Vol.3 No.1

TIP-MAG

2022

Timber Industry Presents Magazine

Do global goals have a place in South African forestry?

Environmental Management Committee Chairperson Louise van Wyk explains why they do

Near InfraRed Spectroscopy (NIRS)

Dr Richard Burgdorf explains why it could be the future of seed screening

SUSTAINABLE DEVELOPMENT GOALS

Geospatial technologies

From mapping to shaping sustainable forestry with Dr Ilaria Germishuizen

FORESTRY SOUTH AFRICA™

THIS ISSUE: DO GLOBAL GOALS HAVE A PLACE IN FORESTRY? | GEOSPATIAL TECHNOLOGIES AND FORESTRY RESEARCH | NEAR INFRARED SPECTROSCOPY (NIRS) – THE FUTURE OF SEED SCREENING | LEPOTCYBE INVASA NATIONAL MONITORING PROGRAMME: 2021 RESULTS AND THREE YEAR TRENDS

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SUSTAINABLE DEVELOPMENT GOALS AND INNOVATIVE TECHNOLOGY-DRIVEN SOLUTIONS

IN THE WORLD OF FORESTRY WHERE NOTHING STANDS STILL, EVEN GREATER INVESTMENTS IN RESEARCH, DEVELOPMENT AND INNOVATION WILL BE NECESSARY IF WE ARE TO STAY ONE STEP AHEAD OF THE GAME

IT SEEMS fitting that in an issue released just before the United Nations (UN) International Day celebrating Women and Girls in Science, we have two opinion pieces written by prominent female scientists, both of whom are driving the sector forward in their respective fields.

The need to consider the sustainability of what we do is becoming more and more evident. There was a time when sustainability was most often found in an environmental context and focused primarily on reducing our environmental footprint. Now it is just as relevant when discussing the long-term viability of CSI programmes or in an economical context looking at forestry investment and circular economies. Sustainability is no longer a "buzzword"; it is a mindset shift that is being orchestrated at the highest levels of international politics through the UN Sustainable Development Goals (SDGs). The opinion piece by FSA Environmental Management Committee Chairperson Louise van Wyk looks at how our industry objectives and SDGs align and provides a very compelling argument for how this could be beneficial for all.

Research, development and innovation play a key role in shaping the forestry sector and in enabling it to deliver on the SDGs. As an industry, we have a great history of collaborative research that has enabled our sector to stay competitive in a global market. Geographic Information Systems (GIS) is a term most are now familiar with, however, in recent years the applications for this and other geospatial technologies have grown exponentially. Meaning, what was once a brilliant mapping tool has now become an innovative solution to a multitude of problems. In her opinion piece, Dr Ilaria Germishuizen from the ICFR gives a compelling overview detailing the potential of these geospatial technologies. Identifying the need to invest in these innovative tools to keep South African forestry globally competitive and able to meet its sustainability targets.

Another area where cutting edge research and development is resulting in exciting innovation is work being conducted by the FSA-funded Analytical Laboratory Platform. Dr Richard Burgdorf presents a compelling argument in his interest piece on Near InfraRed (NIR) Spectroscopy and the feasibility of using it for measuring seed properties.

This issue also includes a technical note by Dr Ilaria Germishuizen and Prof Brett Hurley, who present the findings of the fifth national monitoring survey of the blue gum chalcid wasp, *L. invasa*. As well as providing a conclusive overview of *L.invasa* status across the country, the report highlights the importance of pest and disease monitoring in the decision-making step of an Integrated Pest Management (IPM) approach and how funding challenges continue to hinder a solid and successful forest protection strategy in South Africa despite the best efforts of all involved.

As FSA Director of Research and Protection, the R&D progress our sector has made during two incredibly challenging years, 2020/2021 has made me even more proud of the world-class research our sector conducts, both in-house and through our research partners. Reading through this issue, I am excited by how TIP-MAG has developed over the past four issues. This might not be the thickest issue we have produced but it certainly is an enjoyable and informative read from cover to cover.

With another issue planned for the middle of this year, I strongly urge everyone who is conducting research in the sector to consider contributing. I cannot stress the importance of communicating the world class research our sector is conducting and how this investment in R&D will strengthen our industry moving forwards.

For those not actively involved in forestry research, I urge you to find a few minutes to thumb through this fourth issue of TIP-Mag to get acquainted with the research and opinions that is shaping our sector.

May you enjoy reading and interrogating this fourth issue of TIP-Mag.

Dr Ronald Heath
FSA Director:
Research and Protection

GEOSPATIAL TECHNOLOGIES: FROM MAPPING TO SHAPING SUSTAINABLE FORESTRY

GEOSPATIAL TECHNOLOGIES AND FORESTRY RESEARCH

Dr Ilaria Germishuizen –
Research Group Leader: Sustainable Forest Production, ICFR

GEOSPATIAL tools, techniques, and technologies have rapidly gained a pivotal role in forest management during the past decades and by now, forest managers rely heavily on these tools. Advances in Geographic Information Systems (GIS), Global Positioning Systems (GPS), and remote sensing have provided new means of undertaking forest productivity assessments and inventory, forest health monitoring and harvest planning, to mention a few. With the growing global emphasis on sustainability, these tools have also proved to be more and more indispensable in areas such as carbon assessment and reporting and ecosystem classification and management.

The forestry industry is increasingly adopting geospatial technology to improve daily operations, and technology is progressing fast. GIS systems were simply a kind of mapping tool with integrated databases; now, they can be considered something like a distributed "neural system" that can analyse current situations, generate predictions and develop solutions.

"GIS systems were simply a kind of mapping tool with integrated databases; now, they can be considered something like a distributed "neural system" that can analyse current situations, generate predictions and develop solutions"

The revolution that geospatial technologies have brought to the industry concerns the whole value chain. For instance, sensors can be placed strategically to record the weather, insect pests, fire, and other phenomena, but can also be used to tag timber batches and monitor timber movement and chain of custody. A simple smart phone is now equipped with enough sensors to be able to collect a variety of data related for example to a forest ecosystem and transmit the data into a GIS data warehouse where they can be integrated and analysed for various purposes.

Surveys from drones, airplanes and satellites provide data at varying scales, from tree-level to the landscape. Drones, in particular, are becoming an affordable option for keeping an "eye" on a limited area to collect information relative to the health status of a forest stand, monitoring the recovery from a fire or hail event.

Affordability has been a major hindrance in the uptake of spatial technologies at the operational level. A good example is the slow entrance

Dr Ilaria Germishuizen

that LiDAR (Light Detector and Ranging) has made in the forestry industry as a tool for capturing 3D data. Up to 10 years ago, this technology was hardly used by the industry, while now LiDAR is a key tool used to generate high resolution digital terrain models, biomass estimates and individual tree height and volume.

