SEGMENT

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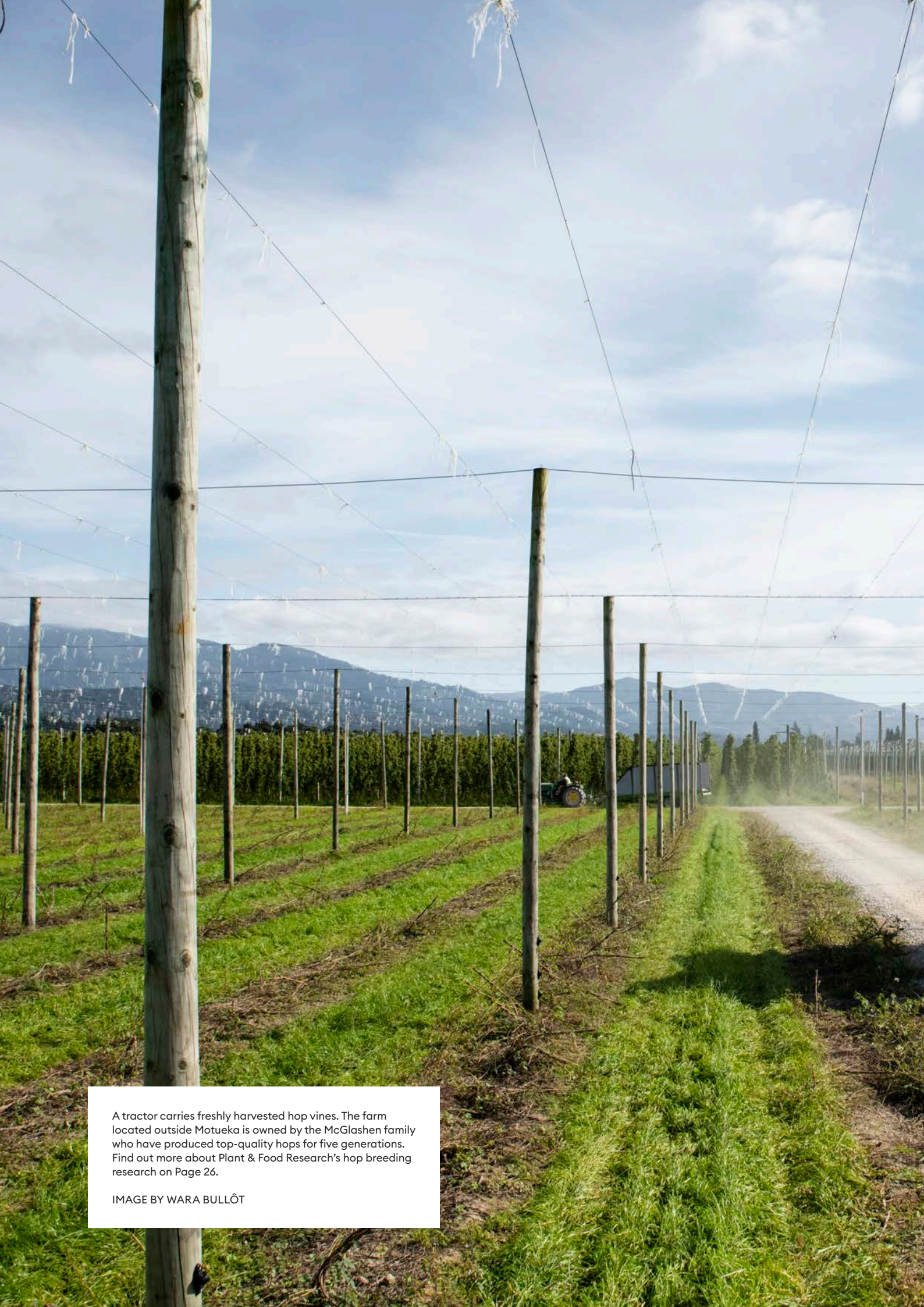

A tractor carries freshly harvested hop vines. The farm located outside Motueka is owned by the McGlashen family who have produced top-quality hops for five generations. Find out more about Plant & Food Research's hop breeding research on Page 26.

IMAGE BY WARA BULLÔT

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Rangahau Ahumāra Kai

FEATURES

INSIDE SLICE

A look inside Plant & Food Research

REGULARS

Welcome to Issue 3 of Segment magazine.

This issue of Segment magazine looks at how science can help shape the future of food, investigating new technologies that could make a huge difference to how we produce food in Aotearoa and globally.

With a growing global population and multiple forces shaping food choices and food production, taking a long-term approach to science will help provide the best options for current and future generations.

In this issue, Matt Philp surveys the future of open ocean aquaculture and explores how new technologies could alter the way we fish. Meanwhile, Gerard Hutching, turns his attention to our land and looks at what can be done in the horticulture and arable industries to adapt to the risks and opportunities presented by climate change.

Richard Rennie writes about some exciting new options for using forage crops, something Kiwis have huge experience in producing, thanks to our dairy industry. And Veronika Meduna explores the possibilities and potential for lab-grown meat.

As proud producers of several world-class hops cultivars, we take you on a fascinating photo journey from breeding to beer. Finally, Volker Kuntzch, CEO of Cawthron, shares his experience and perspective of the seafood industry in Aotearoa.

I really hope you enjoy sharing a bit of our world in this issue.

David Hughes.

David Hughes
CEO Plant & Food Research

Scientists convert plastic waste into vanilla flavouring

In the future, vanilla ice cream could be made from plastic bottles! Scientists from the University of Edinburgh have discovered a way to use genetically engineered *E. coli* bacteria to turn plastic waste into vanillin, the world's most used flavouring agent in food and beverages. It is the first time a valuable chemical has been brewed from plastic waste and the researchers believe that this plastic-derived vanillin is likely to be safe for human consumption.

Health tracker for plants

Researchers from North Carolina State University have developed a sensor that can tell when plants are facing disease or stress, such as crop damage or extreme heat. The 'wearable' patch monitors plant stress and disease in a non-invasive way by measuring the volatile organic compounds (VOCs) emitted by plants. Scientists tested the prototype on a tomato crop, and the patch was able to sense stress and physical damage, including late blight infections to the crop, within just three hours after being applied. This continuous monitoring technology will allow growers to identify plant diseases as quickly as possible, enabling them to reduce the spread of disease.

Kānuka: Aotearoa's liquid smoke

The native kānuka plant (*Kunzea ericoides*) is being transformed into a new 'liquid smoke' food flavouring, described by its creators as a "Hangi in a bottle". Two University of Auckland academics and Ruatōria whānau are behind the start-up Nuka, who are looking to commercialise the product. Putting kānuka wood chips into a pyrolysis machine, exposing them to high heat and starving them of oxygen creates a food-flavouring ingredient with an instant hangi taste.

Eating mushrooms may lower risk of depression

Regular mushrooms – like the type from the supermarket – may have mental health-boosting benefits. New research from Pennsylvania State University College of Medicine found that mushrooms are the highest dietary source of the amino acid ergothioneine, an antioxidant that may protect against cell and tissue damage in the body. Studies have shown that having high concentrations of ergothioneine in the body may help prevent several mental illnesses, such as schizophrenia, bipolar disorder and depression.

A new toothpaste may help treat peanut allergies

Treating food allergies might soon be as easy as brushing your teeth! A team of researchers at New York City–based company Intrommune has developed a new type of experimental toothpaste that may help users overcome peanut allergies. The toothpaste contains small amounts of the active ingredient in peanuts that affects allergy sufferers. The hope is that regular daily exposure to small sums of the allergen will build up immunity in users. In the future, the toothpaste could be adapted to use with other proteins to provide immunotherapy for other allergies.

Cryopreservation: conservation strategy to combat myrtle rust

Myrtle rust (*Austropuccinia psidii*) is a fungal disease that attacks plants in the Myrtaceae or myrtle family, including pōhutukawa, rātā, mānuka and swamp maire. It has spread rapidly in Aotearoa New Zealand since its discovery in 2017, threatening many taonga species that are culturally and economically important. Scientists at Plant & Food Research are exploring cryopreservation freezing as a conservation technique that could protect at-risk species for future generations. The benefit of cryopreservation is that plant material could be stored for decades or centuries without there being changes in its genetic components.

The blue frontier

Growing fish and seafood in the challenging conditions of the open ocean could provide a low impact way to produce nutritious food for a growing global population. For countries like Aotearoa New Zealand, the enormous ocean space could reduce pressure on inshore areas and help mitigate the effects of climate change. Matt Philp looks at how other countries are approaching open ocean aquaculture and what the future might hold here.

SalMar ASA's Ocean Farm 1 being towed to sea.

In the autumn of 2017, three powerful tugs towed the world's first open ocean net pen into position off the coast of central Norway. Christened Ocean Farm 1, it resembled something more like a semi-submersible fortress than an aquaculture facility, comprising a vast circular rig 68 metres high by 110 metres in diameter.

Launched by Norwegian aquaculture giant SalMar as a pilot facility, Ocean Farm 1 is a clear signal that aquaculture is set to move into deeper waters. Already, SalMar has sought permission to deploy a bigger and better successor facility, capable of producing up to three million salmon a year.

A 2021 RaboResearch report (A Deep Dive into Offshore Aquaculture), described taking aquaculture out to sea as a "logical solution" for countries such as Norway, where there's a constraint on new permits to farm in the fjords, and China, which suffers from a dearth of suitable coastal sites. But the development of open ocean aquaculture (OOA) is likely to be a global phenomenon given world population growth and the rising demand for seafood, the effects of climate change, and the increasingly congested and contested nature of coastal space.

The North Sea is central to Europe's exploration of open ocean aquaculture. Norway, the world's second largest exporter of fish and seafood, is taking a heavy engineering approach to farming salmon in that more dynamic ocean setting, drawing in part on decades of experience and wealth built up by its offshore oil industry.

Launched by Norwegian aquaculture giant SalMar as a pilot facility, Ocean Farm 1 is a clear signal that aquaculture is set to move into deeper waters.

The Netherlands is heading down a different route. A 2016 feasibility study by Wageningen University Marine Research poured cold water on the prospect of intensive fish farming in the Dutch North Sea, but suggested there was potential for seaweed and shellfish, particularly when tied to other offshore developments – mussel production alongside ocean wind farms, for instance.

"Offshore aquaculture development is considered a viable option, although the North Sea is a technical challenge owing to its dynamic conditions," remarks one of the report's authors, Marnix Poelman.

The first pilots of mussel culturing will begin next year in less exposed but still challenging waters. Marnix says it's expected that The Netherlands could grow its mussel production by 50%. But he adds a caveat: "This potential will only be feasible by implementing seaweed and shellfish as an integral part of the food system."

Closer to home, Australia is taking a similarly integrated approach to its early OOA work. The Tasmanian-based Blue Economy Cooperative Research Centre (BECRC) brings together 40 research partners

from various countries, including New Zealand, and draws on expertise that runs the gamut from maritime engineering to renewable energy to aquaculture.

Like the Dutch, the Australians, who have the world's third largest exclusive economic zone (EEZ), are looking for ways to marry the development of offshore aquaculture with a transition from fossil fuels – specifically, incorporating something like salmon farming alongside offshore infrastructure deployed to harvest wind and ocean energy and convert it to green hydrogen.

Professor Chris Carter leads the BECRC's Seafood and Marine Products Programme. He cites Tasmanian salmon farming as a key part of future offshore aquaculture, but says there are good prospects for oysters, seaweed and mussels, along with various other high value species in South Australia, West Australia and Queensland.

"The BECRC is particularly interested in aquaculture systems for different regions, temperate to tropical, farming multiple aquaculture species together and integrated with other offshore industry," he says, adding that the benefits of heading into deeper water include being somewhat more insulated from the effects of climate change, and being able to farm on a far greater scale.

