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TIP-MAG 2020

Timber Industry Presents Magazine

Chemistry, the wonders, beauty and BS!

Organic, synthetic, natural - what's the catch when it comes to chemistry?

Tackling Climate Change

Can tree breeding and technology stand up to the challenge?

Context is key

In a world that is becoming increasingly risk adverse, there has never been a greater need for context

FORESTRY SOUTH AFRICA

TABLE OF CONTENTS

OPINION PIECES

INTEREST PIECES

> *"Certain schools of thought want the world to believe that synthetic chemicals are bad and natural chemicals are good. It is a particularly important argument when discussing pesticides and medicines"*
>
> **Chemistry the wonders, beauty and BS!**

TECHNICAL NOTES

TIPWG, GOING ABOVE AND BEYOND

ACROSS the globe, Forestry is a challenging sector to be in. On a daily basis we need to deal with economic, social, biotic and abiotic challenges – most of the time it is a combination of everything! The Industry's success lies in its ability to adapt to these challenges by being proactive and progressive, applying a holistic approach to forest management, utilising new technologies and embracing the implementation of innovation. None of this would be possible without the Sector's strong knowledge-base, generated by world class research and supported by financial investment into R&D that is more than double the country average.

"...the Sector's strong knowledge-base, generated by world class research and supported by financial investment into R&D that is more than double the country average."

It is critical the Industry not only maintains this strong research base, but also works hard to expand it. The scientific research produced by, and for the Industry, will play a fundamental role as it moves forward, helping to negate the challenges we currently face as well as provide potential solutions to the mounting global challenges society will face.

As FSA Director of Research and Protection, I am proud of the world class research we produce, both in-house and with our research partners and commend the dedication of the researchers and support staff involved. I am very privileged to be privy to a large proportion of the incredible research being produced of which only a fraction is ever published. This is an area where the Sector can improve, as the dissemination of information produced by the research sector is critical to enable implementation and increase our return on investment and where TIP-Mag will constructively contribute to the Sector as a whole. The TIP-Mag initiative provides a platform for researchers, as well as students involved in forest research, to publish work that might not fit the criteria for peer-reviewed scientific journals but is still of exceptional quality and valuable to the Industry. This is a novel initiative that will without a doubt be a jewel of the Sector and in this regard, we need to acknowledge Roger Poole, Jacqui Meyer and Katy Johnson. Their creativity, foresight and passion for the Sector has elevated TIP-Mag to another level, making it not only a platform for publishing forestry research, but also a communication tool for knowledge transfer between researchers developing the future of forestry and the foresters on the ground implementing it.

Science should never be done simply for science sake. Even great research could become this if it is only communicated at a scientific level. For science to be adopted and revolutionise industry, it must be communicated to a far broader range of stakeholders. The audience should include everyone, from the forestry decision makers to the forester on the ground and even the contracting fraternity that operate within the Industry. This is no small feat, but one I am confident TIP-Mag will achieve.

To get to this point where we can proudly publish the first issue of TIP-Mag has taken a great deal of hard work, time, belief and patience from all involved, including the many contributors and we would like to acknowledge everyone involved. Although this is only the first issue, I know TIP-Mag has the potential to become far greater and I am convinced the scope and interest will grow. Already we have international contributors and one day I hope it will include research from every aspect of forestry.

May you enjoy reading and interrogating this first issue of TIP-Mag. The first of many!

Dr Ronald Heath
FSA Director:
Research and Protection

DEALING WITH CLIMATE CHANGE: A TREE BREEDING PERSPECTIVE

Dr Marius du Plessis – Mondi Ltd, Tree Breeding Programme Manager

The views expressed are those of the author and not of Mondi Ltd.

IN RECENT years the incidence of pests and diseases in plantation forests have steadily risen to the high levels we experience today. With the increased prevalence of climate change, forests have become more vulnerable to biotic and abiotic influences. This will have a negative effect on forest health and will be of economic consequence to the industry.

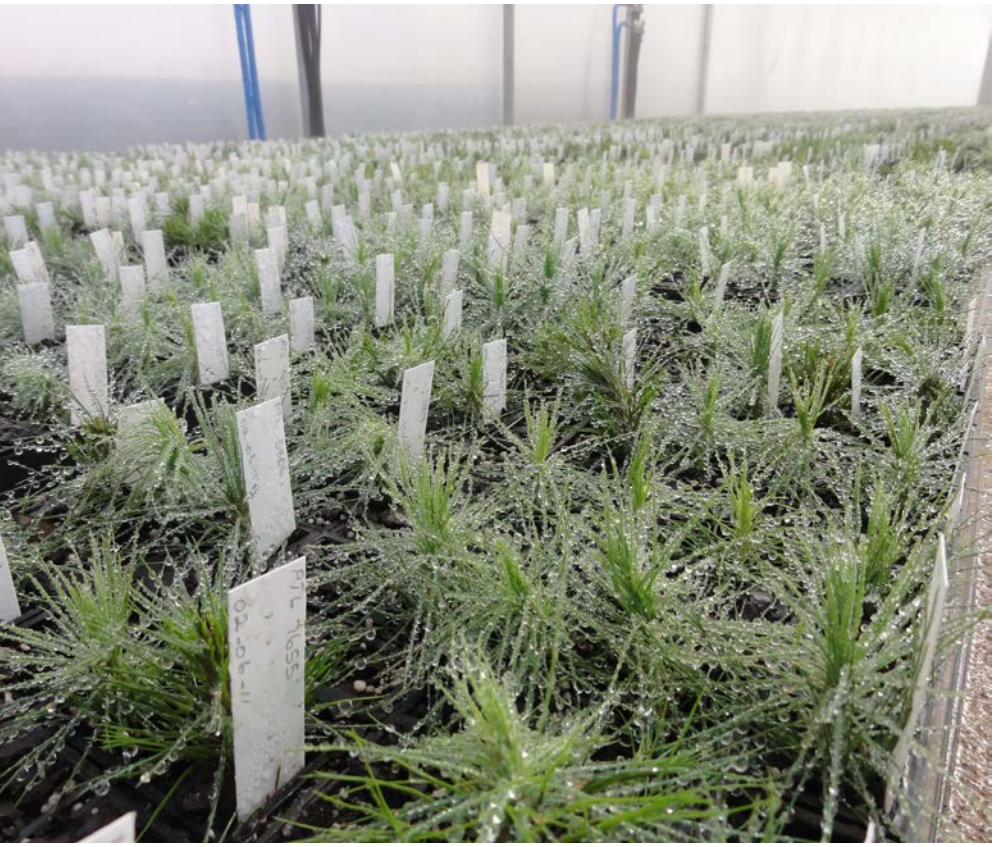
CLIMATE CHANGE

Many would assign the phenomena of increased threats to plantations casually as "climate change", but what really is climate change? Technically, the change in climate is brought on by the emission of anthropogenic greenhouse gases (GHG) e.g. the burning of fossil fuels, the subsequent heating of the Pacific Ocean and the associated El Niño effect, which in turn disrupts the usual weather patterns and global climate. GHGs are measured as the concentration of carbon dioxide (CO2), nitrous oxide (N2O), hydrofluorocarbons and other GHGs in the atmosphere. Most authors make it abundantly clear that the changes in climate are all attributable to human activities, which has amongst other phenomena, given rise to increases in global temperatures and temperature extremes. It is also construed that southern Africa is highly vulnerable to climatic variability and the region by itself may be significantly affected by climate change. The results of climate modelling by running Global Climate Models (GCM) have shown inconsistent predictions of future climates. However, recently greater consistency between projects were reported. Assuming that emissions of man-made greenhouse gases continue to rise at current or higher levels, central southern Africa as a region is likely to be drier in the future during mid-summer while temperatures are projected to keep on rising steadily. This may have an impact on infrastructure, agriculture, water resources and ecosystem services and as one can attest, it has already taken effect! For example, several bird species have changed their distribution or their numbers are declining, 50% of coral reefs globally have been lost or reduced as a result of ocean acidification and warming, also communities are becoming more vulnerable pertaining to safety and food security. Commercially important fish stocks have already shown distribution changes, while some vineyard growers have started to move their crops to higher altitudes to maintain quality.

Dr Marius du Plessis

$$P = G + E + (G \times E)$$

"The productivity of intensively managed Eucalyptus plantations is greatly dependent on genetics, silviculture and the climate."



WHAT IS GENETIC ENVIRONMENTAL INTERACTION (GXE) AND WHY IS THAT IMPORTANT

The productivity of intensively managed *Eucalyptus* plantations is greatly dependant on genetics, silviculture and the climate. Breeding programmes aim to select productive genotypes for different geographical regions and a key determining factor is understanding the interaction between the genotype and environment. This interaction is manifested in the phenotype. The phenotype is the observed trait (e.g. tree volume) which is resultant of its genetic composition and the environment and any interactions between its genetics in that environment, generally shown as **P = G + E + (G×E).**

GxE-interaction in forest tree species arises when the relative performance of genetic entities is not consistent between different environments. Current research indicates that the greatest variability in the phenotype is due to the environmental difference between sites (same genetics) followed by the effect of genetics and lastly the effect of GxE-interaction. Since tree breeders are primarily concerned with the evaluation and selection among candidate genotypes, the change in ranking across environments is of great interest to them; however, phenotype (e.g. tree volume) assists them to decide which genotype to choose for deployment in a particular growing environment (forest site). This strong reliance on field-testing necessitates the establishment of a well-balanced experimental network over the entire landscape. This helps to reduce, remove and determine the pattern and magnitude of the G×E in order to obtain the best genetic gain for the trait of interest. Tree breeders often address G×E either by selecting stable genotypes that are not sensitive to environmental changes and have broad adaptability or selecting genotypes for specific environments in order to maximise genetic gain on that site. The strategy of selecting generalist and stable genotypes with high productivity over a large landscape, is favoured because of the ease of deployment from forest nurseries and the large trial networks that companies have established.

A study completed across an environmental gradient through Brazil and Uruguay, investigating the relationship between growth and climate, disclosed a series of interesting GxE-interactions. *Eucalyptus* growth declined 2.5 MAI points ($m3\ ha^{-1}\ an^{-1}$) with every 1^0 Celsius rise in temperature and volume production increased 1.5 MAI points with an increase of 100 mm rainfall per annum. Although there may be some geographic covariance involved, it is construed that environmental parameters influence productivity and hence climate change may have similar effects, possibly more profound.

Although we talk about environment in a collective way; weather patterns, climate and climate change are unequivocally connected to the environment. This supports the need to test various genotypes in anticipated or projected climate changed environments.