There is no doubt that the application of geospatial technologies and remotely sensed data is leading towards better plantation forest management, and the growing accessibility of integrated platforms where the data acquired from these technologies is stored supports better management decisions.

The future of forestry inevitably relies on the use of these cutting-edge technologies which require a strong investment by the industry in research and capacity development.

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Apart from forest management, spatial technologies are essential tools when dealing with global challenges affecting the forestry industry, particularly climate change and biotic risk.

Climate change contributes to extreme events like heat and cold stresses, altered distribution of rain, drought and flood, storms etc., all having an intense impact on plantation forest yields. In South Africa, climate change predictions are particularly worrying. Temperatures are expected to raise by 2-3 degrees Celsius by mid-century, and 3-4 degrees Celsius by the end of the century. Rainfall patterns are predicted to become more erratic, leading to increased evaporation and the likelihood of extreme droughts. These trends are already clearly visible as is the impact they are having on our plantations.

Understanding our planet and the impact of climate change is crucial at every level. Furthermore, historical time series of accurate and reliable data helps us analyze and conceptualise changes over time. This applies to natural environment as well as, for example, planted forests, where remote sensing data is used to model productivity decline over time, drought severity and frequency, tree stress, and other factors strictly linked to the climate and affecting the productivity and long-term sustainability of our planted forests.

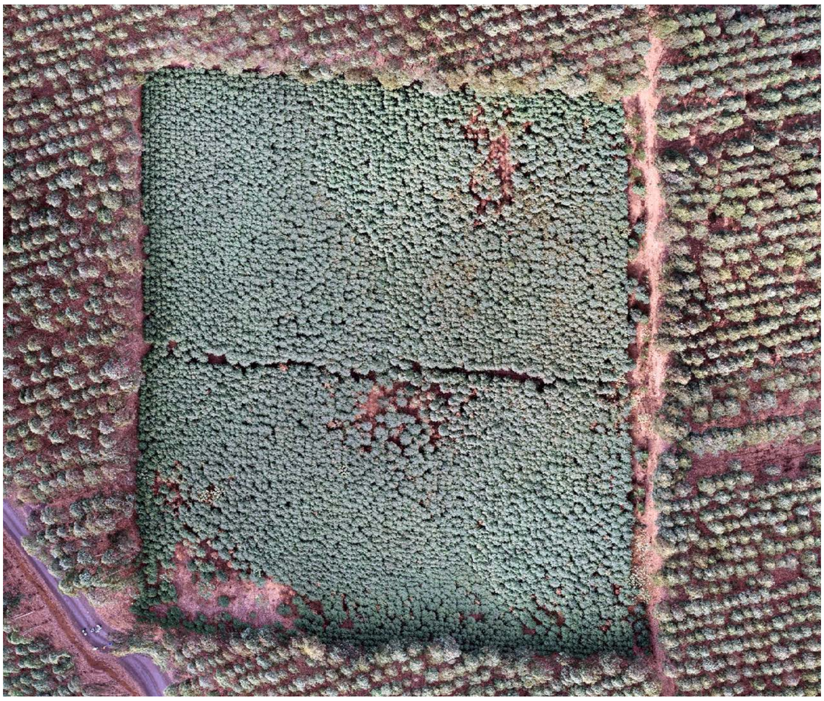
Satellite derived data also allows us to better study and predict climate change effect on ecosystems, for instance, the impact of extreme weather events on planted forests, and monitoring the effectiveness of adaptation measures that have been implemented. GIS-based models, fed by remote sensing data, are also critical to produce spatially-explicit scenarios of how the future might look like if certain trajectories are to be followed in support of long term industry-level strategies.

Climate change and the increasing risk of damage caused by existing and new insect pests and pathogens go hand in hand and protecting our forests' health is a critical challenge for our forest managers. Early detection of a pest or pathogen is fundamental to prevent outbreaks and contain the spread of a damaging agent, and, although conventional field measurements are the most accurate way to detect their occurrence and quantify infestation stages, they are very costly and time-consuming, and rarely solve the challenge of early detection. On the other hand, remote sensing, being spaceborne or airborne imagery collected using a drone or an aircraft, provides a more accurate approach to obtain explicit information that can be routinely analysed to detect changes at the landscape, farm or even tree level, reducing the need for field surveys and focussing resources on problem areas.

With early detection and monitoring being a crucial component of a successful forest protection strategy, new GIS based applications for field data capturing and rapid diagnostic are being developed and implemented by foresters. Image recognition is a particularly interesting remote sensing application that allows a forester to take a picture in field of an insect pest or damage caused by a pathogen, and through an automated image pattern recognition process, provide a real-time first level screening and identification of the damaging agent being observed. These applications, which can be run from a smartphone, have been already implemented by some of our companies in South Africa and are generating a wealth of precious geospatial data that are used to evaluate trends of outbreaks at local and regional level, map the distribution of these damaging agents, as well as analyse the population dynamics of their biological control agents and verify the effectiveness of the control measures. Through the integration of these data with relevant climatic and other environmental datasets, predictive models of the risk of pests and pathogens under current and future climate change scenarios can be developed and fed into a GIS system to produce risk maps and visualise possible scenarios.

The forestry industry is moving towards the era of Big Data, and spatial technologies are a key source for big data from the platforms of satellite, manned and unmanned aircrafts, as well as ground-based structures. Platforms supporting access to databases from different sources are fundamental in this new era, and something the forestry industry in South Africa is perhaps lagging behind. Through the development of the information Hub, an initiative supported by the University of Pretoria and Forestry South Africa (FSA), a data warehouse to serve the specific needs of the forestry sector is being developed via a collaboration between FABI, the ICFR, and other industry and academic partners The Info Hub will provide easy and quick access through a user-friendly interface to the national forestry pest and disease database, historical weather and climate data, and several visualisation and analyses tools to play with.

Spatial technologies are ever evolving, becoming more affordable and accessible, and inevitably part of the toolbox available for the sustainable management of our forest



resources. The fast pace at which these technologies evolve presupposes a high commitment and investment by the industry and sector overall in research and development to gain full benefit from these available technologies and keep up to speed with the time.

In South Africa, within the forestry sector, the uptake of these technologies has been perhaps a bit slow overall, with only the bigger players in the sector exploiting and incorporating these available tools and technologies into their forest management. Investment in capacity development at both technical and academic level is crucial for a sector level move towards precision forestry and agriculture, paired with a strong commitment in support of R&D.