There are challenges, naturally. "Structures will be subject to a whole set of hydrodynamic forces. Do you modify existing technology or is it more about a total rethink and new systems? You'll need to limit the time people would spend out there, too, with safety being critical. And because these structures will be more distant, there are also challenges around transport. That leads to questions about the use of renewable energy sources – in the case of the Blue Economy CRC, hydrogen vessels are being discussed."

"There are also a whole series of technical questions about growing animals in these sites, where there will be quite challenging hydrodynamic conditions, maybe greater current speeds and storm events, as well as biosecurity issues with different pathogens present. Biofouling is another issue. How do we manage that, and what are the implications?"

"So it's definitely early days, but of course that means there is plenty of opportunity, too. For aquaculture, our opportunity is around supplying a range of high quality seafoods of high nutritional value and with transparent sustainability credentials," says Carter.

A virtual representation of Blue Endeavour, King Salmon's proposed open ocean aquaculture farm for Cook Strait.

Dr Damian Moran leads the Open Ocean Aquaculture research direction at Plant & Food Research.

In New Zealand, where the Government's goal is for aquaculture to be a $3 billion industry by 2035 and where we enjoy the advantage of a massive Exclusive Economic Zone (EEZ), a number of entities have irons in the fire. New Zealand King Salmon has applied for resource consent to place its 'Blue Endeavour' farm north of Cape Lambert to take advantage of Cook Strait's cool temperatures, high flow and deep water. Sanford has sought consent to farm salmon in open ocean at the south-east end of Foveaux Strait, and Ngāi Tahu Seafood has done the same for a deepwater site off Stewart Island/Rakiura.

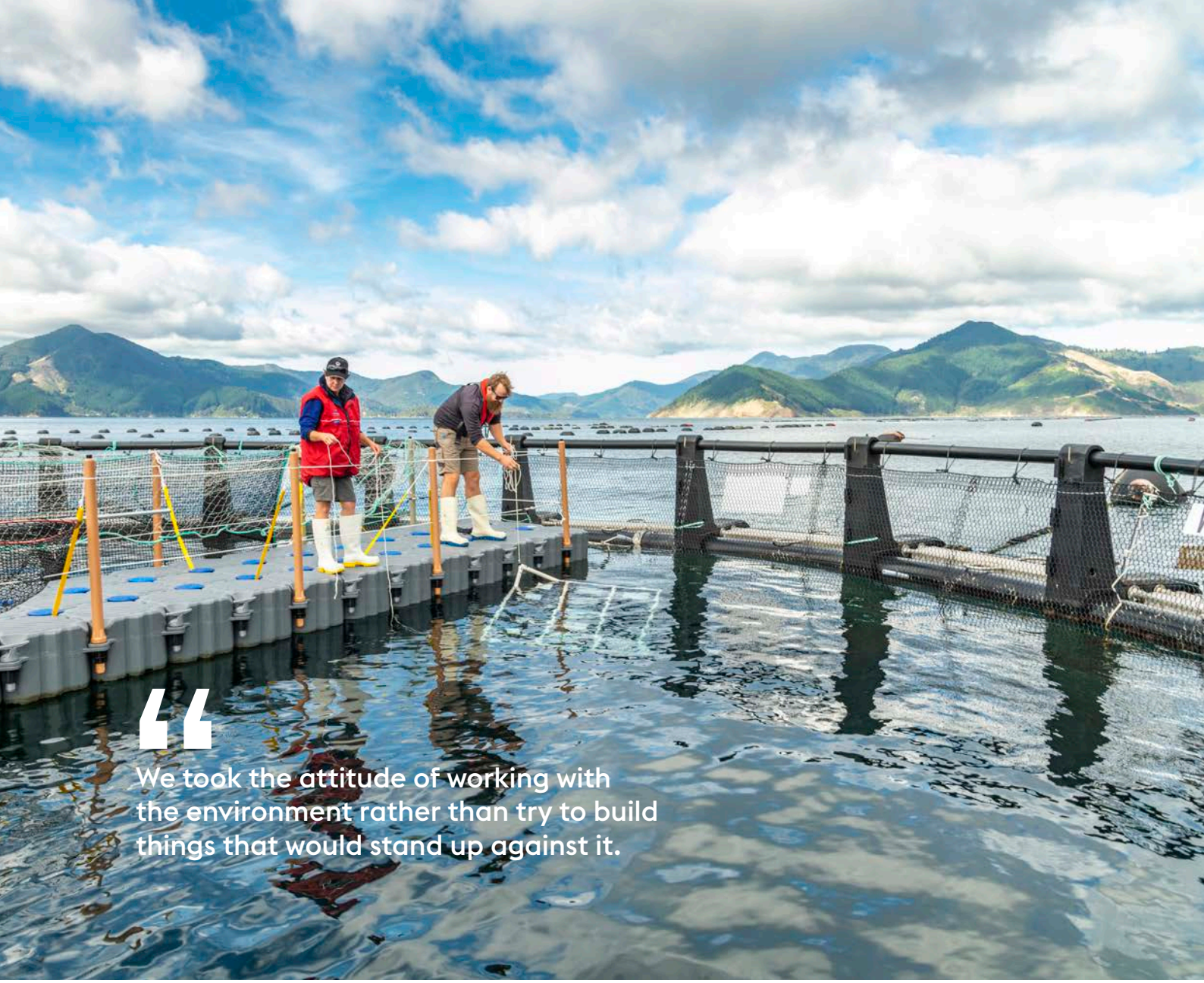
Behind the scenes, the Cawthron Institute is doing valuable research. In early 2021, the Nelson-based organisation, in collaboration with overseas researchers and New Zealand industry partners, successfully trialled a full-scale prototype 'Shellfish Tower', designed to grow mussel spat, oysters and other species in exposed waters. Plant & Food Research is also heavily involved in developing the science that will inform the evolution of offshore aquaculture in this country.

Dr Damian Moran, who leads the Plant & Food Research Ngā Tai Hōhonu Open Ocean Aquaculture research direction, says the same factors driving the development of OOA overseas are in play here. The Marlborough Sounds, for instance, hub of our lucrative salmon industry, has limited scope for any expansion. However, New Zealand seems likely to take a different approach to OOA from those of some other nations. We don't have the oil money or infrastructure of Norway, for instance, and potential investors here probably won't have the kind of capital needed for that heavy industrial approach.

Moran says Plant & Food Research is looking at the potential to adapt conventional sea pen technology from overseas to the New Zealand setting.

"Any fish farm will use services from other marine engineering operators. We might build our finfish farming around mussel farming logistics and services, for instance. We already have some open water mussel farming ventures, so can we tap into that."

Another line of enquiry is mobile oceanic farms. In collaboration with scientists at other New Zealand



Scientists from Plant & Food Research conduct Open Ocean Aquaculture research in the Ngāi Tahu Seafoods-owned Beatrix Bay sea pen.

and overseas research organisations, Plant & Food Research is two years into a five-year proof-of-concept programme to develop a working prototype, with the goal of growing Chinook salmon and tāmure/snapper in 1000 cubic metre moored enclosures in year five. Programme leader Dr Suzy Black says it's a very different approach from that seen in Norway and elsewhere. "We took the attitude of working with the environment rather than try to build things that would stand up against it."

Mobility offers the opportunity to get out of the way of devastating one-off storm events – a bit like a ship taking shelter behind an island. But the advantages go further. "If you're mobile, you can move to places where there are the best temperatures for growth and the best water quality. You can move the animals so they're in optimal conditions year-round."

What are the challenges? "This is an aquaculture system that's a long way from business as usual. If you're several kilometres offshore, just being able to access your fish and general operations are really challenging. On the engineering side, can the materials withstand the forces in the open ocean? And then there's monitoring your fish: if you don't have people on a farm, how do you measure how the fish are growing? Are they happy? Are there predators out there?"

Plant & Food Research is developing ways of measuring performance remotely, using cameras and cutting-edge computing to distil useful data. A group is also working on computer vision analysis to track individual fish – using the fingerprint-like spot patterning of tāmure/snapper, for instance.

"You can get much more information about how a population is doing if you can track individuals,"

In New Zealand, Chinook salmon will always be first cab off the rank, with species such as tāmure/snapper, haku/kingfish and araara/trevally likely candidates for warmer North Island waters.

remarks Moran, who says that Plant & Food Research is also investigating ways to deal with biofouling of offshore infrastructures, with potential solutions including the use of herbivorous service fish and single-use harvestable nets.

What fish will be farmed? In New Zealand, Chinook salmon will always be first cab off the rank, with species such as tāmure/snapper, haku/kingfish and araara/trevally likely candidates for warmer North Island waters. "We're very much about fish-centric design – what does the fish need to be at its best? That's really important to us," says Black.

"We've got a PhD student looking at the flows in which tāmure/snapper grow best, the temperatures they prefer and whether they match optimum temperature for growth. We also have a PhD student in The Netherlands looking at similar things for Atlantic salmon."

The question of aquafeeds also looms large. New Zealand salmon farming relies on imported dry pellets. But as Moran notes, the industry's sustainability credentials will ultimately be determined by what our fish are fed.

"Eventually, we want to be producing fish that are not just 'made in' but 'made of' New Zealand," he says. "So we have to gain control of the bottom of the food pyramid and design and build that ourselves. Technically, that's difficult because it encompasses a huge range of sizes and types – we've got to provide everything from dust-sized live prey up to adult diets – and because these fish are carnivores they require large amounts of fat and protein."

Plant & Food Research is exploring high quality diets for larvae, and, at the other end of the spectrum, investigating novel sources of protein for adult fish, such as insects, and even lucerne, rye grass and other crops.

Whatever particular shape it takes, moving aquaculture into deeper waters would seem to be inevitable. "In the future," predicts Moran, "many of the fish we eat will in one way or another be reared."

TOP: Dr Suzy Black and team are exploring the possibilities around mobile open ocean aquaculture.

BOTTOM: Close up of snapper, one of the species which could be reared in the open ocean in future.

The pasture advantage

Thanks to our temperate climate, New Zealand farmers are expert producers of forage crops. Not only do these crops provide rich food for producing livestock, they have untapped potential as sources of protein or biofuel. Richard Rennie explores the possibilities.

New Zealand has a reasonably reliable rainfall and grass to thank, at least in part, for its verdant lush greenness that makes the country's rural landscape so easy on the eye. But underlying those rolling vistas of pasture and crop is a vast surplus of plant protein that creates a paradox for our farming sector.

"Grass fed" red meat and milk products are in high demand internationally, increasingly recognised for their high-quality, nutrient-dense food value. However, having more crude protein available in pasture than livestock are capable of digesting leads to the protein being converted and excreted as nitrogen. This in turn contributes to excess nitrate-nitrogen in water systems and aquifers.

New Zealand scientists are working on ways to extract protein from our abundant forage crops, including ryegrass and alfalfa, in a way that can deliver an alternative protein for human food. This could offer a means to better balance livestock diets, without diluting the "grass fed" value proposition. Alternatively, after recovering the protein, the residual fractions could go towards making biofuels to drive a low-emissions future.

Dr Lee Huffman Food Solutions Leader at Plant & Food Research, and her team are focused on maximising the total amount of protein extractable from pasture crops. The team have developed proprietary systems and processes to do so that include technology adopted from other sectors, including vegetable juicing and milk protein isolation.

"The technology we have developed could apply to any soft, leafy green plant, including common pastoral feed crops ryegrass, alfalfa, kale and forage brassicas.