DEALING WITH CLIMATE CHANGE FROM A TREE BREEDING PERSPECTIVE

The conventional tree breeding process by repetitive selections and GxE-interactional breeding, has been adequate to produce resistant genotypes until recently. In the past decade it became clear this approach is too slow to capture resistance due to the fast rate of change in pest and disease dynamics. A more modern approach is a complex process whereby genomic tools are introduced to accelerate achieving suitable phenotypes e.g. pest and disease resistance in trees. Supplementary selection approaches such as Marker Assisted Breeding Selection (MABS) together with the aid of new genomic tools e.g. Genome-wide Association Studies (GWAS) and Genetic Selection (GS) can enhance the selection rate of resistant genotypes, which are accelerated into breeding programmes for fast tracked breeding efforts.

Breeding programmes are well structured to provide amongst others, phenotypic information about resistant or susceptible individual genotypes, to study GxE-interaction and to supply information to assist with genome-wide association. Typical challenges to tree breeders are to identify genotypes with resistance to pests and disease, frost and drought tolerance, excellent wood properties, etc. all of which can to some degree be ascribed to climate change. Authors describe the multitude of approaches e.g. phenomics, genomics, metabolomics and transcriptomics to name a few, that are useful to identify protection mechanisms governing resistance if integrated on a systems level. With this information in hand, it is now possible to start using synthetic biology and genome editing techniques in a bioengineering approach based on a deeper understanding and rational design of biological parts, devices and integrated systems.

It is also true that opportunities present challenges, e.g. to fully understand systems biology and its interactive components, large investments in data informatics, machine learning and capacity is required. Furthermore, the bioengineering approach, mainly focussed at biomass enhancement or stress management abilities of plants or both, mainly achieved through transgenics or genome editing, is not popular with certification bodies and therefore it is not practised commercially.

Even still, these tools can be of great use, especially if the requirement of new resistant breeding material is mandatory to keep ahead of climate change and the associated and unintended consequences thereof. Great effort is required to socialise the idea that the engineering of tree mechanisms to withstand climate change, may be the key to the long term sustainability of the forestry industry.

INFORMATION BLOCK:

PHENOMICS is the systematic measurement and analysis of qualitative and quantitative traits for the refinement and characterization of a phenotype.

GENOMICS is a branch of biotechnology concerned with applying the techniques of genetics and molecular biology to the genetic mapping and DNA sequencing of genes of selected organisms.

METABOLOMICS is the study of small molecules, commonly known as metabolites, within cells, biofluids, tissues or organisms which play many different roles in plant growth and development and in plant response to continually changing environmental conditions as well as abiotic and biotic stresses.

TRANSCRIPTOMICS technologies are the techniques used to study an organism's transcriptome, the sum of all of its RNA transcripts. Transcriptomic analysis has enabled the study of how gene expression changes in different organisms and has been instrumental in the studying of diseases of living organisms.

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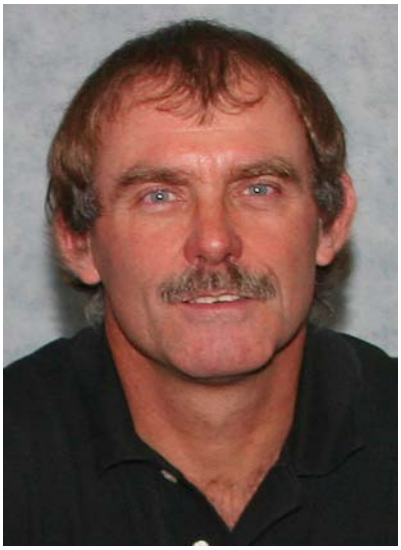
THE WONDERS AND BEAUTY OF CHEMISTRY .... AND THE BS!

Dr Gerhard H Verdoorn – CropLife South Africa, Operations and Stewardship Manager



Dr Gerhard H Verdoorn

IN THE BEGINNING...

…THERE was nothing. No space. No time. No matter. No energy. No sound. Nothing. It was thirteen thousand million years ago. Suddenly, a massive explosion erupted. The Big Bang gave birth to our Universe in which time, space, matter, sounds and energy were all conceived to grow into what we have today: a massive, mystical entity that is unfathomable for the minds of the normal mortals. Guess what: The Big Bang was the largest synthetic chemistry experiment in the existence of the Universe and perpetuates to this very day with chemicals being formed, chemicals disappearing into black holes and chemicals being transformed into energy according to Einstein's amazing theories. The entire Universe is a massive collection of chemicals consisting of elements, molecules, black matter and the wonderful living organisms we have on Planet Earth and hopefully, somewhere else in this massive chemical factory called the Universe there are other life forms as well.

INORGANIC AND ORGANIC CHEMICALS IN THE UNIVERSE

Speculation is rife about the nature and character of the so-called God Particle that scientists postulate as the origin of the Universe, but in the modern day and age we can at least be certain about two things: The Universe has inorganic matter and organic matter. Inorganic matter is the bulk of the Universe's physical matter and is made of elements ranging from the simple hydrogen atom through heavy metals, noble metals like the much sought after gold, radio-active elements such as radium and up to synthetic elements like Moscovium and of course combinations of such elements to form molecules like the fantastic array of minerals we have on the Blue Planet. Stars, planets, galaxies, nebulae, meteorites, comets and other celestial bodies all consist of inorganic matter either in solid, liquid or gaseous form. It is beyond fascinating that we live in and amongst all this chemistry that was born, transformed and wiped out in universal processes over the past thirteen billion years. But despite this enormous pot of scientific wonders of elements and inorganic molecules that make up the minerals, metals, gases and other matter of the physical part of the Universe, humankind is far more intrigued by the organic chemistry of the Universe probably because it is the chemistry of life. The fundamental elements of life are carbon, hydrogen, oxygen and nitrogen with much support from phosphorus, sulphur and a few other elements. Organic molecules are built on carbon skeletons with an ensemble of hydrogen and some oxygen and nitrogen. Simple amino acids have nitrogen atoms in the carbon skeletons and when a few amino acids are cemented together they form peptides and a few peptides combined by chemical bonds form proteins and the rest is simple: life is possible! There is of course big debate about the origins of life: was it a divine intervention or was it purely random events that could have formed organic molecules that over millennia were expanded into life? It is yours to decide but let us look at the scientific side and leave the philosophical part for another day.

ORGANIC MOLECULES

The simplest of organic molecules is formaldehyde (remember the lab and the preservation of lab specimens in formalin?): it has one carbon atom, two hydrogen atoms and one oxygen atom. It is a natural chemical produced by nature while a fairly well qualified synthetic organic chemist can synthesise it in the laboratory in no time at all. Methane or CH_4 is also a very simple organic molecule that is flagged as greenhouse gas but is something that can act as a building

> *"Certain schools of thought want the world to believe that synthetic chemicals are bad and natural chemicals are good. It is a particularly important argument when discussing pesticides and medicines"*

Photo by Anton Darius on Unsplash

block for much more complex molecules. Nature also synthesises other organic molecules from small to very large like the proteins and the code of life namely deoxyribonucleic acid or DNA. They are all organic chemical compounds with carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur and some other elements like iron (haemoglobin) and magnesium (chlorophyll). To date, more than nine million organic molecules are known to science and a very large percentage of those are man-made substances. Synthetic organic chemists like Nobel Prize winner Prof Elias J Corey can synthesise virtually any standard molecule that nature produces, but they also synthesise analogues of natural organic molecules and organic molecules that have never been and will never be synthesised in nature. The link between natural organic molecules and synthetic organic molecules is very, very strong. Scientists often find their inspiration for synthetic organic molecules by searching for biologically active natural organic molecules. A simple example is the amazing salicylic acid found in the willow tree; it is easily transformed into acetylsalicylic acid, one of the oldest pain killers and mildest of anti-inflammatory agents in the world.

THE GREAT NATURAL VERSUS SYNTHETIC CONTROVERSY

Certain schools of thought want the world to believe that synthetic chemicals are bad and natural chemicals are good. It is a particularly important argument when discussing pesticides and medicines. The anti-pesticide lobby wants the world to move away from synthetic pesticides and convince people to use natural herbal remedies as medicines because the synthetic products are "chemicals" and the natural ones are organic. Whoops! Who failed their natural science in the pre-school years?? All these molecules, bar a small percentage of inorganic compounds like magnesium sulphate for example, are **organic molecules –** independent of whether they were produced naturally or man-made – as they consist of carbon skeletons with other elements attached to form the molecules. Forget about the claim of the failed pre-school anti-chemistry graduates that "their" *natural* products are free of chemicals. Brothers and sisters of the Universe: your bodies are chemical factories producing billions of natural chemical molecules annually. There is no synthetic laboratory to match the synthetic ability of a living organism's body!! Not even the awesome Elias J Corey is a match for his own body's synthetic prowess. Yet, we make molecules just like Mother Nature and the only difference is that ours are man-made synthetic molecules while Nature's are natural synthetic molecules. Synthesis in chemical terms means to build a molecule; both us as scientists and Nature do synthesis. Nature though, has huge advantage over us and that advantage lies in the enzymes that synthesise the natural synthetic molecules while Professor Corey and company use reagents and clever reactions to synthesise our man-made synthetic molecules. Perhaps to clear the confusion we should use the terms bio-synthesise versus synthesise, the former being the natural process and the latter being the laboratory process.

To end this paragraph, an illustration of the power or laboratory chemical synthesis is as follows: cane sugar or sucrose (*alpha-D*-glucopyranoside-*beta-D*-fructofuranoside) can be transformed by a series of chemical reactions using a range of chemical reagents to synthesise natural or man-made analogues of prostaglandin hormones! So, what Mother Nature bio-synthesises in our bodies very quickly using enzymes, we can synthesise in the laboratory with a lot of effort and at great cost, but it is possible. Yours truly did that as part of doctoral study in synthetic organic chemistry.

IS NATURAL SAFER AND BETTER THAN MAN-MADE?