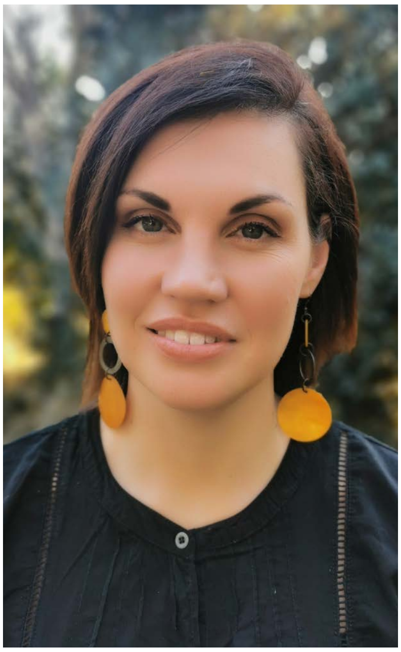
DO GLOBAL GOALS HAVE A PLACE IN FORESTRY?

Louise van Wyk – Environmental Management Committee (EMC) Chairperson, FSA

SUSTAINABLE DEVELOPMENT GOALS (SDG's) are a global concept to which every country, industry or person should strive for. In doing so, it is believed we will achieve success in terms of sustaining life on earth and where we meet our needs now, without compromising the needs of future generations. But is it so simple? How can a global concept make a difference to us and our immediate surroundings? Also, how can our actions in the forestry industry make a difference in achieving a global goal?

It feels like the incessant pounding of someone at my front door, with every phrase, concept or project containing the word sustainability in it. "We should do it sustainably". "Is this the most sustainable option?" "Are we driving sustainable behaviour?". Where once a new concept that had a lot of meaning to it, in terms of staying within our planetary boundaries, it has now metamorphosized into a common catch phrase or buzz word, that has lost its initial standing. Or has it? Surely even now, and especially with the most recent IPCC (Intergovernmental Panel on Climate Change) report indicating a grim projection of the earth's future, we should be more attentive about changing our behaviour, and soon. But how?

The forestry industry in South Africa is uniquely positioned in terms of contributing to the Sustainable Development Goals. Within a socio-economic context, it is an industry present within the rural



Louise van Wyk

"How can a global concept make a difference to us and our immediate surroundings? Also, how can our actions in the forestry industry make a difference in achieving a global goal?"

communities of a developing country where job creation and poverty alleviation are vital and where the most intervention is required. In this context, the South African forestry industry provides development opportunities through group schemes and community farming. Smaller enterprises and communities are not only given opportunity to access the market and generate an income, but to form part of the land use decision making process that can further contribute to sustainable forest management. It ensures value sharing with the very people dependent on the landscape for their livelihoods.

In addition, plantations are not limited to commercial trees. Natural areas co-exist with the commercial compartments, allowing ecological function of the environment. These areas provide corridors for animals, protect surface water features like wetlands and streams, grasslands and indigenous forests. Many of these areas contain keystone, threatened or protected species that contribute to the conservation of biodiversity and ensures that ecosystem services can continue, on which the community and forestry operations depend. This indicates that forestry is ideally positioned to contribute to all three spheres of sustainability, the economic component, social development and environmental values.

Sustainable forest management is further supported in terms of applying the principles of certifications standards, such as the FSC (Forestry Stewardship Council) and PEFC (Programme for the Endorsement of Forest Certification) certification schemes that also uphold the three spheres of sustainability. With most of the timber plantations in South Africa being certified, it paves a way to contribute to the SDGs of the country, not forgetting that products derived from commercial forestry, are from a renewable resource. But why would forestry want to align itself with the Global Goals to which South Africa has committed its actions to?

The SDGs are a collection of 17 global objectives adopted by the United Nations (UN). What makes them important is the fact that they are universal, as they can be applied to any country or context in terms of pathways to achieve these goals. These goals reflect the need to be more integrated, to encompass the three spheres of sustainability and with good governance, this integration can be ensured. It also makes the call to think innovatively, to challenge our behaviour and way of thinking.

The health of our planet directly relates to the support of human life and activities. It is for this reason that markets, stakeholders and clients across the world, have started to call for accountability from the private sector in terms of the SDG's. Aligning to the SDG's not only gives an opportunity to make a difference in terms of these universally accepted sustainability challenges, but presents itself as a business opportunity too, whereby a company or industry can show its commitment to a sustainable future that is worth investing in. With a sustainable business, one can feel more confident that the business will be able to operate continually and uninterrupted, into the future. However, no business or industry, including the forestry industry, can operate in a silo, as we are surrounded by other land uses and

"Aligning to the SDG's not only gives an opportunity to make a difference in terms of these universally accepted sustainability challenges, but presents itself as a business opportunity too, whereby a company or industry can show its commitment to a sustainable future that is worth investing in."

> *"Through our actions as an industry we can facilitate the steps towards a sustainable future, even beyond the boundaries of our operations."*

operations with their challenges, that can impact the business strategy of another. Hence the importance of making it a universal concept, accepted by all countries. By supporting your country through your industry or business to contribute to the SDG's, one illustrates the importance of the industry in terms of investing into the country and therefore in turn, acquire more support from governing bodies in the country. As previously alluded to, good governance is vital to further integrate the spheres of sustainability, but also beyond the silos of different land uses. Therefore, contributing to the SDG's not only aligns the country to global goals, but also aligns different industries and land uses across the South African landscape, unifying all in support of South Africa's commitments.

So, is forestry positioned as an industry to form part of the Global SDG's? Definitely, and based on the difference it can make and the opportunities it presents, we would want to be part of it and play our role in the South African landscape. Through our actions as an industry we can facilitate the steps towards a sustainable future, even beyond the boundaries of our operations. Being a renewable resource, the path to a better, greener and circular economy is but a decision away in collaborating and contributing as an industry and as individuals.

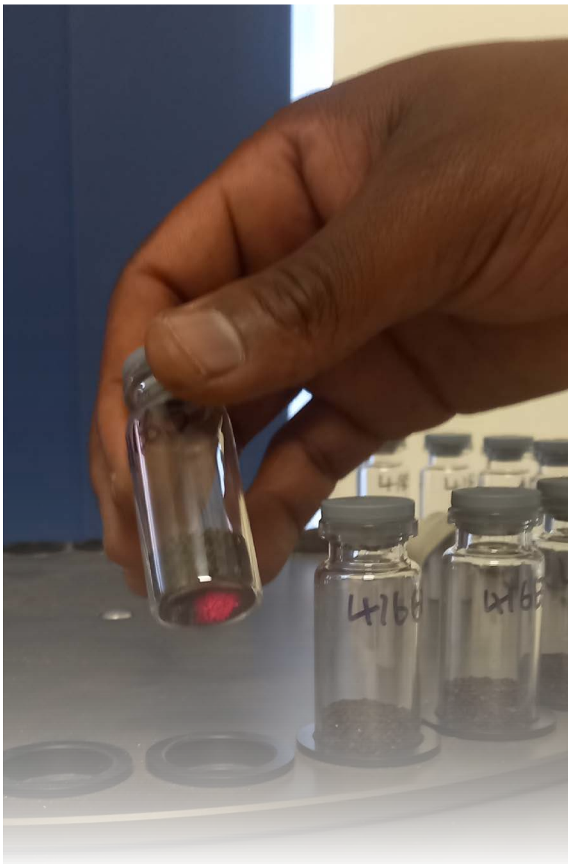
NEAR INFRARED SPECTROSCOPY (NIRS) – THE FUTURE OF SEED SCREENING?