"Our modelling shows that alfalfa and ryegrass are the best crops for establishing a plant protein industry in New Zealand. Traditional technologies have focused on extracting RuBisCO, a protein that is only 50% of the total protein available. We've developed a technology with a much higher yield, extracting as much protein as possible. Combining a high potential yield with existing

land use and reduced environmental impacts creates an attractive economic proposition for establishing a new food sector."

Previous extraction work has also tended to focus mainly on the lower value animal feed market. Huffman and her team see an opportunity for formulating both high-value human and companion animal and fish food products using protein extracted with their closely guarded technology.

Extracting food-grade proteins from leafy plants is not an easy task. The competition from well-established seed crops like soy and peas is significant, amplified by the economies of scale that vast broad-acre farms in the United States, Canada and Brazil offer.

Subsidisation of traditional seed crops in many of those countries can tilt the economics against emerging technologies, which may struggle to achieve the capital investment required to scale up to commercial production.

One advantage in favour of leaf protein is the high nutritional value, with leaf proteins being "complete proteins" containing all nine essential amino acids for human nutrition – a rare attribute for a plant protein.

A further economic challenge facing recovering protein from pasture crops is that New Zealand dairy farmers have great economic success in converting pasture to milk, and the significant capital tied up in their milking platforms encourages maximising milk production. That need discourages growing pasture crops to extract protein directly, rather than through milk solids.

But in a world where dairy farmers encounter increasing pressure to lessen their environmental impact, redirecting a portion of the farm from milk production to grass protein extraction may provide an avenue for that gentler footprint.

Modelling by Plant & Food Research scientist Dr Richard Edmonds established that alfalfa and ryegrass were the two best crops for establishing a plant protein industry in Aotearoa.

Modelling on-farm performance reveals that nitrogen-nitrate losses can be significantly reduced, and greenhouse gas lessened somewhat, when a portion of the farm is closed off to grazing and the pasture recovered for protein extraction, with the residual "cake" fed to cows as a supplementary feed.

Plant & Food Research has engaged farm consultants to analyse how much of a reduction in nitrogen-nitrate losses such a dietary tweak may provide, and how this

could be incorporated into farm nutrient management plans for improved environmental performance. As the primary sector develops mechanisms for allocating and pricing on-farm environmental impacts, the incentive to consider such technology is likely to grow.

For non-dairy farmers the opportunity to grow a pasture crop for protein harvest offers another valuable cash crop or additional diversified income for dry-stock farmers.

"But it is a long runway to commercialisation and involves working hard to bring on board enthusiastic industry players," says Allan Main, Business Manager at Plant & Food Research.

Meanwhile, there is a clear trend towards diversifying protein consumption amongst consumers, which provides a growing opportunity for new plant proteins. Around a third of the population in Aotearoa New Zealand are already limiting their meat consumption, with 15% eating a largely vegetarian or flexitarian diet. That drift is expected to continue as consumers increasingly factor in environmental considerations to their dietary choices.

"The proteins we are extracting also have an amino acid profile that is comparable to the 'ideal' protein, it is functional with properties that can be managed during processing, for example solubility, gelling and emulsifying qualities," says Huffman.

Other pasture protein extraction work is also being undertaken in New Zealand by Leaft Foods based in Lincoln. The company has recently received $8 million funding, through the Ministry for Primary Industries, to develop protein technology.

Just as protein from grass may be used to fuel humans, the cellulose by-product of protein extraction could also play a role as a substrate for low-emissions fuel for vehicles, particularly as New Zealand moves towards a decarbonised 2050.

Just as protein from grass may be used to fuel humans, the cellulose by-product of protein extraction could also play a role as a substrate for low-emissions fuel for vehicles, particularly as New Zealand moves towards a decarbonised 2050.

While electric vehicles will play a role, aided by rebates, internal combustion engines could provide an opportunity to replace petrol with lower-emitting ethanol blends, or "flex-fuel" which includes blends of up to 85% ethanol.

A study by the Argonne National Laboratory in Illinois has found using plant-sourced ethanol will reduce emissions compared with conventional petrol by as much as 88% to 100%, depending upon the feedstock used. In addition, it also reduces the release of other harmful compounds, including benzene, a suspected carcinogen.

Scientists in Wales are developing "grassohol", grass-sourced cellulosic ethanol suitable as a fuel feedstock. Ironically, in a region once renowned for its coal production, the Wales-based work is focusing on high-sugar ryegrass varieties that produce greater volumes of ethanol and which have also proven ideal for high-producing dairy cows.

Researchers in Nebraska have also found switch grass, an adaptable grass that can grow on millions of hectares of land that cannot support grain crops, is a suitable ethanol carbohydrate feedstock. Trials reveal it can produce six times the energy output to energy consumed to create the ethanol, with 94% lower emissions than regular petrol.

Flex-fuel vehicles are not new to New Zealand, and back in 2006 Ford was hailing the arrival of this country's first flex-fuel vehicles, two Ford Focus hatchbacks.

Those vehicles had the ability to run on up to 85% ethanol to gasoline and were touted as a means to assist New Zealand to meet its (then) Kyoto Protocol obligations, with biofuel emissions not counted as greenhouse gases.

Brian Cox, CEO of the Bioenergy Association of New Zealand, says considering grasses for fuels is a "no brainer" that provides the country with a low-emissions option without wholesale electric vehicle (EV) adoption, and farmers another income stream.

"I was first approached by a scientist 20 years ago about this, but little came of it. However, we do now have a government that is wanting to understand more about its options here, and that is encouraging.

Just as farmers turn surplus grass into silage bales to feed out during tight times, the same bales can be held and sold to ethanol processors as needed, providing a useful additional income option.

"For an area using a food bio-digestor to create ethanol, they could add in the silage as needed, depending upon the flow of raw materials."

Sheena Thomas, strategy lead for Z Energy's biofuels, says the company is evaluating whether to re-commission its biodiesel plant in South Auckland as the Government's Sustainable Biofuels Mandate takes effect from 1 April 2023.

The Government mandate initially requires fuel to contain 1.2% sustainably sourced biofuel, rising to 3.5% by 2025.

"The critical thing with any biofuels investment is to have policy certainty, because that is key to having the

Distillation column at Z Energy's biodiesel plant.

confidence to make capital investment. The mandate goes a long way towards providing some certainty, which is why we are currently completing a detailed front-end engineering assessment for our plant."

Whilst the main feedstock for Z's biodiesel is inedible tallow – a by-product of meat production – plants and crops are also considered for the company's other focus on aviation biofuel. For this, Z Energy has worked with Scion researchers on options using forestry waste and woody biomass in consortiums that have also included Air New Zealand, LanzTech and Refining NZ. There is a range of feedstock that can be used for biofuel production, including rotation crop such as sugarbeet, or miscanthus, a plant similar to switchgrass, which has shown promise as a biofuel feedstock in the United States.

Thomas says that the country's medium- to long-term strategy for biofuels should fit within the broader decarbonisation pathway recommended by the Climate Change Commission. Specifically, the focus should be on electrification of the light vehicle fleet (which currently relies on petrol), and biofuels for the harder to decarbonise areas such as heavy freight, aviation and marine. Counter-intuitively, the playing field for biofuels is currently heavily weighted towards ethanol, and this needs to change in order to encourage more local biodiesel processors to engage.

"Ethanol is currently exempt from excise tax as well as carbon tax under the Emissions Trading Scheme (ETS), but this is not the case for biodiesel, which is only exempt from ETS. This effectively gives a significant tax break to ethanol-blended petrol, which is ironic given the diesel fleet will prove harder to decarbonise without a low-carbon liquid fuel alternative and therefore that is where the incentive should be placed."

Dr Stewart Collie, Team Leader for AgResearch's Bioproduct and Fibre Technology Unit, said he and his colleagues are researching how biofuels and bio-refining could fit into the bigger picture of pastoral farming in New Zealand.

"For us it is about understanding what the best combination of processes are for fitting into pastoral farming."

He acknowledges the conflicts that have arisen between "food versus fuel" in the past overseas – for example in the United States there's been a conflict between corn grown for ethanol and for food.

"It is a little more indirect for ryegrass, but ultimately food is where ryegrass has been channelled. But bio-refining may provide the potential to achieve both from the same source, providing both a reduced protein feed source, and a cellulose feedstock stream for ethanol production from the 'squeezed' ryegrass."

AgResearch scientists are analysing the models that may be best suited to farmers participating in bio-refining, including looking at whether some level of on-farm refining could be done, or delivery made to a central point.

"It really comes down to thinking about how the pieces all fit together in a way that is economically as well as environmentally valid."

A kinder kind of meat

From the meat in a burger to salmon in sushi, more of our foods could soon come from the lab rather than the farm. Changing consumer preferences have already prompted record-breaking investments in novel lab-grown foods, and now, the COVID-19 pandemic has given us even more reason to explore sustainable future foods. One promising sustainable, environmental- and animal-friendly technology is cellular agriculture. Veronika Meduna investigates.

Cellular agriculture technologies involve growing cells from animals or crops in the lab to produce new foods. It is part of the booming alternative-protein industry, which raised US$3.1 billion in investments in 2020, according to the Good Food Institute. The first wave of alternative protein companies focused on meat alternatives made from plants – mostly protein-rich legumes such as soy and mung beans, with vegetarian and vegan consumers in mind.

But cellular agriculture is distinct from plant-based meat replacements because it harnesses the potential of animal cells. Its products are, at least in theory, identical to animal foods.

It employs two main methods. In the first method, acellular technologies use microbes or fungi as factories to produce specific ingredients that would otherwise be taken from animals. Perfect Day, for example, add genes for certain cows' milk proteins to fungal cells. Brewed in large fermentation vats, the fungal cells are fed on plant sugars, and the resulting plant proteins are used to make a liquid similar to cows' milk, animal-free ice creams and cream cheeses.

In 2019, Fonterra took a minority stake in Motif FoodWorks, a US company developing and commercialising similar bio-engineered animal ingredients. At the time, innovation executive Judith Swales assured the co-operative's farmer-owners that traditional dairy would remain at the core of business, but that Fonterra had to stay at the forefront of innovation in "complementary nutrition" from plants, insects, algae and animal cells.

In the second approach, cellular technologies involve removing a small biopsy sample of muscle from a plant or animal to isolate specific stem cells, which are grown in a broth of sugars and amino acids, supported by a 3D matrix and mixed with fat cells, to mimic traditional meats. Meat cultivated in this way caters for people who enjoy the taste of meat and dairy products but, for various reasons, prefer not to eat them. Dutch company Mosa Meat, which produced the first "cell-based" hamburger prototype in 2013, hopes to have a burger on the market by the end of 2022.

GOOD Meat's cell-based chicken bites are the world's first and only cellular meat approved for sale in Singapore (in December 2020). The chicken bites look and cook like traditional nuggets, and according to those who've had a chance to try some, they taste like the real thing, too. That's because they are real chicken, at least partly – except that no poultry was killed in the process.

"New Zealand has a great deal to offer in cellular meat research", says Dr Laura Domigan, a researcher at the University of Auckland who leads a $NZ3 million

PHOTO OWNER: GOOD MEAT

GOOD Meat's cell-based chicken products are the first cellular meat products approved for sale in Singapore.

Catalyst Future Foods project, in collaboration with Singapore, to investigate new hybrid foods that combine plant-derived proteins with cultured livestock cells. In this project, Singaporean researchers focus on commercialisation, while scientists here tackle more fundamental research questions, such as finding a replacement for foetal bovine serum, which is used to add growth factors to lab-grown animal cells.

Domigan's lab's focuses on cow, deer and sheep cells, and even on specific livestock breeds, to see if the characteristics of meat translate when cells are grown in tissue culture. Their research will investigate flavour and texture and, eventually, a nutritional comparison of cell-based versus traditional meats.