Be honest with yourself: a significant percentage of what manufacturers and retailers tell about their products are simply marketing ploys. The idea of natural chemicals being better than man-made chemicals is senseless. The penicillin anti-microbials are natural products while some of the other antibiotics are man-made synthetic chemicals and collectively, they serve a great purpose namely fighting diseases that would otherwise have wiped humankind out. Imagine a bubonic plague outbreak without antibiotics to fight the *Yersinia pestis* bacterium; we could have a repeat of the Black

Plague that killed about 20 million people in Europe early in the 14th Century. Natural soaps contain a load of chemicals while man-made soaps also contain a load of chemicals. Some of the natural pesticides like nicotine are better left alone (nicotine is a potent toxin and a main ingredient of tobacco smoke that is categorised as a Class I carcinogen) while man-made molecules like the pyrethroids are more efficient than most natural pesticides. It doesn't mean that natural molecules are not efficient; take for example azadirachtin, abamectin and matrine: these are natural compounds with excellent insecticidal properties. We do, however, have man-made molecules that are equally efficient like the diamides and the old organophosphates, but the latter are rapidly falling out of favour due to their acute toxicity. We can easily dump the man-made synthetic chemistry for natural synthetic compounds, but are we prepared for the sacrifices? Loss of life to dreadful diseases due to loss of synthetic drugs. Loss of crops due to insect pests, rodents, plant pathogens and weeds. Or would you perhaps enjoy food produced with mercury and arsenic as pesticides? And would one cope without detergents to clean laundry, cutlery and crockery? Would the women of the world sacrifice all their perfumes and beauty care products, most of which are serious concoctions of natural and man-made chemicals? Chemistry is part of our lives. Chemistry is life. Without man-made and natural chemicals there is no life for humankind, at least not as we enjoy it today. Natural and man-made chemicals are all chemicals; our mission is to find those ones that serve our purposes and it may very well be that Mother Nature is the synthesiser of such molecules.

ORGANIC, NATURAL AND SYNTHETIC PESTICIDES

If there was ever a misunderstood topic, this one reaches the finishing line ahead of everything else. Various copper compounds are certified for "organic" agriculture, yet the very same chemicals are used in conventional agriculture. Pyrethrum is used in organic agriculture and similarly in conventional agriculture. So is neem oil of which the active ingredient is azadirachtin. It goes on and on but when you walk into some food retailers the organic branding is rife and the prices are high. An opinion is that term "organic food" is seriously abused and totally overrated. It is a ploy to charge more for something that is no better than that produced by conventional agriculture. What is troublesome is chemical analysis has proven beyond doubt that some "organic" pesticides are spiked with classic synthetic or natural pesticide to render "organic" pesticides with some level of efficacy. That is not even fraud, it is blatantly criminal. A pesticide is a pesticide, irrespective of whether it was synthesised in a laboratory by the hands of an organic chemist or whether nature synthesised it in some living organism. The molecules are all organic in the chemical sense of being built on carbon frameworks, so if branded "organic", then tell us as organic chemists what is exactly meant by that.

"We can easily dump the man-made synthetic chemistry for natural synthetic compounds, but are we prepared for the sacrifices?"

SYNTHETIC CHEMICALS ARE HARMFUL TO PEOPLE AND THE ENVIRONMENT: REALLY??

The fact that Mother Nature synthesised a molecule does not mean it is safe. On the contrary is it fact that we have never been able to synthesise a molecule in the laboratory that beats the toxicity of some of the natural

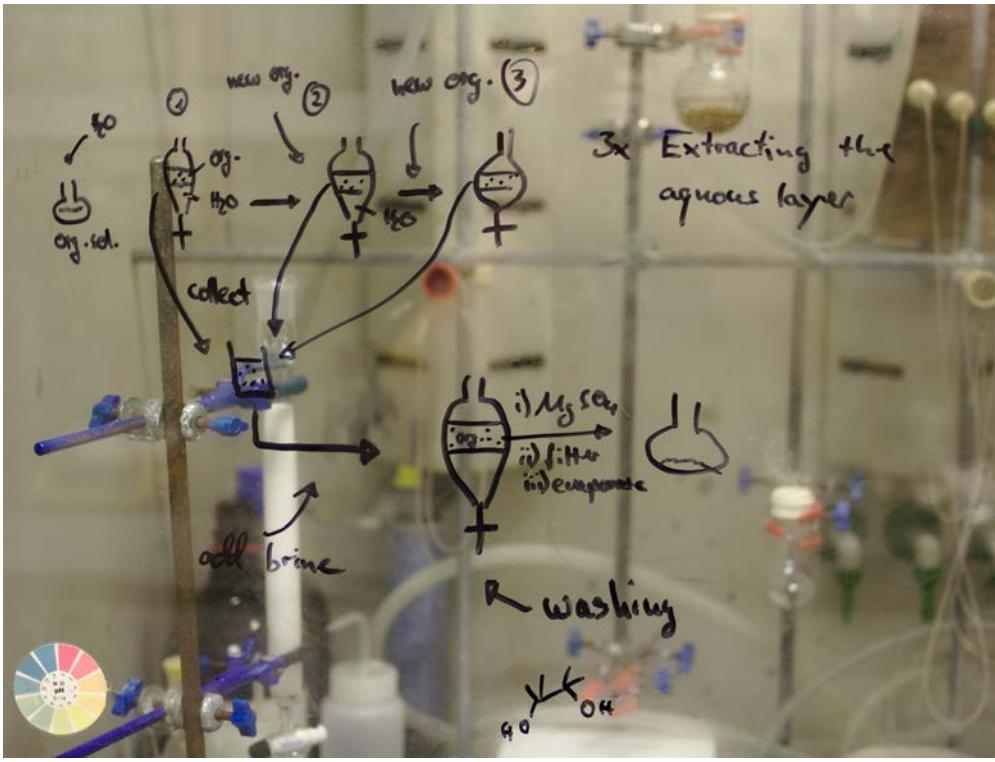


Photo by Chromatograph on Unsplash

> *"Considering the massive amount of chemicals in the environment and what is consumed daily via food, water and beverages, one wonders how we remain alive and healthy?"*

Photo by MILKOVÍ on Unsplash

organic compounds. Try and snack on poorly prepared Japanese puffer fish and feel the effects of tetrodotoxin, a deadly alkaloid that is much more potent than Sarin, one of the feared nerve gases used in chemical warfare. Or touch the vividly coloured poison arrow frogs of the Amazon and collapse in seconds to the incredible power of curare toxins and batrachotoxin that can paralyse a victim in seconds. Go a few steps forward to one of the world's most powerful toxins namely botulinum toxin that is produced and stored in decaying food matter, evaporating water bodies and bones of skeletons. It can be deadly, and it is Mother Nature's ultimate weapon. Wild animals like birds die by the thousands if this naturally made protein poisons open water bodies during high temperatures that cause wilting and rapid evaporation. Ungulates that chew on bones of their fallen mates drop dead due to flaccid paralysis caused by this toxin and people who get food poisoning sometimes wish they could die! Same goes for some natural metabolites of plants. Monofluoroacetic acid of the poison leaf plant is a terrible livestock killer and as little as 4 mg can kill an adult person within four hours. It may take longer to kill a person than aldicarb would do, but death is unavoidable with this potent poison leaf toxin. Yes, some of our man-made synthetic chemicals are very toxic to people and the environment but Mother Nature's chemical arsenal is nothing to play with. A toxin or toxicon or poison or venom is an organic compound (mostly) that need not be man-made to be incredibly toxic! It is safer to touch a pesticide compound like methomyl than play with a Bufo gutturalis toad and lick your fingers afterwards and ingest the bufadienolide compound that is quite toxic.

PESTICIDES ARE POISONOUS: YES, BUT WHAT ABOUT THE OTHER CHEMICALS?

Chemicals are often labelled as "poisonous" by those who have never engaged the science of toxicology but are firm believers in the self-acclaimed scientists of Facebook and Twitter and read any sensational gibberish on Prophet Google. Most people cannot distinguish between peer reviewed science and sensational garbage. The father of toxicology, namely Philippus Aureolus Theophrastus Bombastus von Hohenheim, generally known as Paracelsus, cast the founding principle of toxicology in stone: "all substances are poisons, there is none that is not a poison. The right dose differentiates a poison from a remedy". Without even knowing it, Paracelsus also founded the principles of hazard versus risk with this statement and we will touch on it later. Being mindful of Paracelsus's founding principle, let us evaluate human medicines. Paracetamol must be one of the most widely used pain killers in South Africa and is sold over the counter in pharmacies, retail outlets and even the forecourts of fuel stations. Its acute mammal oral toxicity is on par with that of the pyrethroid cyphenothrin which is used in many household insecticides. The tetracycline anti-microbial doxycycline that is very effective to cure patients who contracted tick bite fever is of the same level of mammal oral toxicity as the organophosphate fenthion. Codeine

hydrochloride is quite a poisonous substance and is also known as a potential habit-forming drug (developing dependence) but is sold over the counter for self-medication. The list of substances that are toxic is endless but what does it mean for the layman who is not a toxicologist? Go back to Paracelsus's statement and don't eat the entire tube of toothpaste because what is supposed to be a remedy, becomes a poison! Take 1,000 mg of paracetamol tablets and not half the container because the medicine becomes a poison at such a dosage, and yes, many patients overdose on paracetamol and end up in hospital with paracetamol poisoning. It is interesting that hospitals administer more medicine related overdose patients than pesticide poisoned patients, but Prophet Google is oblivious of that.

The concept of toxicology is far wider than acute or chronic oral (intake) or dermal (touch) toxicity. Some chemicals are carcinogens (cancer causing agents), other teratogens (cause birth defects), some mutagens (cause mutations of genetic coding in DNA), others clastogens (accelerates existing cancer in a patient), some ototoxins (affects hearing) while some affect vision, organ function and the endocrine system and must also be considered in the discipline of toxicology. The drug that shook the world in the 1960s and 1970s was thalidomide that has virtually no acute oral toxicity but is a terrible teratogen that caused birth defect in thousands of babies.

Considering the massive amount of chemicals in the environment and what is consumed daily *via* food, water and beverages, one wonders how we remain alive and healthy? The answer lies in the science of toxicology.

IT IS ALL ABOUT THE DOSAGE, NOT ABOUT THE SUBSTANCE

A living organism, for example an adult human being can ingest 1 mg aldicarb which is an extremely toxic nematicide and will not feel an effect or develop any symptoms. The same person may drink two 500 ml cans of the popular energy drinks and develop serious tachycardia (very high pulse rate) of a "non-toxic" energy drink. The aldicarb is highly toxic but the patient ingested at least 80 times less of the toxin to generate a physiological response. The caffeine in the energy drinks is in a very high dosage and downing two cans of that stuff is bound to trigger a near toxic response in the person who does so. Meanwhile, caffeine is a stimulant taken in billions of cups of coffee every day all over the world without any adverse effects on people apart from offering serious enjoyment to the coffee drinkers. Paracelsus was very clear: it is all about the dosage. Botulinum toxin is toxic at a level of 0.0001 mg per kg body mass, but does it kill a person with food poisoning? Not always, because the person may not have ingested enough to perish from the toxin. Two dogs, one a Jack Russell and the other a Rottweiler, may lick methomyl-based fly bait. The Rottweiler is unaffected, but the Jack Russell becomes violently ill with shivering, nausea, vomiting, pupil constriction and rapid breathing. Both dogs ingested the same quantity, but the dose was too little to affect the 70 kg Rottweiler but near fatal for the Jack Russell. It is all about the dosage. Why do you think a medical doctor gives a prescription for a scheduled medicine? Not only to cure the patient but also to ensure that the patient takes a therapeutic instead of toxic dosage.