HOW FEASIBLE IS IT TO USE NIRS TECHNOLOGY TO SCREEN SEEDS FOR GERMINATION PROPERTIES?

Dr Richard Burgdorf – Senior Scientist, Analytical and Research Laboratory, ICFR

CUTTING edge research and development continues in the FSA-funded Analytical Laboratory Platform at the ICFR, led by Dr Richard Burgdorf, where scientists, technicians, students, and interns are developing real applications that aim to have a big impact on forestry in South Africa. A particular focus area is developing low-cost high-throughput screening methods for all aspects of the industry, and one potential technology being explored is the feasibility of using NIRS for measuring seed properties.

Seed germination rates determine the number of seeds that are planted in a nursery operation – for example, if a million seedlings are on order from a nursery, and the seed has a 95% germination rate roughly 1 053 000 seeds would need to be planted to meet the order, give or take. Getting this sowing rate wrong means increased labour costs and potential delays in scheduled planting.



"Cutting edge research and development continues in the FSA-funded Analytical Laboratory Platform at the ICFR, led by Dr Richard Burgdorf, where scientists, technicians, students, and interns are developing real applications that aim to have a big impact on forestry in South Africa"

Dr Richard Burgdorf

Historically, to determine the germination rate and other properties of a batch of seeds by conventional testing requires a sub-sample of a batch or batches of seeds to be germinated under set conditions and manually counting the number of seeds that have germinated into normal healthy seedlings. This can take several days, or even weeks before a result is available. Other factors can also affect estimates of seed quality, such as the presence of opportunistic pathogens, variation of the conditions under which the tests are performed, or technical operator errors made during germination testing.

Recent studies, like those of *Al-Amery et al*. (2018) have demonstrated that near-infrared analysis can determine seed quality parameters with a high level of success. Such a rapid non-destructive high-throughput screening method for seed germination could determine certain seed quality parameters with minimal testing time for optimal sowing rate determination, at seed procurement or sowing, i.e., adding to the broader concept of "precision forestry".

The impact that this technology can have on forestry is potentially huge. The ability to rapidly screen seeds for quality properties like their rate of germination, their vigour or chances of survival, can be of huge benefit to the forestry industry. High-quality batches of seeds can be identified quickly and estimates of germination rates and growth properties can further permit high levels of seedling planting precision, avoiding excessive and wasteful sowing, while ensuring the best quality seedlings are available for planting in the field. Saving in time and cost are potentially matched by improved field performance.

Even breeding strategies can be enhanced as scientific literature is showing evidence that NIR can be used to detect hybrids ([*Nie et al, 2019*]) without needing to plant seeds and observe plant traits. It can also be used to select for new phenotypic properties ([*Vollman and Jankowicz-Cieslak, 2016*]) which could represent beneficial properties such as improved disease resistance or growth rates. This means that plant traits could already be detected in seeds so selections for improved trees can be made before a seed is even planted.

A feasibility study at the ICFR, funded by the Seedling Growers Association of South Africa (SGASA) found that the technology could very accurately predict both the percentage of seeds that would germinate in a batch, as well as the rate at which they germinate. Stored batches of *Eucalyptus nitens* and *Brassica oleracea* were the test materials although the focus going forward is on forestry species. UKZN MSc student Mr Nkosi Mkhize found that seed age, total germination, and cumulative germination rates could be accurately predicted using the OPUS FT-NIR system to capture spectra and the OPUS QUANT software to develop Partial Least Squares regression models.

An essential consideration was access to material that would sufficiently represent the seed properties so that a prediction model could be developed. The ICFR has a unique resource in terms of its seed repository with almost 100 *E. nitens* batches from various trials and seed orchards going back to 1988. This contributed to the impressive ability of the technology to predict seed age and germination properties as shown in an example graph (**Figure One**).

The NIRS screening method was even able to predict with high

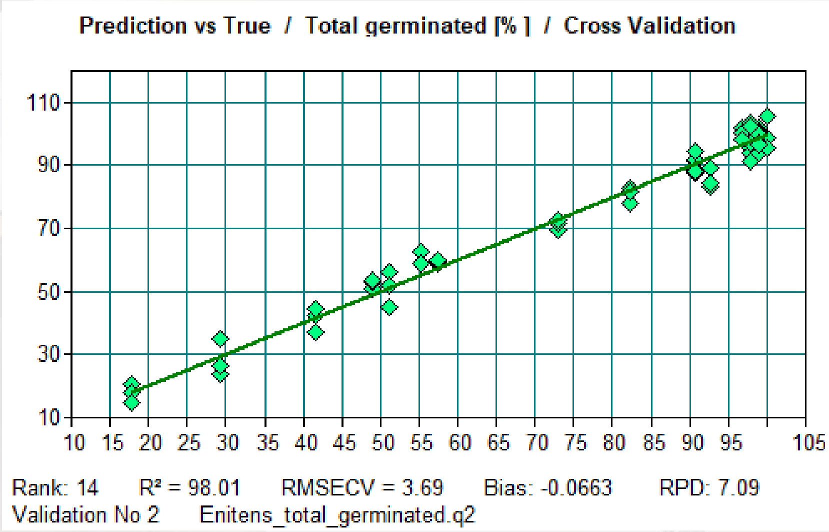


Figure 1: The predicted versus true germination rate for *E. nitens* using an NIR prediction model

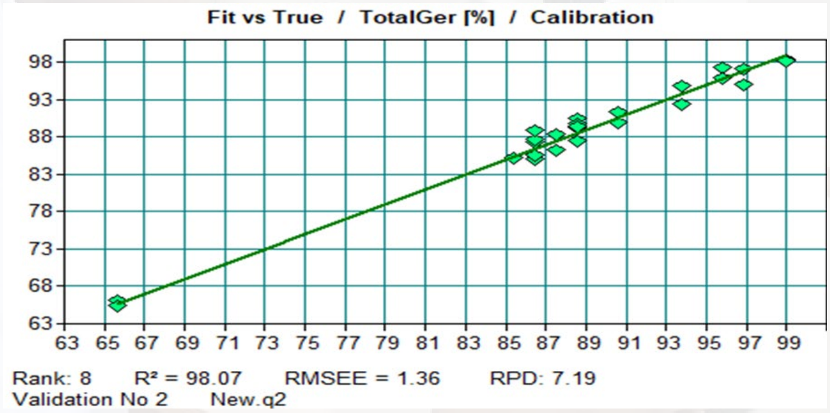


Figure 2: The predicted versus true germination rate for *C. henryi* seeds using an NIR prediction model