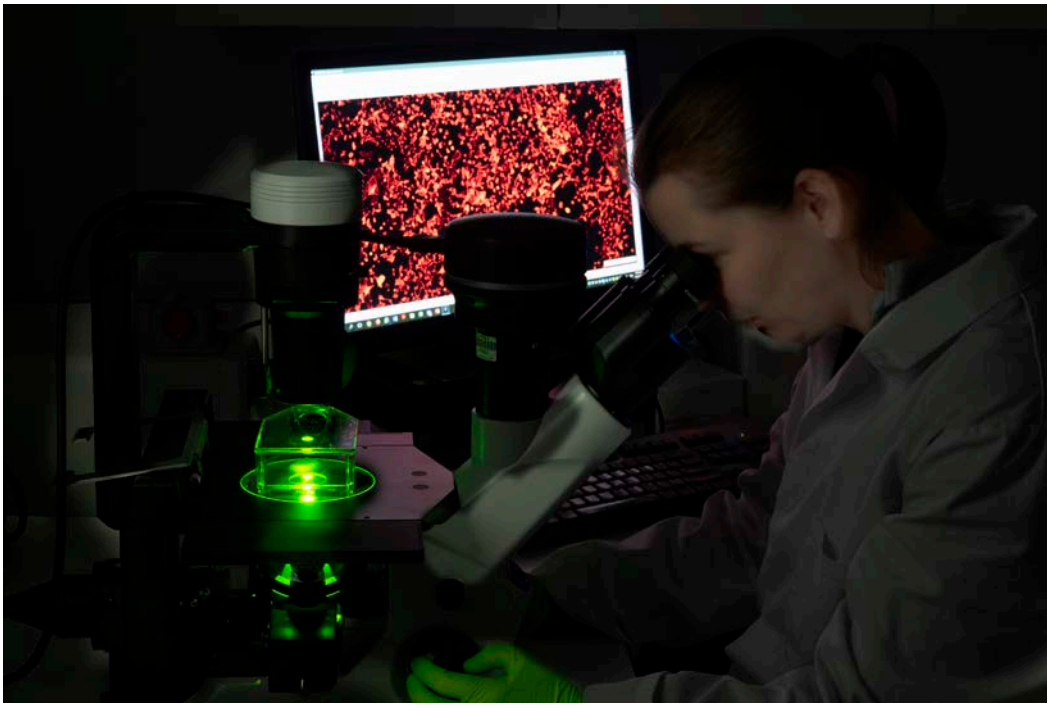
There are several innovation drivers in cellular agriculture, particularly for meat. Currently, livestock farming takes up nearly 80% of agricultural land, but produces less than 20% of the world's calories. Food security is another factor, brought into sharper focus by the pandemic's disruptions to supply chains. As food demand increases globally, consumer concerns about animal welfare and greenhouse gas emissions from livestock have added further incentives. "There are large consumer groups coming through that are very ethically focused in their choices, and also have the income to afford to be," says Domigan.

Like disruptors in other industries, many companies pioneering cellular agriculture are Silicon Valley start-ups, but there are now around 80 worldwide, including in Australia, working to commercialise lab-grown meats and seafood.

Wildtype Foods and BlueNalu, Inc. are two companies redefining seafood. With sushi-grade salmon, mahi-mahi and bluefin tuna prototypes released, this is seafood without the sea, with no need for fishing or farming.

Supported by Smart Idea funding from the Ministry of Business, Innovation and Employment, Plant & Food Research scientist Dr Georgina Dowd and her team are working with researchers in Canada and the University of Otago who have been culturing fish cells and understanding cell signalling mechanisms for decades. Together they are now working with the goal of initiating muscle-derived cell lines from fish important to New Zealand, like tāmure/snapper and Chinook salmon.

Dowd says fish cell culture techniques were originally established to detect viral diseases plaguing



Dr Georgina Dowd at Plant & Food Research is leading research into the cellular agriculture of seafood.

aquaculture industries internationally, and while fundamental research on mammalian cells is ahead of similar fish studies, fish cells have distinct advantages over other animal cells when it comes to cellular agriculture. Mammalian cells have to be grown at 37°C and at elevated carbon dioxide concentrations, but "fish cells can grow in ambient air, and usually at lower temperatures, so straight away your costs of scale-up reduce".

And while mammalian cells eventually stop dividing, fish cells have been shown to spontaneously immortalise, providing a potentially endless supply for cellular production. But the work comes with its own challenges, particularly the cultural acceptance of the technology for taonga species like tāmure/snapper.

As the world warms, and the impacts of climate change become more evident, some crops become more difficult to grow. Coffee is one of them, but Finnish company VTT is developing a cellular equivalent, growing coffee plant cells in a bioreactor and roasting the dried plant matter, just like coffee beans.

Sustainability is one of the main drivers for cellular horticulture, says Plant & Food Research scientist Ben Schon, but the uncoupling from growing seasons and better local availability are added benefits.

Plant cell culture has a long history, particularly in the production of medicines, and as any gardener knows, plants can re-sprout from many parts. "Plant cells can be totipotent – they can grow a whole plant. But whether you can get these cells to … make a piece of fruit or vegetable tissue could be a real challenge."

Schon says cellular horticulture is at an early stage and grapples with similar challenges of replicating the flavours, textures and nutritional qualities of natural foods. But its goal is not necessarily the equivalent of an apple or avocado, but rather a new food with equal properties. Regardless of any future products, Schon says the research will deliver fundamental insights into metabolic pathways in plants and fruit development.

As technologies develop and the range of possible future foods widens, regulation is the next frontier for cellular agriculture, says Dr Olivia Ogilvie, a research fellow at the University of Canterbury. And while Singapore has developed a new regulatory framework for lab-grown foods, it seems likely that each country will develop its own, with New Zealand and Australia relying on existing Food Standards (FSANZ) frameworks, while the USA is developing joint regulation processes between the Food and Drug Administration and the Department of Agriculture.

Studies to explore consumer acceptance are also underway, and Ogilvie says for a technology with such far-reaching implications it is critical to have public discussions early on. She sees great potential for developing intellectual property in New Zealand. Domigan does not expect cellular agriculture to replace traditional farming any time soon. "There's always going to be a place for traditional meats, particularly traditional meats that are produced in an ethical and sustainable manner, which New Zealand tries really hard to do." ●

Growing challenges

Adapting for climate change

Gerard Hutching looks at the potential impact of climate change on the arable and horticultural industries and asks what can be done to ensure the future remains bright.

Dr Brent Clothier, Principal Scientist at Plant & Food Research, is reluctant to be viewed as a Pollyanna when it comes to climate change, but he cannot fail to see a rosy side to a climate-warming scenario for horticulture (extreme events notwithstanding).

"There's massive potential in areas that aren't traditional horticultural areas, such as Taranaki. At present in New Zealand there are about 180,000 hectares under horticulture and arable farming. However, in terms of climate resources, there are around 2 million hectares that could potentially sustain these industries," he says.

That said, there are significant value-chain issues that need to be overcome before Taranaki becomes another fruit bowl.

Clothier's Plant & Food Research colleague Dr Jill Stanley echoes the positive sentiments. "I'm an optimist. I think New Zealand will do well as long as it plans well, including adaptations for more intense weather events. We have a huge opportunity to grow a wide range of crops successfully," she says.

Plant & Food Research is just one of the growing body of organisations, including government departments, regional councils, research institutes and businesses, which are mapping out a path for the future as the planet continues to warm.

Industry body Horticulture New Zealand predicted in 2019 that by 2028 the land area in horticulture would have risen to 140,000 ha, with most export fruit growth expected in avocados, pipfruit and kiwifruit, while the greatest vegetable-growing expansion would be in potatoes, onions and process vegetables.

Victoria University climate researcher Professor James Renwick says climate change means more energy in the atmosphere, feeding into weather features. When there is fine weather under a big high-pressure system, everything dries out faster, it is hotter, and droughts occur more quickly. On the other hand, when there is a storm there is more water in the air, and more rain falls.

For vulnerable crops this could spell disaster, not that apples, cherries and lettuces have never been beset by damaging hail and downpours – just that these events will become more frequent and destructive.

Some of the mitigation measures that researchers are investigating include: covered cropping and precision irrigation, developing new varieties which will perform under hotter temperatures, changing the type of crop grown, and shifting the locations of crops. Others are more transformational as a way of protecting the $10 billion of value that horticulture and arable farming represent for Aotearoa.

In August 2019, the Government launched its draft National Policy Statement on Highly Productive Land, to ensure the country's best growing land is not lost to lifestyle blocks and housing subdivisions.

"Every year we put 40,000 ha under lifestyle blocks, asphalt and infrastructure. The result is ride-on mowers and ponies instead of productive land," Clothier says.

One cause for optimism: horticulture and arable farming have relatively modest carbon footprints. Nevertheless, companies such as T&G Global and

Zespri Group Ltd are conscious of the need to cut down on waste and to lower greenhouse gas emissions.

"A good example of this is our current life cycle assessment of our own-grown apples we are conducting at present," says Sustainability Manager for T&G Global Courtney Simpson. The company is aiming to be net zero carbon by 2050.

"At our Reporoa tomatoes site, Ecogas is building Aotearoa's first large-scale food waste-to-bioenergy facility, which will recover 75,000 tonnes of organic waste and turn it into clean energy," says Simpson. This will provide renewable electricity, heat and CO_2 to enhance the growing conditions of our tomatoes – a fantastic carbon-neutral, circular alternative to natural gas."

Changing tactics

One way to reduce the impact of climate change is to implement tactical adaptations and modify existing production practices.

"The day-to-day stuff stays the same, but flowering and harvest dates come earlier so you have to make a change, such as organising your seasonal harvest workers for different dates," says Clothier.

Zespri, which generated $3.58 billion in global fruit sales revenue last year, sees the upsides in climate change, while not downplaying the downsides. It is possible that warmer temperatures and longer growing seasons could result in higher quality fruit, while some colder regions may become more suited to production.

To make sure they're prepared for what the future brings, Zespri have created a "Climate Risks and Opportunities" report which outlines the physical climate risks and the tactical adaptations growers need to adopt. Among the risks are increases in pests and pathogens, and a reduction in budbreak because winter temperatures are not low enough.

Most kiwifruit orchards in the Far North rely on dormancy regulators to encourage budbreak, but the future of this approach is uncertain, with the Environmental Protection Authority proposing a phase-out of some chemical products.

Plant & Food Research scientists are working on new regulators while also keeping climate warming top of mind when developing new kiwifruit varieties. Stanley says that although climate change will open up opportunities in cooler regions, growers need not abandon their kiwifruit for a different crop.

"The more sensible strategy is to develop new cultivars that perform well in those climates. You can graft new cultivars on to kiwifruit vines quite quickly."

T&G Global has teamed up with Plant & Food Research, the Institute of Agrifood Research and Technology (IRTA) and Fruit Futur, developing and commercialising apple and pear varieties which are climate change adapted. The "Hot Climate Programme" has recently commercialised 'HOT84A1', which was successfully trialled in Spain, where temperatures reach more than 40°C. The apple has proven to be sunburn resistant, whilst still good eating.

"The Hot Climate Programme is unique and addresses both climate change mitigation and adaptation", says Morgan Rogers, General Manager of Operations for T&G's VentureFruit business. "Not only will we be able to grow fruit globally in areas where temperatures are rising, we can also potentially extend into new regions previously not suitable for apple and pear growing."

> "Not only will we be able to grow fruit globally in areas where temperatures are rising, we can also potentially extend into new regions previously not suitable for apple and pear growing.

'HOT84A1' is a newly commercialised 'hot climate' apple cultivar that offers good eating attributes but is sunburn resistant.