In toxicology there are certain safety parameters for all substances most important of which is the ADI or allowed daily intake. Toxicologists do meticulous calculations of the substance's toxicology, the food basket (meaning looking at the average food consumption of a person) and the MRLs or maximum residue limits of the substance and then produce an allowed daily intake of the substance for human beings. That figure is universally accepted as the daily dosage of a substance that a person may ingest without it having any health effects on the person. Glyphosate is in the news, so let's consider glyphosate. The ADI for glyphosate is between 1 and 2 mg/kg body mass per day meaning an 80 kg adult can safely consume 80 mg to 160 mg glyphosate per day without any adverse effects. It is alleged that bread in South Africa contains 2 to 4 mg glyphosate per loaf, so go ahead and eat 20 to 40 loaves of bread if you can! This assessment of the allowed daily intake is not only based on acute oral toxicity; it also considers all other toxicological effects. Some substances may not have a significant oral toxicity but may damage organs over prolonged period of times. Aspirin developed a reputation as a nephrotoxin (kidney toxin) simply because people overdosed on aspirin by continuously using excessive dosages of this wonderful medicine.

To add some flavour here: the same principles are applied to man-made synthetic pesticides, natural pesticides and so-called "organic" pesticides. Every pesticide must have an ADI whether Nature made it, or man made it.

> *"Pesticides are connected by one common characteristic namely to kill undesired organisms. This common characteristic is feared by the uninformed and used as a lobby tool against pesticides."*

RISK VERSUS HAZARD

Pesticides are connected by one common characteristic namely to kill undesired organisms. This common characteristic is feared by the

uninformed and used as a lobby tool against pesticides. Understanding the difference between hazard and risk is perhaps the most valuable tool to allay the public fears of pesticides but also to instil a sense of responsibility into people who use pesticides. The toxicity of a pesticide is mostly expressed as its hazard to human beings using the oral and dermal acute toxicity. Taking a laboratory mouse into a controlled laboratory environment and exposing it to an acute dosage of a pesticide to monitor its response, is a hazard evaluation. Allowing Mr Mouse to range freely in an agricultural system where the same pesticide is sprayed at a highly diluted concentration over a very large area and monitoring the mouse's response to the pesticide is a risk assessment. In the laboratory the mouse is an obligate target of the pesticide because it is either fed the pesticide with its food, injected with the pesticide or exposed to an atmosphere filled with the pesticide's vapours. Such conditions only measure that hazard or the direct toxicity of the pesticide to the mouse. It is impossible to relate that to field conditions where the mouse will never eat food that is deliberately laced with the pesticide (unless it is a rodenticide), be injected with the pesticide or inhale air that is saturated with the pesticide. Although the pesticide may be hazardous, the risk for the mouse in field conditions in negligible.

It is a great pity, and very poor reflection on scientists, that some scientists do laboratory studies, force certain results to prove that certain compounds are hazardous but deliberately fail to express the real-life risks to the environment and people. A classic example is the glyphosate one where a laboratory elected to use mice that are predisposed to cancer development, exposed the creatures to glyphosate dosages that were excessive and included cancer in the mice. The International Association for Research on Cancer or IARC, henceforth classified glyphosate as a category 2A carcinogen. When asked whether there is a true risk of cancer for people being exposed to normal levels of glyphosate, their response was that they only evaluate the hazards and not the risk. The United States Environmental Protection Agency and the European Food Safety Association did an incredibly thorough review of the risks of glyphosate for inducing cancer and found that there is NO RISK OF CANCER! Take a moment and think logically about it: if glyphosate was really such a grave cancer risk why doesn't everyone in the world have cancer? We are exposed to low levels of glyphosate, far below the ADI and yet there is no mass cancer outbreak because the exposure level is far too low. If we really want to ban a real "non-toxic" toxin that kills people, we should prohibit all alcoholic beverages. Ethyl alcohol has a library full of serious adverse effects on people such as intoxication meaning drunkenness, memory loss, liver sclerosis and worst of all, it causes foetal alcohol syndrome. Yet, people shout about chemicals while guzzling alcoholic beverages by the gallon.

That pesticides may pose a risk, is indisputable but it takes some extra logical thinking to unfathom the risk versus hazard. A benign compound like *alpha*-cypermethrin is a low hazard pesticide but it is a high risk in the hands of the public who fail to use personal protective clothing and suffer severe dermal irritation because of skin contamination with the product. Technically speaking, the hazard is an inherent physical property of a compound and the risk is a man-made property. The most benign compounds of low hazard may pose a high risk to people if used irresponsibly while high risk compounds like dichlorvos can be low hazard if used responsibly. Pyrethroids are typical low risk compounds for most mammals and birds but extremely high risk for fish and amphibians due to extreme toxicity for such organisms.

> *"Take the man-made synthetic chemicals out of the picture and as a species, we head for extinction, maybe not too soon but definitely in the long run"*

THE FINAL WORD

A world without chemistry is unthinkable because human beings rely on chemicals for their well-being, food, fibre, homes, transport and medication. Take the man-made synthetic chemicals out of the picture and as a species, we head for extinction, maybe not too soon but definitely in the long run. The medicines will be severely reduced, the household products will disappear, and the pesticide market will collapse. What should we do? Abandon chemistry as one of the life support systems for humankind? No! Simply stop believing all the marketing BS and Google rubbish and be responsible whenever using ANY chemical product. Don't use chemicals of whatever nature excessively. Don't use chemicals when not really required like drenching a room in an aerosol mist because there is one mosquito! Read all the instructions of the chemical's container and follow it, even if it is something like a laundry detergent. Store chemicals in a safe place out of reach of children and pets. A benign compound is a potentially high-risk weapon in the hands of the uninformed, irresponsible and careless person. There is no bad chemical in the Universe, it is people who turn chemicals into harmful compounds by being irresponsible.

WHY CONTEXT IS KEY!

Jacqui Meyer – TIPWG Secretariat, Dr Katy Johnson and Dr Ronald Heath – Forestry South Africa

"Taken out of context, the potential risks associated with an action carry more weight, because they are the sole focus."

CONTEXT: THE BIGGER PICTURE

IMAGINE a world without context, where a single statement was allowed to sum up an entire object, event or individual. It wouldn't paint a very clear or accurate picture. Yet, when it comes to risk, this is exactly what we do.

There are risks and benefits associated with almost everything. Taken out of context, the potential risks associated with an action carry more weight, because they are the sole focus. Yet, when placed in context, where they can be compared and evaluated against "bigger picture" elements such as the potential benefits associated with the action and the risks of not adopting it, a more realistic picture of the potential risk forms.

The same can be applied to potential hazards, which when considered in isolation, can appear far riskier. This was illustrated in the hazard-based approach adopted in 2002 by the Forest Stewardship Council® (FSC®) with regard to pesticides (FSC-STD-01-001 V4-0 FSC Principles and Criteria). The policy considered the inherent hazardous properties of a pesticide, rather than the actual risk it posed.

Risk [R] is a function of two elements:

- **Hazard** [H] – the inherent properties of the pesticide, which could have negative human health or environmental consequences.
- **Exposure** [E] – the likelihood of these negative consequences being realised, which is determined by the amount of, and the frequency in which, exposure to the hazard occurs.

$$R = H \times E$$

By considering the hazards in isolation, the Policy took a highly precautionary approach.

THE PROBLEM WITH AN ULTRA-PRECAUTIONARY APPROACH?

On the surface, a highly precautionary approach seems the sensible idea. However, by taking this stance you are naturally erring on the side of non-adoption, which comes with it's own associated risks. The precautionary approach therefore assumes the risks associated with non-adoption are less than those of adoption.

In a pesticide context, assessing whether a pesticide could be used based solely on the inherent hazards it poses, rather than actual or realisable risk (hazard x exposure), lies the potential to promote the use of riskier pesticides and/or practices.

A classical example of this is the switch from paraquat to glyphosate-based herbicides for tracer belt preparation in forestry. In order to use paraquat under the previous FSC

Jacqui Meyer

"Thus, a risk-based assessment, that enables the three M's: mitigation, management and monitoring to come into play to reduce realised risk, will give a far more realistic picture of the actual environmental and social impact the pesticide's use will realistically cause."

pesticide policy, companies had to apply for a derogation. A derogation is simply the "permission to use" a pesticide deemed by FSC's policy as highly hazardous. In order to qualify for a derogation, Certificate Holders (CH) had to prove that there were no other options available; that research was being conducted to find alternatives and that the cost of NOT using the pesticides far exceeded the potential risk of using the pesticide. For CH who didn't have the capacity for this, a simple switch to glyphosate-based products provided a quick-fix solution.

Environmentally benign paraquat was placed on FSC's Highly Hazardous Pesticide (HHP) list due to its acute toxicity. While these pose a significant human health hazard, this can be mitigated with the use of correct Personal Protective Equipment (P.P.E), regular medicals, limiting exposure, pesticide training and the implementation of safe working standards. As these are all legislative requirements for anyone using pesticides within the South African Forestry Industry and as such, the exposure to this hazard is minimal, as is the realisable risk.

Glyphosate on the other hand is far less environmentally benign, which is why the Industry opted for paraquat when preparing tracer belts for fire breaks, many of which are set in conservation areas. When compared to paraquat, the inherent environmental hazards glyphosate-use posed – its mode of action kills the whole plant and thus long-term use can lead to erosion and possible silting of watercourses – were considered acceptable under FSC's hazard-based pesticide policy. However, the likelihood of exposure to these inherent hazards was far greater than the likelihood of exposure to paraquat's inherent hazards and less easy to manage. As a result, the potential realised risk of glyphosate-use is much higher.

The paraquat-glyphosate example is an ideal illustration of why hazard needs to be placed in the context of exposure when evaluating risk and why the South African Forestry Industry pushed for a risk-based approach in the updated FSC pesticide policy.