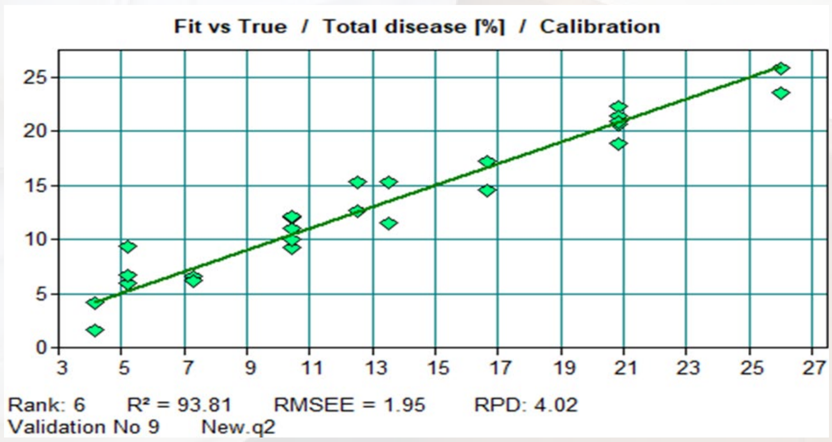


Figure 3: The predicted versus true levels of fungi infecting selected *C. henryi* seed batches using an NIR prediction model

accuracy the number of seeds germinated on particular days, i.e., percentage germinated on day 2 versus day 5 or day 11, and it was found that treated seed coatings did not interfere with the NIRS ability to estimate germination rate. Based on the success of this work NCT has funded Nkosi for 2 years to expand the range of seeds and testing, as part of a larger project looking at NIR applications in nursery seedling production.

Another project that was spurred by the success of the SGASA funded work was an ICFR-hosted Honours project in collaboration with Dr Nokwazi Mbili at UKZN's Plant Pathology Department. The Honours student, Mr Melusi Mthethwa used NIRS to detect the presence of seed-borne fungi and predict seed germination properties of *Corymbia henryi* (**Figure Two**).

Batches of seeds with known fungal contamination issues were used to develop a seed fungus detection model, which was remarkably able to detect fungal seed contamination levels that are potentially associated with seed mortality ([*Alomran et al, 2020*]) (**Figure Three**).

Some of these fungi (**Figure Four**) were isolated for future work to look at how they affect seed germination and seedling survival, as well as methods of treating seeds to improve germination rates and produce normal healthy seedlings (**Figure 5**).

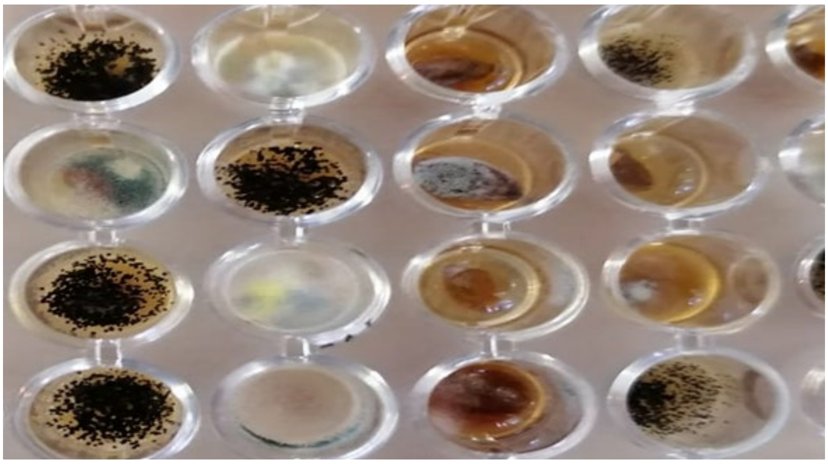


Figure 4: Fungi growing on dead *C. henryi* seeds

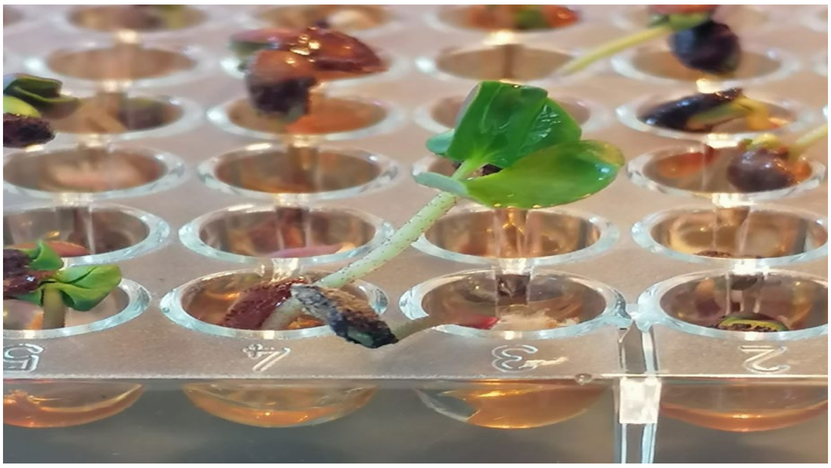


Figure 5: A healthy and normal freshly germinated *C. henryi* seedling

> *"The impact that this technology can have on forestry is potentially huge."*

THE TAKE HOME MESSAGE

NIRS has the potential to provide rapid high throughput analyses in a variety of areas for the forestry industry and more applications are in the pipeline. This will benefit the industry by not only providing cutting-edge high-tech solutions to practical challenges for the industry but also developing and training young scientists who will enrich the industry with their skills and expertise developed at the ICFR in the FSA funded Analytical and Research Laboratory platform.

What needs to be done now is work on developing portable NIRS technology which can be used for applications such as varietal purity testing on nursery ramets used for producing clonal seedlings. This is currently only possible using expensive and laborious DNA analysis. A portable NIRS system will enable the screening of many thousands of ramets at a typical nursery, to ensure that companies are planting the correct varieties for specific sites. Other work includes developing portable NIRS models and methods for nurseries to monitor plant health and nutrient status, using hardware such as the recently developed pocket-sized ***DLP NIRscan Nano from Texas Instruments***, which costs less than $1000 and is thus within the financial reach of many operations, potentially bringing the services of a fully equipped analytical lab to their pockets!