The use of canopy covers and two-dimensional growing systems in crops (like in this cherry orchard) may help reduce the effects of intense weather events.

Dr Jill Stanley leads the Crops Physiology team at Plant & Food Research and says Aotearoa New Zealand will do well as long as it plans well.

Stanley and her colleagues have been observing modified systems, like canopy covers, which protect or reduce the effects of some of the more expected intense weather events. In the last year kiwifruit and pipfruit orchardists in Motueka and cherry growers in Central Otago suffered significant losses from hail and severe rain.

While canopy covering cannot completely stop the damage from heavy rain, it does help.

"When you look at things like the heavy rain that occurred in Central Otago last summer, there were growers who lost 80% of the crop. But those who had covers didn't have anything like the same loss of crop," says Stanley. "There was some flooding, but some of the trees that were covered had less than 10% splitting in the fruit."

"We're also working on developing new growing systems for some crops such as apples, cherries, apricots and pears," Stanley says.

Stanley and colleagues have been trialling trees grown with very narrow row spacings of 2m between rows in a two-dimensional system – similar to traditional espalier growing, where the plant canopy is only 30–40cm wide – as opposed to a 3D system of a much wider tree. Not only have the yields been greater, but rain does not appear to hit the fruit to the same extent, and the canopy dries out faster because it is more open. The two-dimensional system could also reduce pests and diseases in future.

Still to be fine-tuned are the effects of covers on pollination. Honey bees can become disoriented under shade cloth, so bee behaviour scientists are working out strategies to avoid high bee mortality.

"We are also developing a virtual orchard for scientists and growers that mimics a real orchard," says Stanley. We will create simulations to see what happens when we make changes – for example, by putting on a cover or growing the orchard in different climate conditions. We will then be able to run a scenario to see whether this improves the outcomes or not."

A strategic approach

In its research – and sometimes practice – the horticultural industry is looking at adapting production systems in a more substantive way – termed a strategic adaptation; for example, changing the type of crop grown from apples to summerfruit.

And even if by comparison plants are not as thirsty as dairy cows, horticultural regions in the east of the country are likely to be more constrained by water supply.

Supported by funding from the Provincial Growth Fund via Kānoa – Regional Economic Development & Investment Unit, the Kaipara District Council has led the charge to future-proof its region against climate change with its Kaipara Kai project. Best known as the kumara capital of the country, the region has the potential to grow new crops such as peanuts, hops and sorghum, and to expand its avocado plantings. The project includes a full suite of research covering topo-climate and kai feasibility research as well as funding for an on-the-ground service centre (Kaipara Kai Hub) to operate for a period of time. Kaipara Mayor Dr Jason Smith says the region needed an "activation plan" to connect researchers and growers.

Innovation and transformation

Over the past 15 years, Plant & Food Research has worked with regional councils, companies and Māori entities to chart ways in which they can prepare for climate change by potentially developing completely new production systems and industries.

For successful growing of horticultural crops, each crop has several climatic pre-conditions required, and this can vary between cultivars of the same crop e.g. different kiwifruit varieties, and depends on the specific crop. However in general, many crops require a certain number of chill hours of 7°C or below between May and September; a certain number of accumulated heat units when the daily average temperature is 10°C and above (called growing degree days); and a frost-free period.

Clothier says one of the key findings from Plant & Food Research has been that existing farming operations can exist alongside new types of production.

"We did a study in Northland which showed that across conventional farms they had niche locations to support horticulture; they didn't have to be a 100% dairy farm. It's not about horticulture replacing a dairy farm, it's about adding horticulture to existing land uses."

In 2020 Clothier and others prepared a report for Venture Taranaki which identified there were about 207,000 ha of land potentially suitable for generic horticulture within the boundaries of the Taranaki Regional Council. It looked at the viability of eight mainstream crops that could offer commercially successful horticultural opportunities for the region's land-owners.

But, as the Chief Executive of Te Puna Umanga/ Venture Taranaki, Justine Gilliland, points out, it's not just a matter of whether the crops can be grown.

"Success will be achieved as much by these factors as by people, knowledge transfer, and the emergence of new chains, processing, and products to deliver these growing opportunities to market."

Crops that were marked out as having promise were apples, avocados, blueberries, wine grapes, potatoes, hazelnuts and walnuts, hops, hemp and CBD cannabis.

Clothier points out that changes to existing land uses require building up capacity behind the scenes.

"We did a job for post-quake Kaikoura, asking, 'do we put fences back up and carry on as if nothing happened?' There were some pretty neat river flats there, which might come under pressure from changes in water quality regulations. Rather than having a sharemilker, you might end up having a shared horticulturist.

"But one of the challenges is: where is the packhouse, coolstore, or the horticulture consultancy? There's nothing like that in Culverden, so you have an infrastructural knowledge deficit. You need an investment strategy to support land-use change," Clothier says.

One way to prepare for climate change is by developing completely new production systems and industries.

GLOBAL FOOD LEADERS

An interview with Volker Kuntzsch, Cawthron Institute

Segment talks to Volker Kuntzsch, CEO of the Cawthron Institute, New Zealand's largest independent science organisation, about his experience in the seafood industry. Volker's distinguished international career spans three decades and includes his previous role as CEO at Sanford Limited as well as a number of senior executive roles. As a leader, Volker has focused on innovation and sustainable economic growth and played a key role in the early accreditation of the New Zealand hoki industry.

You studied science at university, did you want to be a scientist? When did your focus change to the business side?
Yes, I do have a Master's degree in zoology. Originally, I wanted to become a teacher. Then I imagined myself as an environmental ecologist studying Southern African wildlife. As life had it, I started a family while still doing my MSc and, when the opportunity presented itself within the fishing industry, I jumped at the chance to shift my income from bank loans and government funds to earned income.

What are the biggest challenges for the seafood industry that science can help address, both at home and globally?
The first thing that comes to mind is the limitation on sustainable growth of the blue economy due to social licence. Scientists are trusted to bridge the gap between what is happening on the water and public perception. That would entail (on the one hand) creating improved environmental and economic outcomes across industry and (on the other hand) communicating those in a trusted manner to society.

What are some of the big changes you have seen or experienced during your career?
The introduction of Marine Stewardship Council certification into wild fisheries globally and the subsequent improvement of stocks as a result of that.

Secondly, the shift beyond a mere bottom line focus to a more holistic appreciation of business impact on the planet and one another.

The impact of a changing climate on our oceans and the increasing urgency for more agile ecosystem management.

You've been part of the seafood industry in several different countries. What do you think is special about the Aotearoa New Zealand sector?
We are a maritime nation like no other. Our ocean makes up 96% of our territory, yet we look to the land to solve our problems. From a cultural perspective, Kiwis stand out as a caring nation, and a high degree of collaboration would create immense and immediate impact, especially in the blue economy.

What do you think are some of the biggest opportunities for Aotearoa's seafood industries?
Bringing New Zealand Inc. together (industry, government, science and communities) to develop innovative brand, product and technological solutions that will help us overcome the increasing distance to market and consumer expectations.

Sustainability is obviously a big focus for the seafood sector right now, but are there any other (consumer-driven) trends that you think the industry will have to respond to or be prepared for in the near future?

> We are faced with increasing expectations to be circular in our production methods, especially as raw material producers.

Yes, we are faced with increasing expectations to be circular in our production methods, especially as raw material producers. This is one area where science can play a big role in helping industry retain a competitive edge (for example, alternative harvest/farming methods, high-value product innovation and IP development). Also, trends towards foods with less environmental and social impact (like veganism and alternative proteins) will also force the industry to think differently about its competition in the marketplace.

How does seafood feature in your home life? Are you a recreational fisher, for example, or is it a food for everyday or special occasions?
Growing up in Namibia, the thought of beach casting on a desolated coastline never attracted me much. I preferred to spend my time diving for crayfish. However, working in the seafood industry has provided the opportunity to fish with many incredible people in many extraordinary places around the world. I have six children, so I still don't own my own fishing rod but you can imagine we eat more seafood than your average family.

Are you adventurous when it comes to new foods?
I grew up with meat and potatoes for lunch pretty much every day and so I was not very adventurous in terms of trying new foods. But, as I travelled across the globe, I often ended up in situations where I had no choice but to eat what was on the table, even if I didn't know what it was. It usually turned out ok!

Do you prefer eating out or dining at home?
I love eating out, but nothing tops a dinner with the family at home.

Growing great beer

Aotearoa New Zealand boasts over 200 craft breweries, the highest number of breweries per capita in the world. Locally grown hops support this domestic industry. But it's not just here that our hops are loved. Each year we export around 1200 tonnes to over 20 countries and, while that accounts for only 1.5% of the total used globally, the unique flavours and clean, green profile of our hops command a premium with buyers and generate in excess of $50 million a year.

It takes a lot to get hops from the ground to beer and even more — around a decade — to breed a new cultivar. The following photos help tell that story.

PHOTO BY STORY NINETY-FOUR ON UNSPLASH

A hop garden near Tapawera with the Kahurangi Mountains in the background. In the past, many New Zealand's hops have been grown in the Tasman district, where they thrive thanks to the free-draining alluvial soils, an even rainfall, light winds and a temperate oceanic climate, but recently growers are planting hops elsewhere in New Zealand. Scientists at Plant & Food Research are looking at the potential for growing hops further afield – from the far north to the far south.

IMAGE BY ROBERT LAMBERTS

Plant & Food Research and its legacy organisations have been at the forefront of hop breeding and genetics for around seven decades and have released 22 cultivars to industry, offering a variety of flavours from tropical and citrus to notes of Sauvignon blanc. Around 95% of the commercial hops used locally and exported are from cultivars developed by Plant & Food Research.

Thanks to their interesting flavour profiles that set them apart from traditional hops, Kiwi hops are esteemed internationally. The first breeding efforts, conducted in Motueka, developed disease-resistant cultivars, followed by seedless triploid cultivars. After that, researchers began experimenting with flavour, producing novel cultivars that have put Aotearoa New Zealand on the map and pleased craft brewers the world over.

Hops breeders at Plant & Food Research are legendary. Dr Rudi Roborgh, the original breeder, has an Auckland bar, Dr Rudi's, named after him. Dr Ron Beatson produced 16 cultivars during his career, with a range of flavours that brewers love, including the recently released Nectaron®, inspired by his name.

New Plant & Food Research hop cultivars, commercialised through grower co-op NZ Hops Ltd, are exported to major brewing companies in 15 countries, with key markets in the USA, Europe, Asia and Australia.

Close-up of a hop plant tendril. Hops are dioecious, which means they have male and female flowers on separate plants, but only the female is used for brewing. Hops are related to cannabis and are both members of the hemp family (*Cannabaceae*).

IMAGE BY ROBERT LAMBERTS

Hop extracts are filtered for bitter acid analysis. The bitter acid composition is an important characteristic in hops and brewers utilise it to make beer with particular flavour characteristics.

IMAGE BY MINNA PESONEN

Hops are grown on trellises 5m high. To create new seedlings for breeding purposes, researchers cover the flowers on the hops plant with pollination bags. The original germplasm used for hop breeding at Plant & Food Research came from Europe and North America but after decades of breeding Plant & Food Research has a unique germplasm base.

IMAGE BY WARA BULLÔT

Photo of hop cones used for plant variety rights (PVR) which provide the right to propagate varieties for commercial production.

IMAGE BY ROBERT LAMBERTS

Plant & Food Research scientists Dr Ron Beatson and Kerry Templeton smell hops to assess their aroma. If selected, the hops will go to the pilot brewery (the Hop Lab) to make small-scale brews (below). A panel of trained staff and local experts then test and score the brews for flavour and consumer appeal. Those that make the grade go to industry for growing and trials.