Exposure, and thus risk, can be managed and mitigated against, while hazard is an inherent property and cannot. Thus, a risk-based assessment, that enables the three M's: mitigation, management and monitoring to come into play to reduce realised risk, will give a far more realistic picture of the actual environmental and social impact the pesticide's use will realistically cause.

While the new FSC pesticide policy now contextualises the hazard pesticides pose, does it do enough to contextualise the risk?

ENVIRONMENTAL, SOCIAL.... WHAT ABOUT ECONOMIC?

The new FSC policy challenges National Standard Development Groups (SDGs) and CH's to evaluate the environmental and social (or health) risks posed by all chemical pesticides applied on certified plantations and forests. This is to be presented in the form of an Environmental and Social Risk Assessment, or ESRA for short.

Managing and reducing their environmental and social impact has been a key concern for the South African Forestry Sector since the early 1990's. This is demonstrated by the level of self-regulation applied by the Industry with regards to water-stewardship, the management of conservation areas, afforestation and wetland delineation, which goes above and beyond what is required nationally and internationally. This becomes increasingly apparent when the Industry is considered in context against other agricultural landowners, who simply do not have the same level of self-imposed regulations applied. The same can be said for the Forestry's social programmes, which

has seen the Sector invest billions of Rands into the rural communities neighbouring forestry-owned land in the form of educational and health-based programmes, infrastructure, food security projects, community development and entrepreneurial schemes. Programmes aim to reduce and manage the Industry's environmental footprint and bring about positive social impacts and need to be contextualised against the economic benefits that the Sector provides not only to justify the expenses associated with them. Contextualisation is needed to get an accurate picture of the Sector, this can only be done by considering the economic benefits forestry brings alongside the potential environmental risks and social impacts (both positive and negative) and the ways in which these are managed and mitigated against.

The need to see the environmental and social impacts of forestry in context with the economic impacts, can equally be applied to the regulation of pesticide use within the Industry. Surely the economics of using certain products, or management techniques, over others also be factored in, if it means the control of an alien species (a legislative requirement) could be negatively affected if not?

The reason for not including an economic evaluation is probably not a result of the process required to do so. Cost benefit and other economic analysis have been factored alongside risk assessment processes across a number of disciplines for a large variety of risks.

Instead, it is probably a result of the potential "Pandora's box" that could be opened, when making a decision on whether the risk posed by a specific pesticide is acceptable or not. Currently, the environmental and social assessments of risk are designed to identify potential risks, not benefits. Whereas an economic assessment may present a benefit of using a specific product, then how do you weigh this against it's potential environmental and social risk? Suddenly it becomes more than a simple assessment of risk, as it enters the realms of risk acceptability, threshold values and risk weightings.

It seems there is no simple answer, so perhaps for now a simple assessment of just the environmental and social risk is preferable, but it doesn't change the fact that by doing this we are getting an incomplete picture of the risk posed.

BUT WHAT ABOUT THE POTENTIAL BENEFITS?

Evaluating pesticide use purely on the risks it poses, suggests that the benefits of their use do not exceed the unacceptable risk thresholds currently set. However, without a direct benefit assessment, how can this be known?

The new FSC Pesticide Policy takes a far stronger stance with regards to minimising pesticide usage than any of the previous versions, "*the CH shall use Integrated Pest Management (IPM) and silviculture systems which avoid, or aim at eliminating the use of chemical pesticides.*"(FSC Pesticides Policy FSC-POL-30-001 V3-0 EN , p14). However, they do recognise in certain circumstances, and after considering other pest management strategies, the use of chemical pesticides may be the only feasible way of controlling the pest problem and stress the legal responsibility of CH when it comes to managing alien species (FSC Pesticides Policy FSC-POL-30-001 V3-0 EN, p4). It is abundantly clear, that this Policy and the FSC is striving towards zero-pesticide use, so why should they include a benefit assessment?

We would argue that without one, you cannot properly understand the risk associated with not using the pesticide in question. The question remains; Could a change in the pesticides available to CH's mean that key plantation pests can no longer be effectively managed? Could it increase the cost of controlling alien species, without infinite funds available, meaning that alien encroachment increases? What about the impact of emerging pests and diseases, some with devastating effects? How do changes in pest management affect productivity further down the forest value chain and what would the economic impacts of this be? This could lead to significant financial loss as well as negative social impact due to loss of employment in the value chain?

While we agree that the risk assessment cannot include every 'knock-on' implication, the need to consider economic implications and the risk associated with not using the pesticide in question (the benefits that product brings) should be a topic for debate. We have only touched on the challenges that incorporating the economic impacts and benefit assessment would bring, as it would require an evaluation of the risks vs. benefits before a decision on usage could be taken. However, if done, there is no doubt that we would have a far better idea what the impact banning or restricting the use of specific pesticides would have.

"If done, there is no doubt that we would have a far better idea what the impact banning or restricting the use of specific pesticides would have."

"The need to see the environmental and social impacts of forestry in context with the economic impacts, can equally be applied to the regulation of pesticide use within the Industry."

ARE ALL OUR EGGS IN ONE BASKET?

Dr Benice Sivparsad – Institute for Commercial Forestry Research (ICFR), Senior Scientist

IMIDACLOPRID, the active ingredient in the two currently registered insecticides in South Africa for white grubs, has been listed by the Forest Stewardship Council (FSC) as a restricted highly hazardous pesticide (HHP). Any future use of these insecticides in FSC certified plantations will require the formulation of an integrated pest management (IPM) framework that considers all possible alternatives.

Imidacloprid's listing has therefore made the search for a viable alternative more important than ever. Even if one is not found, this research will contribute towards any future IPM strategy used to justify imidacloprid use.

> *"Imidacloprid's listing has therefore made the search for a viable alternative more important than ever."*

WHITE GRUBS: A NOTORIOUS SOIL PEST

The success of plantation regeneration can be particularly impacted by pests and pathogens that reduce post-plant survival. Several soil-dwelling pests, including termites, white grubs and cutworms can cause high post-planting mortality during plantation regeneration. Of these pests, white grubs are considered the dominant and most economically important soil pest because of their abundance, frequency of occurrence and type of damage. They affect all three plantation genera grown in South Africa.

WHAT ARE THEY?

"White grub" is the collective term given to the larval stages of chafer beetles including the large wattle chafer, longleg chafer and wattle leaf chafer. The larvae are C-shaped, white in colour with a distinctive brown head and three pairs of well-developed legs. Larval development consists of three instar stages: first, second and third. They grow from about 1–2 mm in length (first instar) to 10–30 mm when mature (third instar), depending on species.

WHAT DAMAGE DO THEY CAUSE?

The second and third instar stages of white grubs feed on the fine roots of newly planted seedlings. In severe cases, the root plug is completely eaten, with the under-ground portion of the stem ring-barked up to ground level. Damaged seedlings appear stressed and can be easily uprooted by gentle pulling. Root damage can result in reduced tree growth and if severe, death of young transplants.

HOW ARE WHITE GRUBS CONTROLLED?

Two insecticides containing the systemic neonicotinoid imidacloprid are used to prevent damage from white grubs: Apache Gold 350 SC® (mixed into planting water) and Suppositree® (a tablet placed in the planting pit). However, imidacloprid has been listed by the Forest Stewardship Council (FSC) as a restricted highly hazardous pesticide (HHP) and its use is under scrutiny.

THE NEED FOR MORE BASKETS!

The FSC may advocate the use of HHPs in an Integrated Pest Management (IPM) programme, but only after "*careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations.*" Therefore, additional work is required to justify the use of products containing imidacloprid and this involves research looking into alternative pesticide solutions. We can therefore no longer put all our eggs in this one white grub control basket without looking for possible, preferably biological, alternatives that comply with FSC regulations.

Dr Benice Sivparsad

FINDING MORE BASKETS: A POT TRIAL STUDY

A series of pot trials was carried out by the Institute for Commercial Forestry Research (ICFR) to test a range of chemical, natural and biological insecticides for the control of white grubs during eucalypt and wattle establishment (Sivparsad & Morris, 2017; Sivparsad *et al.*, 2018). A total of 14 insecticides (three biological, three natural and eight chemical) were evaluated:

BIOLOGICAL INSECTICIDES

1. Fungus: *Beauveria bassiana* strain R444
2. Fungus: *Beauveria brongniartii* strain HHWG1

3. Bacterium: *Bacillus thuringiensis* subspecies kurstaki

NATURAL INSECTICIDES

1. Neem oil: *Azadirachtin*
2. Diatomaceous earth
3. Potassium silicate

CHEMICAL INSECTICIDES

1. Imidacloprid granules
2. Clothianidin
3. Imidacloprid + clothianidin tablet
4. Imidacloprid + clothianidin + metalaxyl (fungicide) tablet
5. Imidacloprid + *Trichoderma asperellum* (fungus) tablet
6. Imidacloprid liquid (registered product)
7. Imidacloprid tablet (registered product)
8. Deltamethrin (currently used)

Acacia mearnsii and *Eucalyptus grandis* seedlings were planted in 30 cm pots and treated with the various treatment options. Biological and natural insecticides were also tested in combination with potassium silicate.

White grubs of *Schizonycha affinis* (a major species) were collected from the topsoil of sugarcane fields near Wartburg, KwaZulu-Natal where sugarcane and forest plantations exist as a mosaic in the landscape. Four healthy grubs were placed into each pot. After three months, seedlings were harvested and growth measurements of root collar diameter, height, shoot biomass and root biomass were taken and analysed.

KEY FINDINGS

- Currently registered products (imidacloprid tablets and liquid) worked the best out of all products tested.
- The most promising alternative insecticide was clothianidin.
- The most promising biological agent was *B. brongniartii* strain HHWG1.
- Treatment with *B. bassiana* strain R444, *B. thuringiensis* subspecies *kurstaki* and azadirachtin did not protect seedlings from damage.

SO....ARE THERE MORE BASKETS?

No….well…maybe in the future. Clothianidin, the most promising alternative, does not currently appear on any FSC lists of HHPs; however, it is a neonicotinoid and may be added to the list in the future.

That leaves *B. brongniartii* strain HHWG1, which is an experimental entomopathogenic fungus that was sourced from the South African Sugarcane Research Institute (SASRI). Although this strain is a good killer, it does not produce enough spores to make a formulated product.

More research is needed into the development of biological agents for white grubs.

This means for now, imidacloprid is still our only basket!

PLACING OUR BASKET UNDER THE WIDER IPM UMBRELLA

Aside from researching alternative pesticides, a strong IPM strategy for white grubs requires monitoring of grubs and adult beetle populations. ICFR conducted a two year monitoring study in the KwaZulu-Natal Midlands area to determine trends that increase risk of white grub damage (Sivparsad *et al.*, 2018). This, combined with the results of the pot trial can be used to develop a FSC-compliant IPM strategy for the control of white grubs, which for now at least, we will rely on **imidacloprid** to control.