Collaborators and partners are always welcome and for any queries, please contact Dr Burgdorf at the ICFR at richard.burgdorf@icfr.ukzn.ac.za.

LEPTOCYBE INVASA NATIONAL MONITORING PROGRAMME: 2021 RESULTS AND 3-YEAR TRENDS

Dr Ilaria Germishuizen[1] and Professor Brett P Hurley[2]

[1]Research Group Leader: Sustainable Forest Production, ICFR

[2]Associate Professor FABI, University of Pretoria

Dr Ilaria Germishuizen

Prof Brett Hurley

SUMMARY

The fifth national monitoring survey of the blue gum chalcid wasp, *L. invasa*, took place between February and August 2021. One hundred and eighty-two sites were surveyed for the presence of *L. invasa* – induced damage, intensity, and presence of other important eucalypt canopy insect pests and diseases. Damage caused by *L. invasa* was observed at 41 % of sites sampled, indicating a slightly lower presence than in 2020 (55.5%). When present, damage was predominantly of low intensity, and in most plots, 50% or less of the trees assessed showed damage cause by the wasp, while in previous surveys, when present, damage, was found on most of the trees in the plot. *Eucalyptus grandis* and *E. grandis* x *E. nitens* were the most affected species, while the incidence of *L. invasa* in *E. grandis* x *E. urophylla* continued to decrease. An important result is the steady increase in the presence of *Gonipterus* sp. n. 2, which rose from 24% of surveyed plots in 2019 to 32% in 2020 and reached 45% in 2021. The leaf and shoot blight disease caused by *T. destructans* was also more widespread and recorded at 32% of sites (2019:14%; 2020: 28%). Infestations of *G. brimblecombei* were observed at 3% of the sites (2020: 8%) and infestations of the shell lerp psyllid *Spondyliaspis cf.* plicatuloides at 6% of sites (2020: 6%). For the first time, the bronze beetle *T. peregrinus* was detected, although its presence was still very limited (3% of sites).

INTRODUCTION

The blue gum chalcid, *Leptocybe invasa* Fisher & La Salle (Hymenoptera: Eulophidae: Tetrastichinae), is a gall-forming wasp native to Australia that has become a major pest in eucalypt plantations globally. The first record of the wasp outside its native distribution was in 2000 in the Mediterranean basin and the Middle East (Mendel *et al.* 2004) and it has since spread to most *Eucalyptus* growing areas in India, South-East Asia, South America and parts of Africa (Dittrich-Schröder *et al.* 2012). In South Africa, the wasp was first detected in Pretoria in 2007 (Neser *et al.* 2007) and it is now present in most forestry areas where susceptible eucalypt species are planted. Outside its native distribution, in the absence of natural enemies, *L. invasa* causes severe damage to trees by laying eggs on newly produced growth resulting in the formation of galls (Mendel *et al.* 2004). Affected trees suffer stunted growth, deformity and, in severe cases, mortality (Mendel *et al.* 2004).

In South Africa, the most effective means of control available to the forestry sector are based on biological control, such as the deployment of the biological control agent *Selitrichodes neseri*, (Kelly *et al.* 2012, Dittrich-Schröder *et al.* 2014), and planting stock resistant to *L. invasa* (Dittrich-Schröder *et al.* 2012).

Since 2016, an annual national survey has been conducted under the guidance of the Eucalypt Pest and Pathogen Working Group (EPPWG), a sub-committee of the Pest and Disease Committee of Forestry South Africa (FSA). The survey has two key objectives:

1. To monitor *L. invasa* -caused damage in eucalypt plantations
2. To monitor parasitism levels of *S. neseri* and other biological control agents

Other eucalypt canopy pests and pathogens are also recorded, even if the assessment is limited their presence or absence.

Results from the previous national surveys were reported in Germishuizen and Hurley (2017), Germishuizen (2019), Germishuizen *et al* (2020), and Germishuizen and Hurley (2021). This document describes the results from the survey of *L. invasa* -caused damage conducted in 2021, and the spatio-temporal trends of the main eucalypt pests and pathogens between 2019-2021.

The implementation of the national survey is made possible through a collaboration between participating forestry companies, the Tree Protection Co-operative Programme (TPCP) of the Forestry and Agricultural Biotechnology Institute (FABI) and the Institute for Commercial Forestry Research (ICFR) and supported by the Eucalypt Pests and Pathogens Working Group (EPPWG) of Forestry South Africa (FSA).

MATERIALS AND METHODS

The eucalypt plantation dataset consisted of compartments of ages between 0 and 18 months supplied by the participating companies. Older stands were excluded from the dataset due to *L. invasa*'s preference for newly produced growth (Neser *et al*. 2007). Furthermore, the assessment of older stands may be challenging and likely less accurate due to the size of the trees. Due to lack of funding, companies conducted the surveys using in-house capacity.

A total of 190 sites were selected following the methodology described in Germishuizen (2019). Due to the limited number of sites, not all species and genotypes could be included in the survey, but, within each region, preference was given to the ones more commonly planted and known to be susceptible. At each site, 50 trees were assessed for the presence of *L. invasa* and type of damage following a zig-zag pattern, by changing direction every fifth tree. In stands planted to clonal varieties, the number of trees assessed was limited to 30 considering the uniform susceptibility of trees. The entire canopy of the tree was assessed to detect the presence of *L. invasa* and other canopy pests and diseases by walking around the tree. Damage severity was assessed on the outer branches of the living canopy, and dead bottom branches were excluded from the assessment. Severity of damage associated with the presence of *L. invasa* was determined based on the percentage amount of canopy affected, 1 (Low) <25%; 2 (Moderate): 25-50%; 3 (High): 50-75%; and 4 (Very High) >75%. The presence and percentage of trees affected by little leaf syndrome were also accounted for when determining the occurrence and severity of damage caused by *L. invasa*. The occurrence of galls on the petioles, midribs and / or branches was recorded. Little leaf

Figure 1: Galls, oviposition scarring and little leaf syndrome caused by *Leptocybe invasa* on young eucalypts.
Photographs supplied by Izette Greyling – Mondi

syndrome and its co-occurrence with oviposition scars was also noted (**Figure 1**). Little leaf syndrome is the deformation of young leaves caused by *L. invasa* laying eggs in plant tissue. The presence of oviposition scars rules out other potential causes of little leaf syndrome such as vegetation chemical control. The presence of *Gonipterus* sp. n. 2, *Glycaspis brimblecombei, Thaumastocoris peregrinus*, the shell lerp psyllid *Spondyliaspis* cf. *plicatuloides* and the leaf and shoot blight disease caused by *Teratosphaeria destructans* were also noted. Surveys were conducted between February and August 2021.