IMAGE BY WARA BULLÔT (RIGHT) & ROBERT LAMBERTS (BELOW)

A cross-section of a hop cone showing the active ingredient lupulin (yellow) that gives beer its aroma and flavour. Hops produce three chemical groups important for brewing and brewers originally added them to beer for their antibacterial qualities rather than for flavour. These days scientists are exploring the potential health properties contained in hops.

IMAGE BY ROBERT LAMBERTS

Hop bines (climbing stem of the hop plant) grow on strings that are cut down at the end of the season. The strings run between the ground and the top of the wire. Hops are a perennial plant and die back in winter. Stringing is an annual (springtime) job and once in place the hop bines are trained to wrap around the string.

IMAGE BY ROBERT LAMBERTS

A colour wheel of information on hop cultivars. The breeding programme at Plant & Food Research has developed many cultivars including craft beer 'rock stars' like Nelson Sauvin™, Riwaka™, Motueka™ and Nectaron®. These four cultivars are highly sought after here and overseas.

Close-up of hop flowers in early January. They will expand and the mature inflorescences will be ripe by March.

IMAGE BY ROBERT LAMBERTS

Avocados

Whether you like them on toast, mashed with some lemon juice with your tacos, or wrapped with salmon in your sushi, avocados are a healthy, nutritious food enjoyed around the world.

Globally, growers produce more than 7 million tonnes of avocados each year and this volume is rapidly increasing. The fruit are shipped around the world for consumers to enjoy.

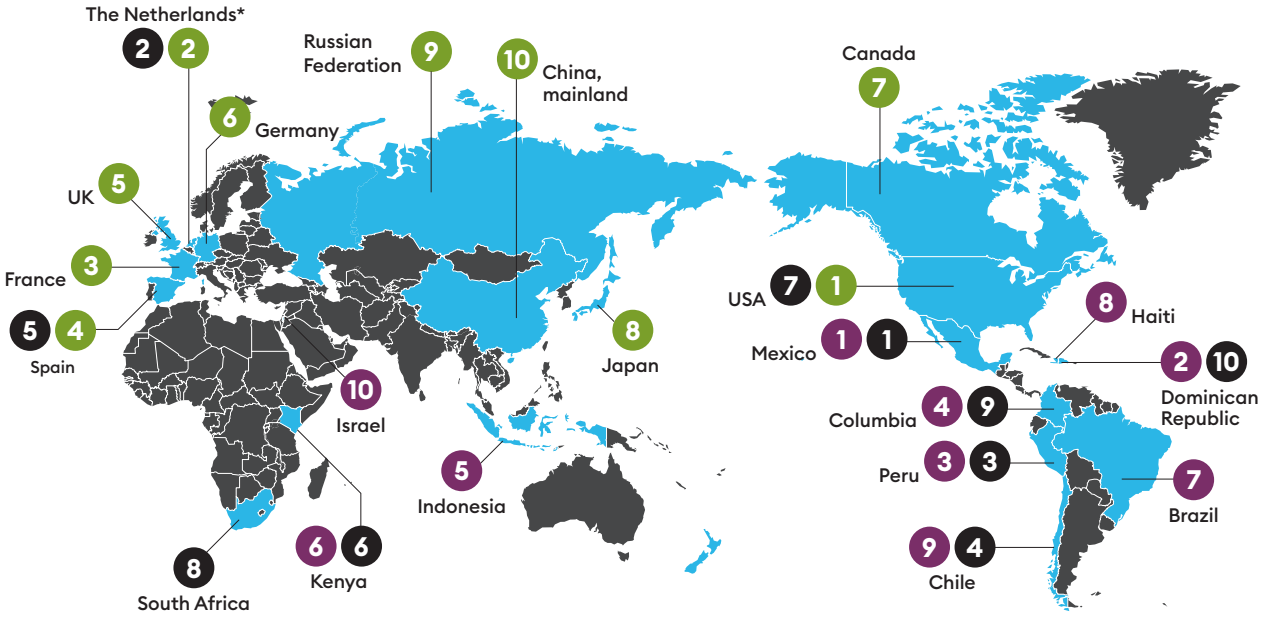
Avocados grow well in a number of countries – they like moderately warm temperatures and not too much water – but unsurprisingly, Mexico, the birthplace of the avocado, is the biggest player, producing about 30% of globally traded fruit.

There are more than 50 varieties of avocado, but the most common cultivar in international trade is 'Hass', first grown in 1926 by Rudolph Hass in California.

TOP 10

(BY VOLUME)

Producers
Exporters
Importers



*The Netherlands is a gateway to the EU and many of the fruit arriving there are 're-exported' to EU countries.

Perfect every time — the science of avocados

Consumers love a great avocado, but many consumers are at a great distance from the sites of production. Producing the fruit and getting them to the consumers in good condition is a continual challenge. Research is looking at how best to manage the trees, orchard environment, pests, diseases and the fruit handling and shipping conditions, to make sure each avocado arrives at the consumer in the best condition possible.

Making every year a high-production year
Annual tree fruit volume is inconsistent. Spring weather and previous cropping history can all affect yield. In a high-yield year, fruit can overwhelm the market and prices can be lower, whereas low-yield years can make it difficult to supply key markets with the volume they demand. Research is looking at the factors that influence flower numbers, pollination success and fruit retention to ensure a well-balanced, productive tree that produces a consistent yield year-on-year.

Healthy roots
Avocado root rot is caused by the soil-borne pathogen *Phytophthora cinnamomi*. *Phytophthora* kills the roots of trees, reducing water and nutrient uptake, and eventually causing leaves to wither and eventually tree death if not treated. Scientists are breeding new rootstocks with resistance to root rot, which can then be grafted to produce 'Hass' or other cultivars. Research is also developing better ways to detect and treat the disease.

Making sure insects don't mess it up
Insect pests, such as leafrollers, mites and thrips, damage leaves and fruit. Scientists are developing new ways to manage pests in orchards, such as biological control agents and mating disruption techniques, as well as methods to treat fruit post-harvest to ensure no insects remain on fruit destined for export.

Not even one bad avocado
Rots infect fruit in the orchard, but are mostly not visible until they develop as the fruit ripens. Whilst fungicides can control rots to some degree, not all markets accept fruit after these chemical treatments. Research seeks to minimise the risk of infection in the orchard and also create new, more acceptable, ways of controlling those rots which are present on the fruit.

Getting the fruit to the consumer
Most international trade in avocados is by sea. There are increasing volumes of fruit being transported, mostly successfully, and research is looking at a range of issues that can influence fruit quality during the movement from the tree to the consumer. These include how fruit are picked, sorted and cooled, the conditions during transportation and, in some cases, the ripening of fruit just before retail. The role of shipping is under scrutiny more than ever with disruption and extended shipping times caused by limited container availability and congestion around major ports during the COVID-19 pandemic.

Plant & Food Research is the science sponsor for the World Avocado Congress, to be hosted by New Zealand Avocado in 2023.

What makes an avocado healthy? Avocado is one of only a few fruits to contain significant amounts of healthy oils, around 23% or more by weight, and mostly the 'good' oils. Avocados are a great source of a range of vitamins, including some of the B vitamins (folate, B6 and niacin), vitamins A and E, as well as potassium and dietary fibre.

DATA SOURCE: New Zealand Food Composition database, foodcomposition.co.nz

Waste not

Stop throwing away these surprisingly nutritious foods.

Food waste is a major issue in Aotearoa New Zealand. According to Love Food Hate Waste NZ, Kiwi homes throw away 157,398 tonnes of food per year, all of which we could eat.

We often discard things like produce skins and stems, which are not only edible but also a great source of additional fibre and nutrients. Curb food waste in your household by adding peels and stems you would normally throw away into nutritious, delicious recipes.

For more information on the nutrient content of these foods and over 2700 commonly prepared and eaten foods in New Zealand, visit New Zealand Food Composition Data at **foodcomposition.co.nz**

To find out more about food waste in Aotearoa, visit **lovefoodhatewaste.co.nz/food-waste**

Watermelon rinds

Not only do watermelon rinds have all the same nutrients found in the refreshing fruit, but the rinds also contain even higher concentrations of certain minerals, vitamins and bioactive ingredients. While low in calories, watermelon rind contains high concentrations of provitamin A carotenoids, vitamin C, vitamin B6, zinc and potassium. The nutrient-dense rind also contains chlorophyll, lycopene, citrulline, amino acids, and phenolic compounds such as flavonoids.

Perfect pickled

Wash the watermelon well before use. Make a refreshing summer drink by blending watermelon flesh and rinds with lime juice and mint, or add a few watermelon slices (including the rind) to your favourite smoothies. You can also add the watermelon rind to fruit salad, salsa, chutney, stir-fries, coleslaw, or pickle it.

Cucumber skin

As cucumbers contain 95% water and are low in calories, they are a refreshing, nutritious and incredibly versatile addition to any diet. The skins of cucumber are rich in vitamin K and phytochemicals and also contain magnesium, potassium, vitamin C, manganese, pantothenic acid, molybdenum and insoluble dietary fibre.

To gain the maximum nutritional benefits, eat cucumbers with the skin on, as peeling reduces the amount of dietary fibre, along with some vitamins and minerals. The skin of a cucumber contains more vitamin K than the flesh, which supports bone health and blood clotting.

Low calorie

Often eaten raw, cucumbers make great low-calorie snacks, perfect with hummus, olive oil, salt or your favourite salad dressing. Slice or grate, skin on and add to salads and smoothies.

Broccoli and cauliflower stems and leaves

The stems and leaves of brassicas like broccoli and cauliflower are high in dietary fibre and other nutrients.

Broccoli stems contain many of the same nutrients as the broccoli head, including provitamin A carotenoids, vitamin C, potassium and folate. Additionally, the stem contains vitamins B1 (thiamine) and B2 (riboflavin), iron, magnesium, zinc and sulforaphane, a phytochemical with a range of potential health benefits including anti-inflammatory properties.

Cauliflower leaves are rich in iron, dietary fibre, potassium, beta-carotene, plus folate and are one of the richest sources of calcium in vegetables. Foods rich in calcium and iron have several health benefits including healthy bones and better immunity, and the high dietary fibre content aids digestion, keeping the gut healthy.

Healthy gut

Broccoli and cauliflower stems are great in stir-fries, curries, pasta or soup. Grate or finely slice stems of broccoli or cauliflower and add to coleslaw or salads. The leaves can be sautéed, roasted or added to stir-fries, soups, or frittatas.

Beet greens

Beet greens are the young leaves of the beetroot plant and are high in vitamin B6, magnesium, potassium, copper, and manganese. Low in calories, fat, cholesterol and sugar, beet greens contain more iron than spinach or kale and generally possess higher concentrations of vitamins, minerals, and dietary fibre than the root (with the exception of folate). The provitamin A content in beet greens helps strengthen the immune system, can help fight inflammation and support brain health.

Immunity, and brain health

Adding a handful of beet greens to your favourite smoothies will boost the vitamin and mineral count without altering the flavour. Delicious in a salad or toss them in a homemade pesto by replacing half your herbs with beet greens. Chop and sauté beet greens with garlic and olive oil for a fast, tasty side. If you are making a soup that requires spinach, kale, or any other green vegetable, use beet greens instead.

Carrot tops

Did you know carrot tops have more provitamin A carotenoids, important for a range of body functions including vision and immunity, than the orange root? Fat and cholesterol–free, carrot tops also contain significant amounts of dietary fibre, vitamin C, calcium and iron. These nutritious greens also contain vitamin K and various phytochemicals, such as phenolic compounds and polyacetylenes.