ACKNOWLEDGEMENTS

This research project was made possible through funding from Mondi, Sappi, NCT and TWK. Sunshine Seedlings provided the eucalypt and black wattle seedlings. The South African Sugarcane Research Institute (SASRI) provided the ***B. brongniartii*** HHGW1 strain and facilitated the collection of white grub larvae from sugarcane fields. I-CAT planting solutions, Klub M5, Nufarm, Madumbi, Midlands Spraychem and Plant Health Products (PHP) provided the various biological and chemical products used in this evaluation.

More information on the pot trial and monitoring studies: https://www.icfr.ukzn.ac.za/publications or email Karusha Singh karusha.singh@icfr.ukzn.ac.za

GLYPHOSATE DRIFT CAN REDUCE EUCALYPT GROWTH BY MORE THAN 35%, EVEN AFTER FOUR YEARS

Jacob Crous – Sappi Forests, Programme Leader - Land Management

The opinion expressed here is that of the author and does not reflect the opinion of Sappi Forests.

I HAVE often wondered when walking though Sappi varietal trials (square blocks of new "clones" are planted to select the best of the best) why some trees just remain runts, as in this case genetics cannot be blamed. Is it due to the propagation technique, the site, the planter or the silviculture weed control after planting?

The most common herbicide used in forestry is glyphosate, a non-selective, systemic herbicide designed to kill almost any actively growing plant containing green chlorophyll. Often when unexplained damage or mortality in young eucalypt compartments is investigated one will notice tall, dried out weed(s) next to the tree(s) which show strange growth behaviour, chlorotic leaves or dead leaves and branches. The most likely explanation in these cases is that some of the glyphosate intended for weed control was inadvertently spayed onto the crop trees. Resulting in glyphosate intoxication or as Marcel Verleur calls it "glyphositis".

Spray drift (quantity of product carried out of the sprayed area by air currents) has been researched by the agriculture industry. The factors that affect spray drift are wind speed, the physical properties of the spray solution, height of the spray nozzle, level of shielding, nozzle type, pressure and numerous weather conditions, such as temperature and air humidity. What is concerning is that under ideal weather conditions ground based application equipment can result in a spray drift of 3 to 10 % of the product one meter from the spray source. Imagine what the drift could be when there is production pressure and spraying is done under less than favourable conditions.

Jacob Crous

Should we worry about the potential effects of spray drift? We know from experience that the trees exposed to drift will recover from the wilting, chlorosis and leaf curling as long as they do not die. What we do not know is how much the spray drift affects tree growth and for how long. To determine the effect of sub-lethal doses of glyphosate on tree growth a short-term commissioned study was implemented in 2015 by the ICFR. Overspray or drift was simulated onto six-month old *E. grandis* x *E. nitens* trees. Three application rates were used, namely; 50, 100 and 200 g active ingredient per hectare. This equates to 4.6%, 9.3% and 18.5% of the active ingredient when 3 litres of glyphosate (360 g ai per litre – standard rate) is applied. Thus, the first two rates correspond to the lower and upper drift levels observed in agricultural trials. The third level was based on earlier research conducted in Brazil that showed glyphosate caused visual leave damage (yellowing) and growth reduction at rates between 144 and 288 g active ingredient per hectare.

The early results were reported by the ICFR in a Technical Note (1 of 2016) by Dr Louis Titshall. Sappi has continued the trial measurements. Four-year results indicated that only the highest level of glyphosate had a negative effect on tree survival. However, volume production decreased significantly with the simulation of glyphosate drift. Although no damage symptoms were visible after the application of the lowest glyphosate concentration, after four years tree growth was reduced by 34% compared to the control (**Figure 1**). The middle and high concentration application reduced growth by 44% and 64% respectively. The growth trends over time indicate that the herbicide-damaged trees are still growing much slower than the control trees and that significantly lower production will be maintained until rotation age.

In an operational stand it is unlikely that every tree will be exposed to high levels of herbicide drift, unless the climatic conditions are extremely unfavourable. However, this trial highlights the potential growth losses that can be avoided by reducing glyphosate spray drift.

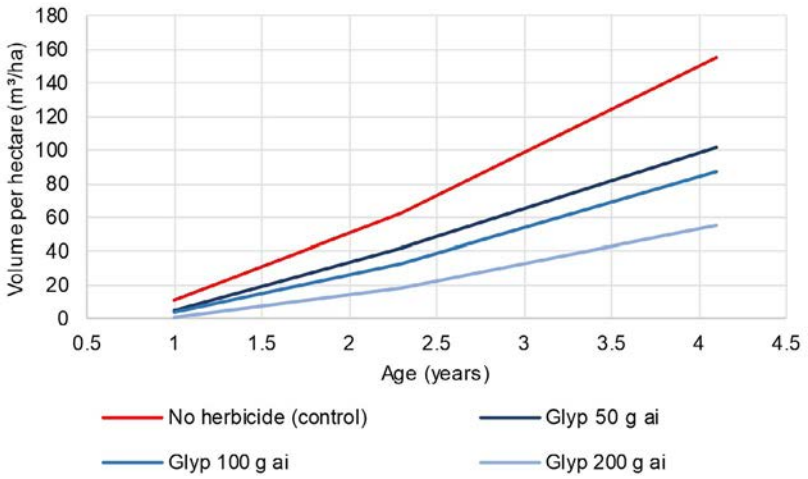


Figure 1. Volume production over time per treatment in a glyphosate drift trial in an *E. grandis* x *E. nitens* stand showed that a very low concentration glyphosate (50 g ai per ha) application reduced growth at four years by 34% compared to the control, even when no visual scorching symptoms were visible after the event.

ENVIRONMENTAL FATE OF PESTICIDES IN PLANTED FORESTS

Brenda R. Baillie – Scion, Freshwater Scientist, New Zealand, Dan Neary, Loretta Garrett and Carol Rolando

WHAT is the environmental risk of using pesticides in planted forests?

Pesticides are an important management tool in planted forests. They provide an efficient and cost-effective method for controlling weeds and insect pests and pathogens to ensure that the tree crop establishes successfully and to maximise timber production and economic returns.

However, there is increasing national and international concern around pesticide impacts on humans and the environment. Forest certification schemes such as the Forest Stewardship Council® and the Programme for the Endorsement of Forest Certification® aim to assist forest companies in reducing and eventually eliminating herbicide use.

It is important to understand the environmental characteristics of the pesticides being used in forestry and to manage their use accordingly. Some pesticides are more mobile than others or persist for longer in the forest environment, and some are more toxic than others. Some pesticides leach easily and are transported off-site mainly by drainage through the soil profile and water flow. Others bind to soil and sediment, so soil erosion and movement of sediment during high flows are the main transportation pathways.

Brenda R. Baillie

"It is important to understand the environmental characteristics of the pesticides being used in forestry and to manage their use accordingly."

In New Zealand, there was very little information on the environmental risk of using pesticides in planted forests. Scion (New Zealand's government funded science institute that specialises in forestry, wood product and biomaterials research), embarked on a series of field trials to assess the environmental fate of some of the key pesticides used by the forestry industry.

Two of the most common herbicides used for weed control in New Zealand's planted forests are terbuthylazine and hexazinone. We carried out two field trials and monitored the fate of these herbicides in the forest litter, soil, stream water, algae and sediment after aerial application.

In the soil, the greatest risk of herbicide movement off-site was during the first month after spraying. After one month the risks were low as the rapid degradation of the herbicides in the forest environment resulted in low amounts of the herbicide remaining on site.

Hexazinone was more prone to leaching. However, the movement of terbuthylazine down the soil profile was limited, largely because it readily binds to the organic matter in the forest floor litter. This shows the

"Herbicide residue levels in streamflow were rarely above analytical detection levels and did not at any time exceed water quality standards."

importance of harvest residues in determining the environmental fate of this herbicide.

The highest concentrations of herbicide in stream water, algae and sediment occurred either on the day of herbicide application, or during rainfall events shortly after spraying, and up to one month after application. A 'no-spray' margin along the stream channels assisted in minimising the amount of herbicide entering waterways.

At the landscape scale, a cumulative effects analysis of these two herbicides in a 118 000 ha catchment with 86 to 108 annual treatment sites did not detect any water quality or aquatic organism toxicity problems. Herbicide residue levels in streamflow were rarely above analytical detection levels and did not at any time exceed water quality standards.

Another key pesticide used in New Zealand's planted forests is cuprous oxide, a fungicidal treatment for the control of the pathogen *Dothistroma*. Because of the potential toxicity of copper in the aquatic environment, we investigated the environmental fate of copper in stream water and sediment following aerial application of this fungicide. Similar to the herbicide studies, the highest concentrations of copper were detected in stream water on the day of copper spraying. As copper binds to sediment it persisted for longer in the stream sediments than in the water. However, the concentrations and persistence measured in both the water and sediment were below the thresholds for risk to aquatic organisms and human health.

CONCLUSION

Our studies have found that the highest concentrations of pesticides in soil and water and possible risk to the environment occurred on the day of application and/or during rainfall events in the first month and rarely exceeded water quality standards.

The risk of leaching from soils into waterways only occurs if there is sufficient rainfall to initiate drainage and runoff. Forest floor litter played an important role in limiting the movement of pesticides down through the soil profile and should be retained on site.

In applications using Best Management Practices, pesticide concentrations become rapidly diluted downstream. The risk to aquatic organisms and human health (drinking water) is considered to be low, when assessed against environmental and human health guidelines.

These results showed that pesticides applied following manufacturer's instructions, using latest technology and best operational practices, forestry pesticides have a very short-term impact on the receiving soil and water environments in New Zealand's *P. radiata* pine forests.

Pesticides need to be managed within sustainable limits, and regulatory and certification requirements. Forest managers need to undertake their own trials to assess the environmental risk for the pesticides used in their forests, using their own technologies/methodologies under local environmental conditions (i.e. climate, soil, topography, geology) to minimise any negative impacts on human health and the environment.

SEARCH AND DESTROY: MANAGING NEW ZEALAND'S WILDING PINE POPULATIONS

Thomas Paul, Johnathan Dash, Michael Watt, Brian Richardson and Carol Rolando – Scion, Pest Management Scientist, New Zealand

Wilding pines in the South Island high country of New Zealand

WILDING pines are the unplanned and unwanted results of windblown seeds from early forestry, shelterbelt and farm plantings in New Zealand. Indigenous grasslands, scrublands and even forested land can all be affected, damaging the ecology and economy of these ecosystems. Over the whole country, around two million hectares are estimated to be infested. However, the South Island high country (> 600 m above sea level) has the most visible, largest and fastest spreading wilding infestations. The rapid spread of the trees is spurring local, regional and national efforts to halt the invasion and push the conifers back.

