What we learn in this programme will be applicable to New Zealand's indigenous forests too, helping us to protect all forests from climate change."

Collaborators in this programme include Lincoln University (New Zealand), University of Western Sydney (Australia), Woodwell Climate Research Center (USA) and Wright State University (USA).

FOR FURTHER INFORMATION
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