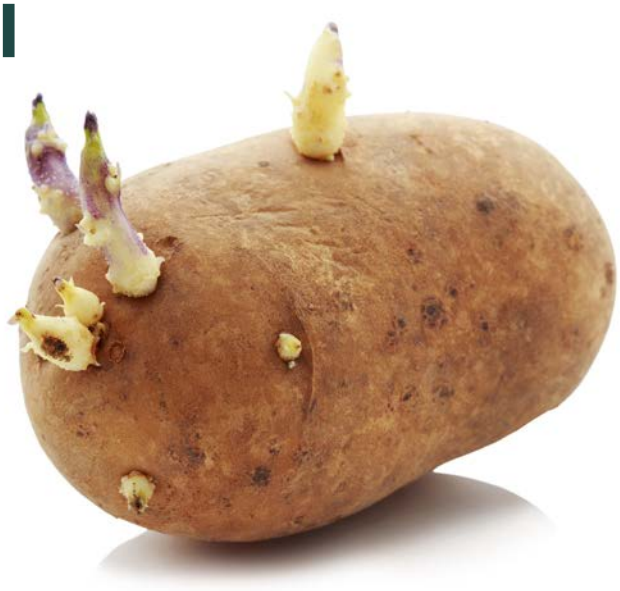
Herb substitute

Carrot tops are a great herb substitute in any dish you are already using carrots in, or skip the basil and use them with equal parts baby spinach in pesto. If you are not a fan of their bitter taste, you can add them to soup stock or blanch the carrots greens in boiling water to help reduce the bitter flavour.

Quick facts

Potato/Rīwai

Spanish explorers introduced potatoes to Europe from South America in the mid-155Os. Now they are part of almost every cuisine, featuring in diverse dishes from gnocchi and cottage pie to samosas and tapas.



Everyone loves potatoes

There are hundreds of varieties grown globally and they comprise 18% of vegetable sales in Aotearoa. Taewa (or rīwai) is the name for the varieties of potatoes cultivated by Māori prior to organised European settlement. Each variety has its own unique texture and flavour.

It's all in the cooking

Potatoes contain vitamins, minerals, antioxidants, protein and fibre. Their high potassium content along with available energy makes potatoes an effective sports replacement food. To maximise the health benefits, skip the deep fryer and lashings of sour cream and instead bake or microwave potatoes in their skins. They also contain resistant starch for gut health. To optimise resistant starch, refrigerate pre-cooked potatoes before eating.

How big?!

According to the Guinness Book of Records, the biggest potato grown weighed 4.98 kg. This record is set to be challenged by a giant Kiwi spud, nicknamed Doug, which was unearthed at the end of 2021 by Hamilton couple Colin and Donna Craig-Brown.

The best spud for the job

Choosing the right potato makes all the difference. Floury potatoes like 'Agria' and 'Ilam Hardy' are good for roasting. Waxy potatoes like Perla®, 'Haylo' or Nadine' are best for potato salads. Or choose an all-purpose potato like 'Red Rascal', 'Rua', 'Desiree' or 'Purple Passion'. If you see starchy residue on the knife when you cut the potato, it is probably a floury variety.

Potato-based, dairy-free cappuccino anyone?

A new trend in non-dairy beverages is coming, with potato alternatives boasting nutrition, taste and environmental credentials. Swedish brand Dug recently released a range of new potato milk alternatives. Expect to see other potato-based dairy alternatives and potato protein products. The Simple Root, a brand backed by McCain, is developing a pipeline of innovative potato-based products.

A crunchy accident

Chef George Crum supposedly invented potato crisps/chips as a form of revenge when he served them to a customer who complained about thickly cut potatoes.

The whole potato

Scientists are looking at how to turn bio-waste from potato scraps into higher value products. Italian designers recently created "Peel Saver", a packaging material for fries made out of potato peels.

Long live the potato!

Potatoes can last months, depending on storage. They are best kept in a ventilated, dark, dry environment, slighter warmer than a refrigerator. Storing potatoes in the refrigerator can change the flavour. Sunlight will turn them green and generate glycoalkaloids, which are toxic. Never eat potatoes that have fully sprouted (remove small sprouts, along with the eyes). Store onions and potatoes separately to avoid decay.

Potatoes or rice?

Potatoes are more environmentally sustainable than staples like rice or pasta and also deliver more nutrients. The Chinese government is promoting potato growing to promote food security, and research in the journal Nature Food suggests this dietary shift could cut China's greenhouse crop emissions from food staples by 25%.

INSIDE SLICE

At Plant & Food Research, we believe science can create a better future.

By finding smarter, greener options today, we're helping secure the world we want to live in tomorrow. With our partners, we use world-leading science to improve the way they grow, fish, harvest and share food.

A smart green future. Together.

Plant & Food™ Research
Rangahau Ahumāra Kai

A smart green future. Together.

Every day we have 1000 people working across Aotearoa New Zealand and the world to help deliver healthy foods from the world's most sustainable systems. Here's what a smart green future together means to them.

A smart green future together includes creating value from science that addresses a wide range of important sustainability and food production challenges that matter deeply to our sectors, partners and stakeholders. It's about science discovery and that discovery being applied to deliver impact. Working collaboratively we're tackling important issues related to climate change, environmental impacts, resource use, ecosystem health and biodiversity and high efficiency food systems.

DR PAUL JOHNSTONE
General Manager, Sustainable Production

I think a smart green future together means using scientific knowledge to develop innovative ways of producing and marketing crops to deliver what consumers want, while ensuring that what we produce is economically, socially and environmentally sustainable. It's about forward thinking that combines good science with traditional knowledge. And it's about kaitiakitanga – to ensure that we use resources efficiently and reduce the impacts on the environment. For me, the most important part is 'together' – collaborating with a range of people including scientists, growers and marketers to ensure greater success.

DR JILL STANLEY
Group Leader, Fruit Crops Physiology

A smart green future together means thinking holistically, weighing inputs and outputs against costs and benefits for society and environment. As scientists we need to think about the whole system. Everything is connected, so a change to one part ripples through the entire system. A smart green future is about understanding those relationships and then thinking long term and using science to support environmental resilience and a sustainable and circular future for Aotearoa.

DR RICHARD EDMONDS
Bioprocessing Engineer, Food Solutions

For me, a smart green future together means using our research and science knowledge to create a better world – one that is more sustainable and agile. It is about future-proofing Aotearoa's food production sectors to maintain social licence for our food industries. A smart green future means predicting future trends and challenges so that we can help prepare for them. It's also about leaving the world a better place for future generations.

KERRY TEMPLETON
Scientist, Premium Crops and Technology

A smart green future together, for me, is about partnering with tangata whenua for knowledge-based food production that protects taonga for future generations.

DR ASHLEY MORTENSEN
Scientist, Productive Biodiversity and Pollination

For me, a smart green future together is about our work having a positive impact, not just for people, but also for our environment. Developments in technologies, challenges from climate change and the ever increasing need for nutrient rich foods means new questions are always being posed. Our challenge, is to navigate the diverse knowledge available and strive for the best outcomes. To be *smart* suggests there is always more to learn, a *green future* acknowledges that people are integral to the state of the world around them, and it is only *together* that we can harness the knowledge needed to recognise what Aotearoa can uniquely offer the world.

CHRISTINA ROIGARD
Scientist, Consumer and Product Insights

A smart green future together means building enduring partnerships with stakeholders so that our science enables real-world impact. Understanding their challenges and opportunities, highlighting where science can make a difference, and then building research programmes that deliver. A Smart Green Future might mean improving crop yield and quality with reduced waste; moving from low-residue to no-residue pest and disease management; breeding climate-resilient cultivars or building carbon-positive orchard systems. Or it may mean something we haven't yet discovered. It's all a step or a jump along that shared journey.

DUNCAN SCOTLAND
Business Manager / Team Leader, Perennial Crops

THE NUMBERS

14 sites across New Zealand as well as offices in Australia and the USA

1000
total staff

781
science staff

421 ha
research farms

Our Strategy

We believe our science can make the world a better place. That by working together, we can create a smart green future for Aotearoa New Zealand and the world.

We invest in our people, our facilities, our information systems and in future science. We believe that these are vital parts of creating an organisation that delivers world-class science.

We know our science can only make a difference if it is applied outside the lab. We build relationships with customers and partners, including with Māori organisations, to find the best ways for our science to help their businesses grow.

We then share our knowledge and skills, so that our customers, our partners and Plant & Food Research itself receive fair value from the results of our science. We provide R&D services for those that need it and create pipelines of new technologies for commercialisation, either directly by us or in partnership with others.

For us, a smart green future means we use all available knowledge to produce healthy, nutritious food from the land and sea, while ensuring we protect our environment and create opportunities for future generations.

Our strategy has three elements that together will deliver a smart green future for Aotearoa New Zealand:

1. Invest / Whakangao
   to create world-class science

2. Apply / Whakamahi
   that science to create maximum value

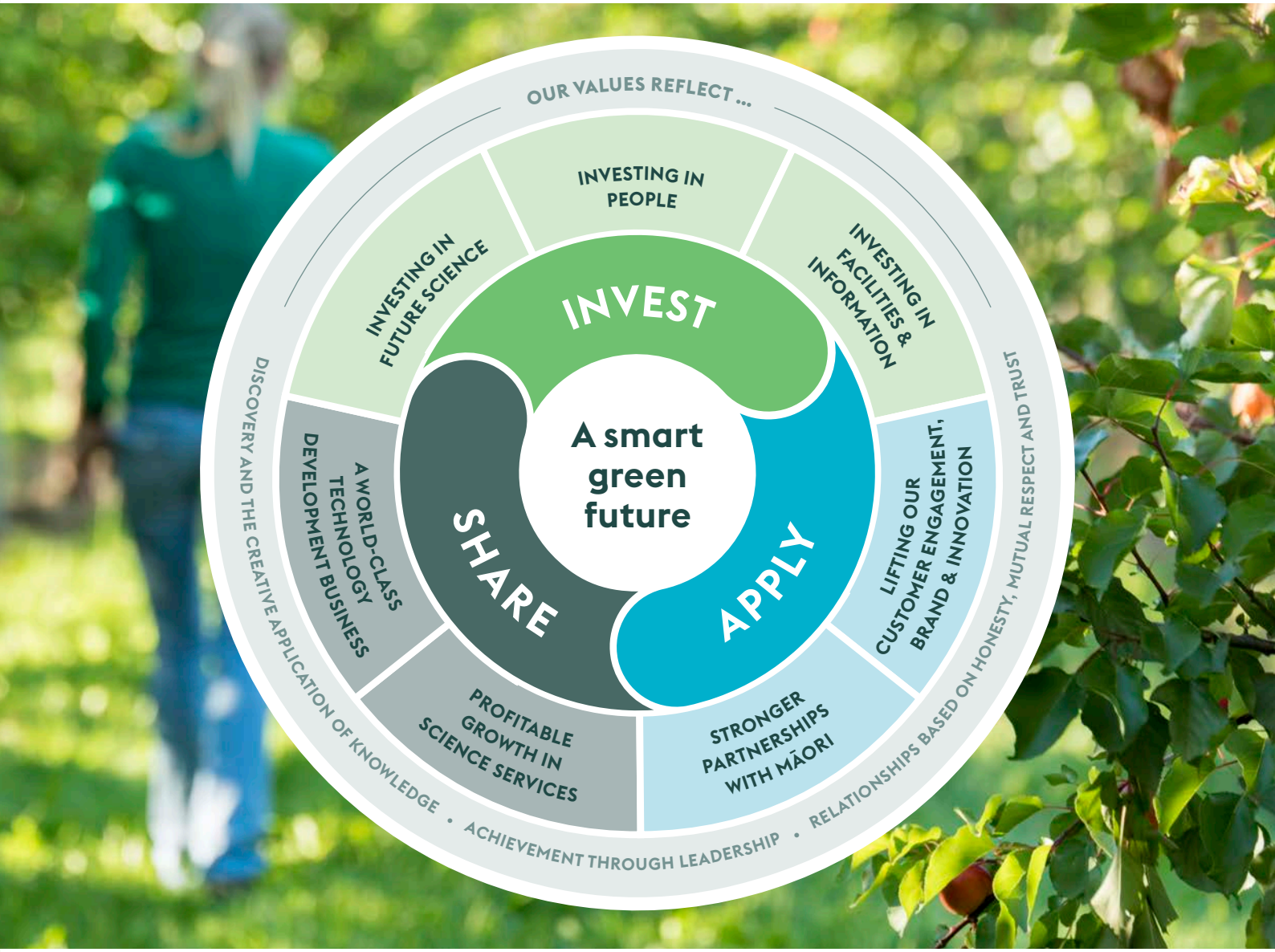
3. Share / Tuari
   that value fairly with those who have contributed to its creation, to increase the sustainability of their businesses.