The most common wildings include *Pinus contorta* (Lodgepole pine), *Pinus nigra* (Corsican pine) and *Pseudotsuga menziesii* (Douglas-fir). *Radiata* pine (Pinus radiata), the mainstay of New Zealand's forestry industry, does not usually cause wilding problems in the high country of New Zealand.

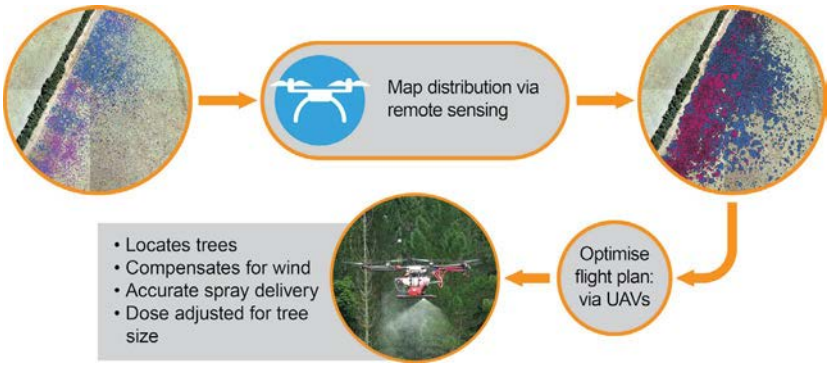
REMOTE SENSING OF WILDING PINES

Managing wilding pines, involving finding the trees, controlling them and monitoring the results in vast and rugged landscapes, is challenging and expensive.

Scion, New Zealand's government funded science institute that specialises in forestry, wood product and biomaterials research, has been investigating the potential of remote sensing for finding wilding pines in different landscapes. This information is critical for prioritising and guiding various control operations. The effectiveness of control operations and vegetation recovery following spraying can also be monitored with repeated remote sensing to make sure that wildings do not re-infest a controlled site. At a landscape level, successful and carefully planned control operations will ensure that seed sources of wildings are removed to prevent future re-infestations.

DETECTING WILDING PINES IN DIFFERENT LANDSCAPES WITH REMOTE SENSING

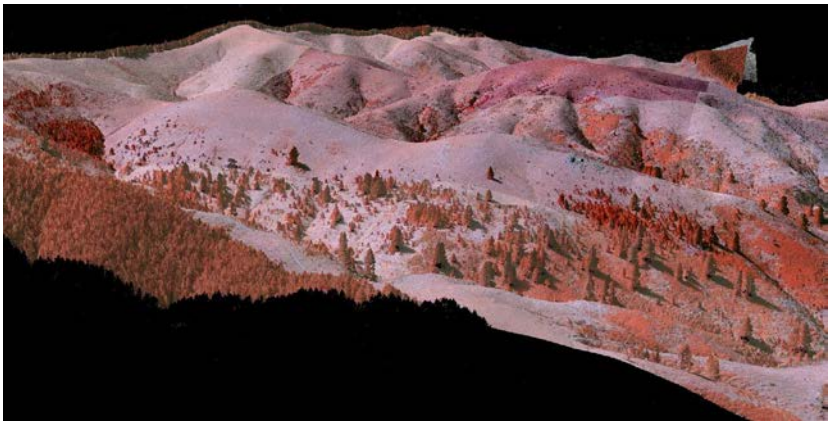
Successful detection methods need to precisely locate wildings occurring as scattered single trees, clumps or dense



Possible integrated remote sensing/control operation

> *"Over the whole country, around two million hectares are estimated to be infested."*

> *"Successful detection methods need to precisely locate wildings occurring as scattered single trees, clumps or dense stands growing on grasslands, shrublands or in between native trees."*

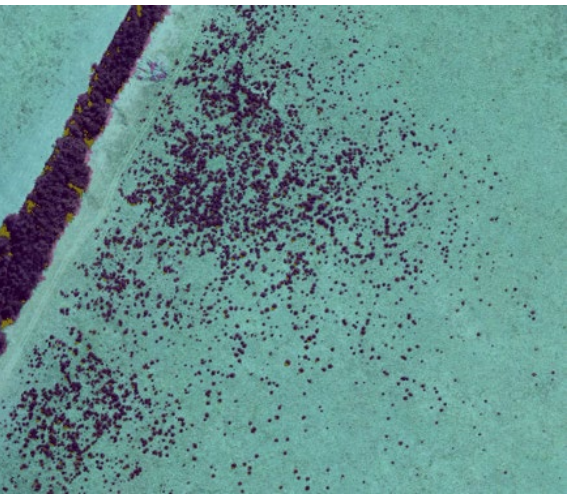


A fusion of spectra data (red, green, near infrared) with lidar data results in a point cloud image where each individual point is coloured.

stands growing on grasslands, shrublands or in between native trees. Finding any trees that are coning is critical to ensure further spread through seed dispersal is prevented.

The sensors used by Scion's remote sensing experts include lidar (light detection and ranging), and those that register different bands of the electromagnetic spectrum, including red, green and blue light and wavelengths that are beyond the range of human vision. Data has been collected from sensors mounted on UAVs (Unmanned Aerial Vehicles), helicopters, fixed-wing aircraft, and satellites.

Laser scanning data is useful for finding taller, isolated trees in short vegetation and can help in combination with other sensors, which capture the reflective wavelengths (light spectra) of trees and plants, to detect wildings when tall grasses, shrubs and other trees are present. Lidar may not be as effective by its own in such circumstances. Detection based on light spectra works well as wilding pines have a unique spectral range within grassland ecosystems like the native tussock and exotic grasslands which are common in the high country. The spectral difference between such vegetation types and the target wildings is pronounced in the red-edge and near-infrared parts of the spectrum.



Wilding pines spreading downwind from a shelter belt

GRASSLANDS

Short stature grasslands are possibly the easiest environment in which to spot wilding pines. Recent work has quantified pine seedling spread from a shelter belt, where a thorough field survey was able to accurately record the location, height, crown and coning status of 17,000 trees. The area was scanned using laser and spectral scanners mounted on both a plane and a drone. Using a combination of the visible and near infrared spectra, combined with the canopy height derived from lidar data, practically all wildings greater than one metre in height were detected. The data from the drone-mounted sensors were slightly more accurate than those mounted on the plane.

WILDING PINES SPREADING DOWNWIND FROM A SHELTER BELT

One of the most effective and cost-efficient ways to control wildings is to find and eradicate them before they start producing cones. Over 99% of trees ≥ 1m in height were detected. Our data showed that wildings at this grassland site started only coning when their height was well over 1m and therefore nearly all coning trees were detected, showing it is possible to detect pines before they become prolific seeders. Most pines take more than 10 years to reach full maturity, but Lodgepole pine, the most problematic wilding conifer species, starts coning at a much younger age (around 6 years) and when just over a metre tall which will make detecting this species via remote sensing more challenging but possible as our study in grasslands showed.

MIXED LANDSCAPES

A second experimental site was chosen with steep and broken terrain and a mixed cover of Douglas-fir (our wilding species in this study), bracken fern, grass and shrubby stands of native woody vegetation up to four metres tall. A field survey was carried out where the location and measurements of every wilding pine was recorded, as well as non-target vegetation. Lidar and multi-spectral imagery data from the site were then combined for maximum detection efficacy, with 84% of the conifers mapped during the field survey correctly identified. For this site, light in the near infrared was most useful for differentiating invasive conifers from the surrounding woody vegetation of the same height.

WILDING CONTROL

Ideally, control of wilding infestations should start as early as possible (as soon as they become detectable) as numbers are still few and the

scattered trees haven't started coning and releasing seed. Left for too long these early invasion stages can rapidly turn into dense forests. Often the first step to control a wilding infestation is to control scattered seedlings and outlying trees, and subsequently work back to the original seed source. Monitoring and ongoing management is needed in the following five to six years after the initial control, as smaller trees are easily overlooked, and seed rain occurs till the seed source is removed. Further, a short-lived (2-5 years) seedbank might be present resulting in freshly germinated seedlings.

When infestations get out of hand, and in inaccessible country, aerially applied herbicides are the main tools used to manage wildings. They can be effective, but high usage rates are needed, and the unwanted effects on surrounding vegetation and waterways are a concern. Scion scientists are working on improving both the efficacy of currently available herbicides and their application methods, especially where conifers are clumped and/or scattered across large areas. The first aim is being addressed through research to increase the efficiency of herbicide application and uptake that will result in more effective control and also reduced cost and off-target effects.

UNMANNED AERIAL VEHICLES (AGAIN)

UAVs offer a new level of application precision over helicopters as they fly more slowly and spray from lower heights, albeit with lower payloads and reduced flying time. A vision for future control operations is to create an integrated and automated system that combines: (i) remote sensing technologies for precisely locating small wilding conifers in the landscape; and (ii) using multiple (swarms of) unmanned aerial vehicles (UAVs) for accurately spraying the wildings with herbicides following optimised flight paths for greater efficiency (more wildings controlled per hour flying). Our research to date has focused on quantifying the targeting precision and spray coverage capabilities of UAVs, particularly for spot spraying of individual conifers.

One of the crafts that we have tested has a spinning disc nozzle under each rotor offering improved droplet size control when compared to conventional hydraulic nozzles. It can position itself over the target tree then spin on its central axis as it delivers the specified dose of herbicide. Scion trials have found the performance of this craft to be excellent in terms of high precision and accuracy of positioning over the target.

HOW EFFECTIVE WAS THE CONTROL?

Remote sensing offers a new way of monitoring the effectiveness of wilding control programmes. Scion, collaborating with researchers from the University of Trier, Germany, set up a 'lab' experiment to monitor herbicide effects using hyperspectral imagery. Lodgepole pines around two metres tall were sprayed with either a contact herbicide (diquat as Reglone), or a systemic herbicide (triclopyr as Grazon), both commonly used to kill wildings. Diquat works by inhibiting photosynthesis, whereas triclopyr mimics a hormone that causes uncontrolled and disorganised plant growth that leads to death.

A hyperspectral camera was used to monitor the changes in the trees brought about by herbicide spraying. High resolution hyperspectral cameras measure light waves across a wide range of spectra covering the infrared range, including wavelengths that can pick up physiological changes in the needles and needle death. Using this system changes in the photosynthesis processes were tracked during the trial.