KEY FINDINGS

Overall, the occurrence of *L. invasa* was slightly lower than what was observed in 2020, with 42% of sites surveyed showing signs of its presence.

- Damage caused by *L. invasa* was more common in plots located in cool temperate (58%) and warm temperate (41%) areas, while it was only detected in 19% of plots in sub-tropical areas.
- *Eucalyptus grandis* and *E. grandis x E. nitens* showed overall higher susceptibility to the wasp, followed by *E. smithii* (22%) and *E. benthami* (18%). Low damage occurrence was observed in E. *grandis x E. urophylla* plots (8%).
- A steady increase in the presence of *Gonipterus* sp. n. 2., *T. destructans* and *S. c.f. plicatuloides* was observed, while the incidence of *G. brimblecombei* was slightly lower than in 2020.

For the first time, the presence of the bronze bug *T. peregrinus* was also detected.

RESULTS

A total of 182 sites out of the 190 selected were surveyed, with 7 423 trees assessed, of which 1 115 (15%) presented galls or little leaf syndrome caused by *L. invasa.* Damage intensity was estimated in a sub-sample of 474 trees. *Leptocybe invasa* was the second most frequent eucalypt canopy pest, occurring at 75 of the 182 sites (41.2%) (**Figure 2A** and **B**). Limpopo (93%), Eastern Cape (70%), Southern KZN (64.3%) and Northern KZN (50%) were the regions with the highest incidence of *L. invasa* damage. *Gonipterus* sp. n. 2 was the most prevalent insect pest, being recorded at 81 sites (45%). *Glycaspis brimblecombei* was found only at 6 sites (3%), while in 2020 its presence was recorded at 6% of the sites. The leaf and shoot blight disease caused by *T. destructans* was observed at 58 sites (32%), and the shell lerp psyllid S. cf. *plicatuloides* was observed at 11 sites (6%). The bronze bug *T. peregrinus* was detected for the first time since the first

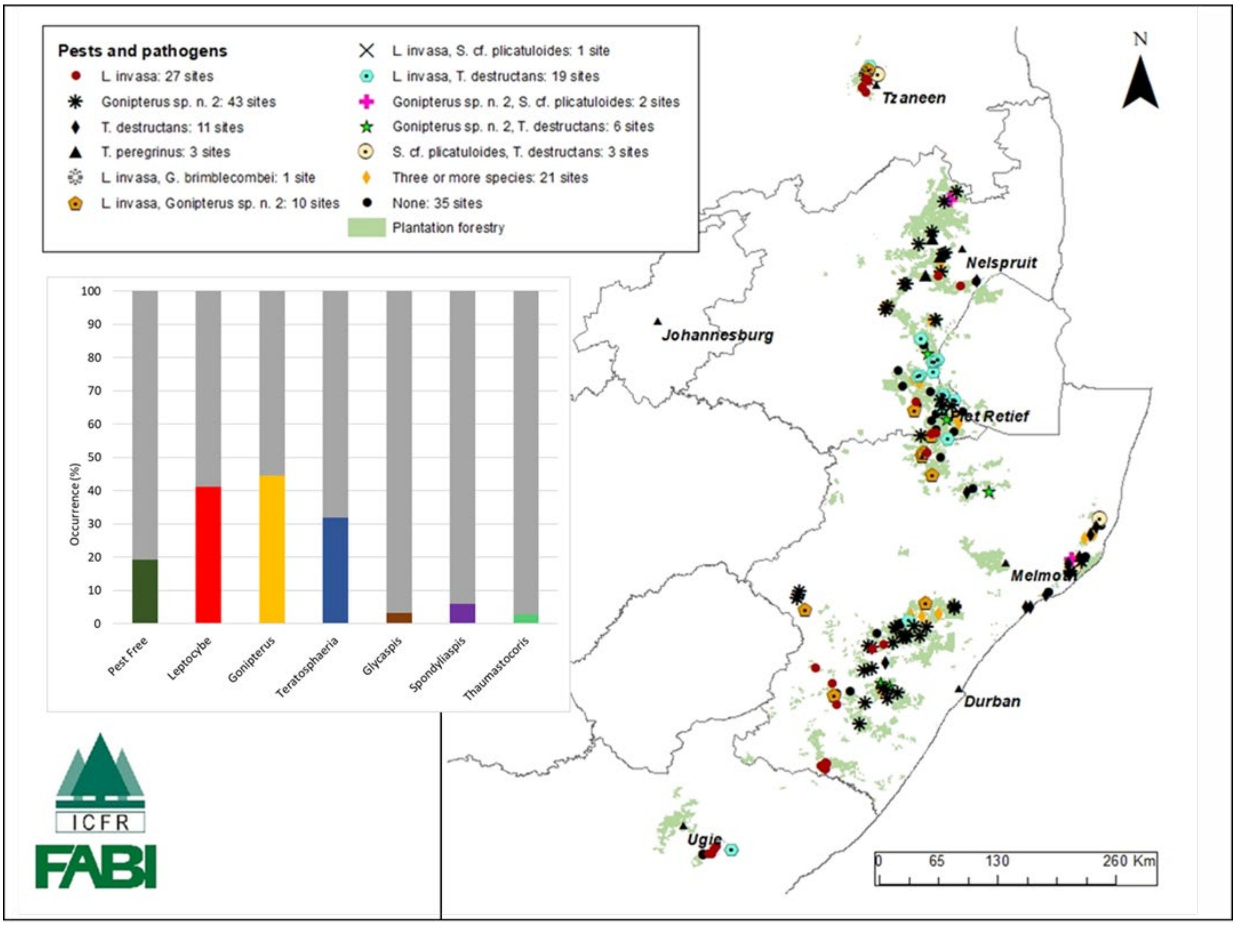


Figure 2A: Occurrence of eucalypt canopy pests and pathogens at the monitored sites in South Africa