This strategy is realised through seven strands that ensure our activities align with the requirements of our Institute, our customers and our partners.

Meet some of our leaders:

Name: Dr Jolon Dyer
Position: Group General Manager Science Services
Education: PhD (Chemistry), BSc Hons 1st Class (Chemistry), Diploma Teaching & Learning
Interesting fact: I lived in Japan for three years and developed a fondness for karaoke!
Favourite food: "Kanburi" (Winter Yellowtail) Nigiri Sushi

Name: Colin Dawson
Position: Deputy Chair
Education: Batchelor of Veterinary Science, Master of Business Administration, Chartered Fellow of NZ Institute of Directors
Interesting Fact: Prior to going to vet school I was an iron ore miner in Western Australia and a trucking contractor in the Middle East
Favourite Foods: Thai. I grow my own Kaffir lime leaves, lemongrass, chillies, horapa and galangal



Our activities are funded through direct commercial research for our customers, the reinvestment of royalties and the New Zealand Government's investment in science.

For the year ending 30 June 2021

$43.2M
Strategic funding
Government investment allocated directly to each Crown Research Institute

$14.8M
Contestable
Government investment allocated through competitive bidding

$58.0M
Royalties
Commercial return from plant varieties and IP

$57.2M
Commercial
Direct investment by customers

$8.8M
COVID-19 recovery funding
Government allocated COVID-19 funding

$2.0M
Other
All other income sources

Triple wins for Plant & Food Research at KiwiNet Awards

Plant & Food Research received three awards at the 2021 KiwiNet Awards. The Awards celebrate Aotearoa New Zealand's commercialisation heroes and help support the role commercialisation plays in promoting our prosperity. Plant & Food Research CEO David Hughes received the inaugural Commercialisation Icon Award for showing visionary leadership in advancing commercialisation. Senior Commercialisation Manager, Darja Pavlovic-Nelson received the Commercialisation Professional Award for her work in capturing value from the IP behind Scentian Bio (see below). Plant & Food Research, along with Zespri Group Ltd and UPL, also received the Commercial Impact Award for Aureo®Gold, a new environmentally friendly biocontrol product that protects against the Psa disease in kiwifruit.

Harnessing the power of insect sensors

In 2021 Plant & Food Research and Sprout Agritech (with help from investment partners Finistere Ventures, Fonterra and OurCrowd and with funding from Callaghan Innovation's Tech Incubator Programme) partnered to spin out a new company called Scentian Bio. The new company will develop technology based on nearly two decades of research by Dr Andrew Kralicek and his team, who investigated the potential for combining insect smell receptors with electronics to create a "camera for smell". This research catalysed the development of a highly sensitive technology that can smell and taste chemical compounds. The Scentian Bio technology has many potential applications, including detecting variations in water, wine and food, or even disease detection. The global opportunity for the technology is estimated to be worth more than $1 billion.

New dedicated kiwifruit breeding centre

2021 saw the opening of the Kiwifruit Breeding Centre (KBC), an exciting 50/50 joint venture between Plant & Food Research and Zespri Group Ltd. Based at Te Puke, the Centre will drive greater innovation with kiwifruit breeding, focusing on creating healthier, better tasting and more sustainability-focused varieties. The Centre represents the next phase of the successful 30-year relationship between Plant & Food Research and Zespri, which has delivered Kiwi heroes like Zespri™ SunGold Kiwifruit and Zespri™ RubyRed Kiwifruit. Massey University Chancellor, Michael Ahie, has been appointed Chair of the Board, with Dr Matt Glenn the inaugural Chief Executive Officer.

Kiwifruit Breeding Centre™

Recognising science achievements — Science New Zealand Awards

The 2021 Science New Zealand Awards honoured three Plant & Food Research scientists and teams – an accomplished crop scientist, a consortium working on myrtle rust disease, and an emerging researcher looking at foods that support human health. Dr Jill Stanley achieved a Lifetime Achievement Award for her contribution to crop science over four decades. Her research has helped growers use resources more efficiently to lift returns, and has delivered high quality fruit for consumers. The Team Award was given to the Myrtle Rust Consortium, a multi-party, multi-disciplinary team who mobilised to mount an exceptional biosecurity response for Aotearoa against myrtle rust disease. Dr Odette Shaw received the Early Career Researcher Award for her work on understanding how compounds in fruits and vegetables can support health and wellbeing. Science New Zealand represents the country's seven Crown Research Institutes (CRIs) and Callaghan Innovation, and the annual awards recognise research excellence at each organisation.

Prestigious award for beer industry legend

Leading hops researcher Dr Ron Beatson won the Morton Coutts Trophy at the 2021 Brewers Guild of New Zealand Awards. The trophy recognises Dr Beatson's outstanding contribution to the New Zealand hops and brewing industries. Dr Beatson has led the research and development of hop breeding and genetics at Plant & Food Research for more than three decades. During this time, New Zealand-grown hops have developed a strong reputation globally for novelty and quality. Dr Beatson has been instrumental in the research, development and release of 16 speciality hop cultivars including superstars Motueka™, Riwaka™, Nelson Sauvin™ and the recently released Nectaron®, named after its creator. Read about hops breeding in the photo story on page 26.

Supporting Aotearoa New Zealand's horticulture sector to prepare for climate change

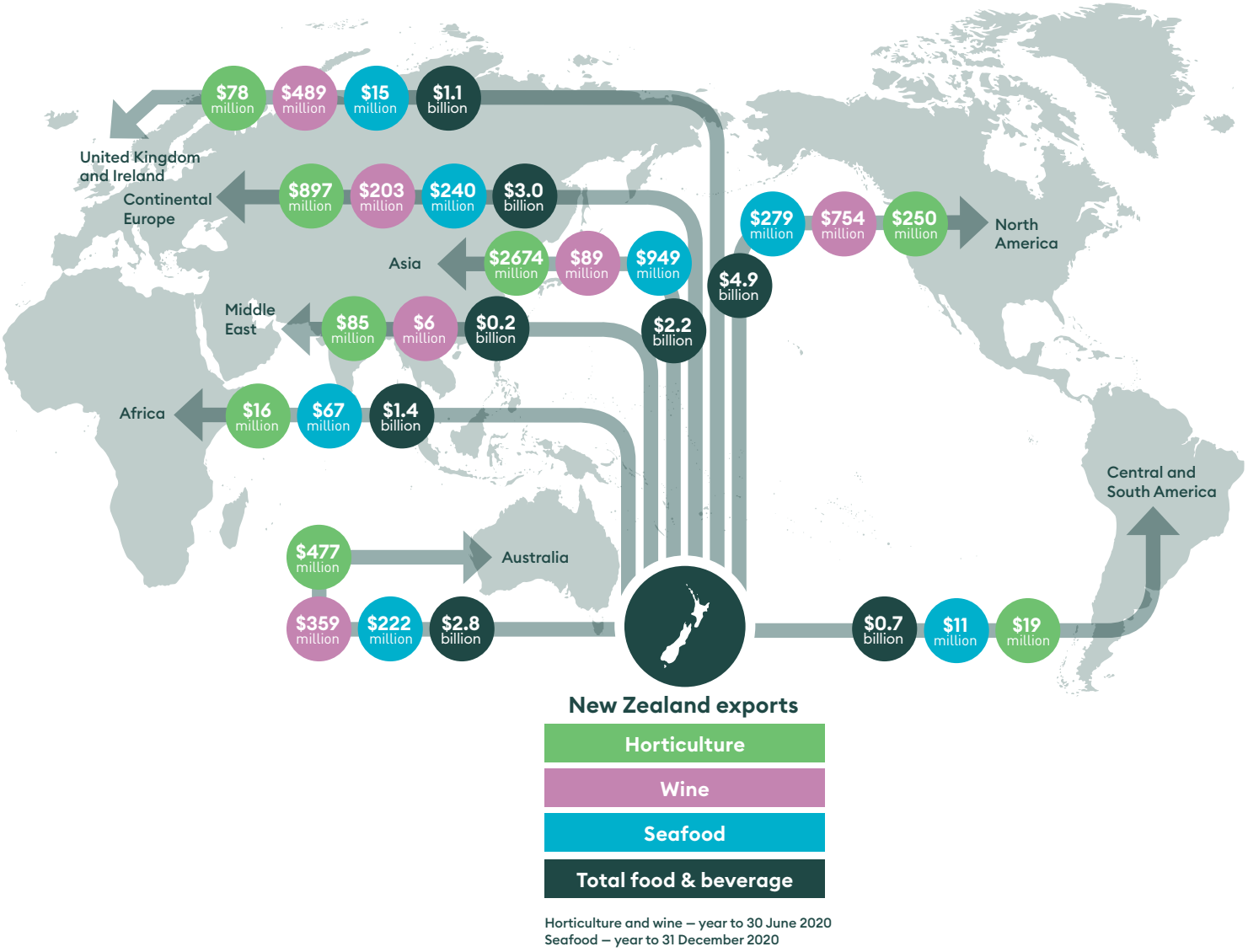
With funding from the Ministry of Business Innovation and Employment (MBIE), Plant & Food Research scientists are looking at how to prepare Aotearoa's horticulture sector for climate change. A warming climate could affect flowering in many plants, which could have a significant effect on horticulture production. This 5-year programme will look at the genes that control flowering; investigate ways in which these may be triggered at the molecular level; and incorporate the knowledge into breeding of new varieties. The programme also aims to engage the public in discussion around how climate change could affect New Zealand crops, and options for creating 'climate-ready' plant varieties.

Berries for the world

T&G Global's new VentureFruit business unit and Plant & Food Research launched a partnership in 2021 to breed new varieties of berryfruit. Building on T&G's extensive experience in creating value from new fruit varieties, the venture will bring new and superior fruit to consumers, retailers and growers around the world. Global berry consumption has doubled per capita over the past decade and is expected to grow further. The two partners will co-invest in the development and breeding of unique new berries, including raspberries, Boysenberries, blackberries and blueberries.

Our sectors

In 2020, New Zealand exported close to $39 billion of food and beverage products, 65% of the country's total exports. Plant & Food Research works with partners across the food sector to create new knowledge and technologies. These support development of the most sustainable food production systems in the world, delivering products that meet the demands of the most discerning global consumers.



Horticulture and wine – year to 30 June 2020
Seafood – year to 31 December 2020

Scigest

podcast-sized servings of digestible science

The Scigest podcast, hosted by scientists from Plant & Food Research, delves into our science and the fascinating stories of the people behind the science. Discover a diverse range of stories covering everything from a gene discovery for cloning to the science of soil health.

Listen on our website plantandfood.com/welcome-to-scigest or subscribe via your favourite podcast app.

A smart green future. Together.

Plant & Food™ Research
Rangahau Ahumāra Kai

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