The two herbicides elicited quite different visible and spectral changes, and changes in the photosynthesis responses. Changes due to diquat application were detected almost immediately and the needles were brown after three weeks. Discolourations from triclopyr were only visible after two weeks, with changes in photosynthesis parameters also occurring later for triclopyr.

The hyperspectral data were used to calculate an index named the Photochemical Reflectance Index, which gives an indication of how efficiently plants are using light during photosynthesis. The index was able to differentiate between herbicide treatments and the control two days after spraying, suggesting it could be used to monitor the effectiveness of a spray programme.

For this research the camera was close to the trees, and the next step to show that more distant monitoring, using a drone for example, is possible. Satellite hyperspectral imagery would possibly be the most useful form of remote sensing to monitor the effects of herbicide control of larger denser wilding stands.

> *"A vision for future control operations is to create an integrated and automated system..."*

CONCLUSION

Collecting remote sensing data is becoming cheaper and more accurate as technologies mature and spatial and spectral resolution improves. Satellites that make frequent scans (and hence provide more time-sequence data) look to be the most appropriate source for monitoring large and dense wilding infestations across New Zealand. At a regional landscape level, aerial- and drone-based remote sensing techniques will be useful to guide and monitor control efforts of scattered and clumped wildings. Remote sensing combining hyperspectral and laser scanning data is set to play a significant role in New Zealand's efforts to identify and control wilding pines.

This work was partially funded by the Winning Against Wilding Programme (New Zealand Ministry for Business, Innovation and Employment), and the New Zealand Forest Growers Levy Trust.

WHY THE PREVIOUS HAZARD-BASED FSC PESTICIDE POLICY INCREASED THE RISK OF PESTICIDE RESISTANCE

Jacob Crous – Sappi Forests, Programme Leader - Land Management

The opinion expressed here is that of the author and does not reflect the opinion of Sappi Forests.

THE PREVIOUS hazard-based Forest Stewardship Council (FSC) pesticide policy has restricted the number of chemical pesticides available to the forestry industry, as over time the number of chemicals on the Highly Hazardous Pesticide (HHP) list has increased. In 2007, there were 87 chemicals on the HHP list and by 2015 this increased to 389. Although the listing of a pesticide as an HHP did not prohibit the use under any circumstance, it did require a laborious FSC derogation application and approval process. The intention with this policy was to find less hazardous pesticide alternatives. In addition to limitations due to FSC criteria, only a limited number of pesticides have been registered for use in forestry crops as required by the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act 36 of 1947. This has left the Forestry Industry with very few registered chemical pesticides with different active ingredients, for which a derogation was not required, to control weeds and other pests and diseases.

The main problem I have with a very limited list of pesticides to use is that it encourages the use of the same chemical with the same mode of action (MOA) repeatedly on the same land. Repeating the same control tactics may result in the evolution of avoidance mechanisms in the pest population through random mutation events and this even applies to non-chemical control methods. In Asia, repeated hand-weeding in rice resulted in the selection for barnyardgrass populations that are very hard to distinguish from the rice plants, making hand-weeding difficult and ineffective.

> *"Case studies of reported herbicide resistance incidents suggest that the single most important factor resulting in herbicide resistance is over-reliance on a single herbicide or a group of herbicides with the same mode of action (MOA) without using other weed management options."*

The factors that affect how rapidly weed populations become resistant to herbicides are: 1. the selection intensity (which is a function of herbicide dosage, frequency and timing of application); 2. the mutation rate of the weed; 3. the genetic basis of the resistance; 4. life-history characteristics of the weed species (annual vs. perennial, self-pollination vs. cross-pollination, level of seed dormancy, etc.); 5. the reproduction rate; and 6. potential of recruitment of susceptible or resistant individuals from outside the population.

Case studies of reported herbicide resistance incidents suggest that the single most important factor resulting in herbicide resistance is over-reliance on a single herbicide or a group of herbicides with the same mode of action (MOA) without using other weed management options.

In the forestry industry glyphosate is the predominant herbicide, roughly used in more than 90% of all herbicide applications, for several good reasons. It controls a broad spectrum of weeds; is relatively inexpensive; easy to apply; and was not classified as an HHP by FSC in the past.

At the commercialisation of glyphosate, scientists thought resistance to glyphosate was unlikely to evolve and this was indeed the case during the first 15 years (1972 to 1997) of glyphosate use. Unfortunately, with the introduction of glyphosate resistant crops in 1996,

Jacob Crous

glyphosate started to be used as a stand-alone selective herbicide on large areas of crop land in pre-emergence and multiple post-emergence applications. With this kind of selection pressure, it was to be expected that glyphosate-resistant weeds would evolve. In the following 15-year period (1998 to 2013) glyphosate resistance in 24 weed species on six continents was documented. The glyphosate-resistant weed total currently stands at 47 species indicating that an additional 23 species became resistant in the past seven years. This exponential trend should make us think about our glyphosate reliance in forestry.

It is very expensive to control herbicide resistant weeds, as larger quantities of herbicides must be applied or alternative, often more expensive herbicides or control methods (mechanical and cultural) must be employed. Herbicide resistance management strategies should therefore be implemented pro-actively and not reactively, but as proactive management has little to no immediate economic benefits, it is difficult to motivate increased short-term costs to realise the certain long-term benefits. We should not think that resistance management strategies will be a waste or that there will be new technologies in future to solve herbicide resistant weed problems. The conservation of the existing herbicide resources is just as important for sustainable crop production as the conservation of soil, water and genetic diversity.

"The most effective means to conserve pesticide MOAs is to rotate chemicals with different MOAs and to incorporate nonchemical control tools (manual or biological)."

The most effective means to conserve pesticide MOAs is to rotate chemicals with different MOAs and to incorporate non-chemical control tools (manual or biological). To assist non-specialists, it is important to implement a MOA labelling system for all pesticides. This is an aspect that TIPWG might consider adding to the current approved pesticide list. It is also important to apply the recommended label rates at the appropriate weed or crop stage. In the future we might have to use pesticides that are slightly more hazardous in order to implement sound Integrated Pest Management principles to be able to diversify our reliance on a single MOA pesticide. Weed management programmes need to change over time as weeds adapt. Monitoring and early identification of herbicide-resistant weed populations are essential. The key to successful control (or even better the eradication) of a herbicide resistant weed is early recognition of resistance when the population is still small with low seedbank density.

ADDITIONAL INFORMATION:

Norsworthy JK, Ward SM, Shaw DR, Llewellyn RS, Nichols RL, Webster TM, Bradley KW, Frisvold G, Powles SB, Burgos NR, Witt WW. Reducing the risks of herbicide resistance: best management practices and recommendations. Weed Science. 2012;60(SP1):31-62. Available at: https://www.cambridge.org/core/services/aop-cambridge-core/content/view/2E46792A8800CB7B292EB1AAAEA3ACE9/S0043174500021871a.pdf/reducing_the_risks_of_herbicide_resistance_best_management_practices_and_recommendations.pdf

http://www.weedscience.org/Summary/MOA.aspx?MOAID=12

LITERATURE REVIEWS AND TECHNICAL NOTES

TIP-MAG IS CALLING OUT TO ALL THOSE IN ACTIVE RESEARCH – SEND US YOUR PAPERS!

OVER the last few years, it has become increasingly apparent that the forestry industry needs an outlet for the great research being done, albeit "behind the scenes".

While a proportion of the research funded and carried out by the industry is published in peer reviewed journals, there is a lot of research that never sees the light of day. It simply does not fulfil the research criteria stipulated by scientific publications. These publications are looking for new and novel science that move the sector forward, rather than duplication, pilot or area specific studies that confirm and retest existing hypothesis. While these studies are done with equal scientific rigour and are necessary to test existing theories under specific South African conditions, they often remain unpublished and therefore lost to the forestry sector.

TIP-Mag was conceptualised to address this by providing a platform for forestry academics and scientists to communicate their findings to their colleagues and a wider lay-audience. By facilitating this transfer of knowledge, TIP-Mag will help reduce unnecessary duplication of research.

Another goal of TIP-Mag is to introduce areas where further research is required as well as the overarching goals of industry-funded research projects which are in their early stages. As such, this particular section of the magazine will also be open to literature reviews. These reviews will aim to highlight the current knowledge situation and where there are gaps, and what can be done to address these matters.

HOW TO FORMAT YOUR TECHNICAL NOTE

TIP-Mag Technical Note follows a standard scientific research paper format, with one small but significant difference – the inclusion of a lay-summary rather than a typical scientific journal abstract.

STANDARD RESEARCH PAPER FORMAT	TIP-MAG SPECIFIC REQUIREMENT
INTRODUCTION – outline the current situation and why the research is needed, as well as how the specification of this study will bridge a knowledge gap or move the industry forward.	Summary rather than Abstract Researcher should produce ***a summary of the research rather than formal scientific abstract.***
MATERIALS AND METHODS – detail sampling protocol and procedure, along with the data analysis methodology.	The summary should communicate the research in lay-terms, enabling a non-scientific audience to understand the following: • Why the research was commissioned by answering: *What was the issue the industry faced?* • What was done and perhaps more importantly, *how this will help address the issue identified?* • The key findings, but more importantly, *how the findings will impact the forestry sector.* • Take home message – summarise *the findings in one sentence: what is the most important message that you want the reader to understand.*
RESULTS AND DISCUSSION – deal with each key finding separately, presenting the results with supporting statistics and discussing each before moving on to the next. Tables, graphs and diagrams should be used where appropriate to simplify/reinforce key messages.	
CONCLUSION – outline key findings and the practical implications of these on the industry; identify areas where additional research is required.	
REFERENCING – based on the format used in Southern Forests Journal.	
ACKNOWLEDGEMENTS – if and when required, keep below 100 words.	

LITERATURE REVIEW FORMAT

The literature review needs to be concise and should clearly lay out:

- The problem/issue.
- Where the industry is in terms of understanding the problem/issue?
- Where are gaps in our knowledge?
- How they propose/suggest these knowledge gaps be addressed?

As a literature review, references to the literature are key. They must be laid out in the same format as stated above for the technical notes.

The same applies to acknowledgements, although this section should be short – one sentence max. There are no limits to the amount of references included.

Most importantly, the literature review should start with a lay-person summary rather than a traditional scientific journal abstract – as per the technical note. Consider this as the bridging paragraph, helping those without a scientific background to understand the article.

The lay-summary is outlined in the Technical Notes section above.

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