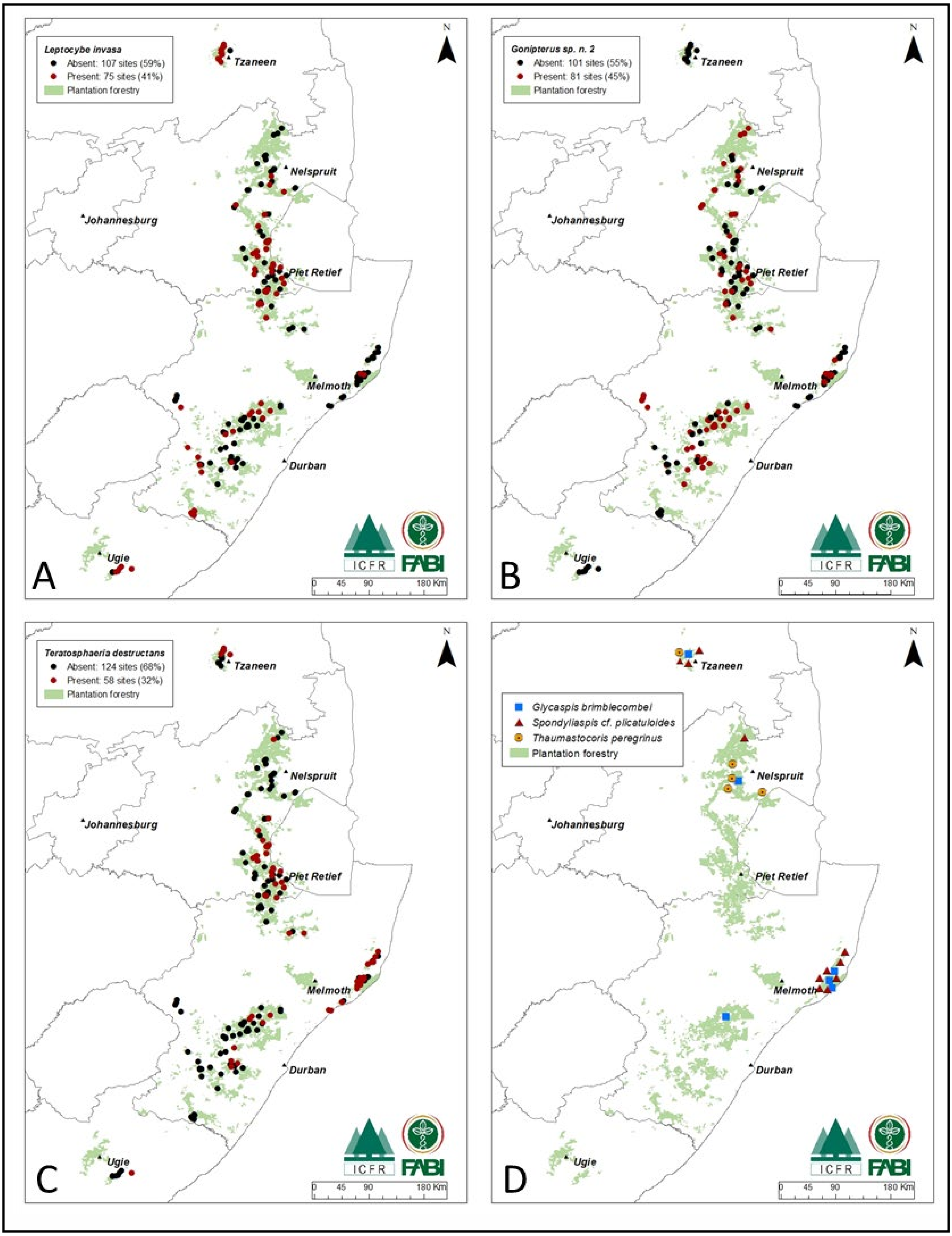


Figure 2B: Occurrence of (A) *Leptocybe invasa*, (B) *Gonipterus* sp. n. 2, (C) *Teratosphaeria destructans*, and (D) other eucalypt canopy pests at the monitored sites in South Africa survey in 2016, with its presence recorded at 5 sites (3%). At 48 sites (26.4%), *L. invasa* co-occurred with other pests or pathogens (**Figure 2 A** and **B**).

DAMAGE TYPE AND INTENSITY

When *L. invasa* was present, damage intensity was mostly mild. In 80% of the trees assessed for damage severity, damage affected less than 25% of the canopy (**Figure 3**), indicating a lower damage intensity than in 2020, when damage affected less than 25% of the canopy in 60% of the trees assessed. When present, *L. invasa* affected less than half of the trees in the plot (**Figure 4**), which contrasts with what observed in previous surveys, where the spread of the damage was generally uniform within a plot. An interesting, new result is the lower occurrence of *L. invasa*'s damage in plots located in the sub-tropical climate zone than in the cool-temperate climate zone (chi-squared = 11.196; p-value<0.01) (**Figure 5**). In addition, when damage was detected in sub-tropical areas, it affected less trees in the plot (**Figure 4**). This is partly due to the decreasing susceptibility of *E. grandis x E. urophylla* observed in the last three surveys. However, this trend was also observed in *E. grandis* plots, where in cool-temperate and warm-temperate areas, damage was detected in more trees within a plot than in sub-tropical areas (**Figure 4**). The higher presence of *L. invasa* in cool-temperate areas planted to *E. grandis x E. nitens* may be related to the recent warmer than normal weather trends (SAWS 2019; SAWS 2020; SAWS 2021) which resulted in a more suitable environment for *L. invasa* in these areas and higher level of stress in trees due to sub-optimal climate conditions. In all species, galls were predominantly located on the petiole (82%) and midrib (47%) but also frequently on the branches (28%). Little leaf syndrome was observed in 5% of trees (**Figure 6A** and **B**). At 79% of sites where the little leaf syndrome was observed, oviposition scars attributable to *L. invasa* were noted. Little leaf syndrome was only observed in *E. grandis* and *E. grandis x E. nitens*, which where overall the most affected species.

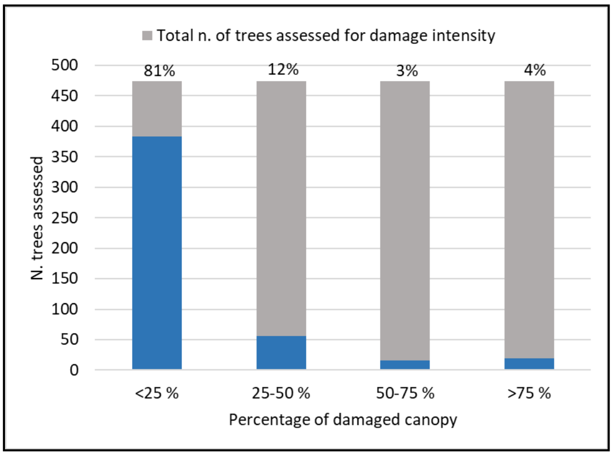


Figure 3: Damage intensity at sites affected by *L. invasa*. Intensity was measured based on 4 classes: 1 Low (<25%); 2 Moderate (25-50%); 3 High (50-75%); 4 Very High (> 75%)

Co-occurrence of galls on different parts of the tree was observed in 42% of trees. As observed in previous surveys, the most frequent associations were "Midrib+Petiole+Branch" (20.1%), "Midrib+Petiole" (15.9%), and "Petiole+Branch (4.5%). When occurring only in one part of the tree, galls were more often located on the petiole (41.5%) or midrib (10.4%), and less often

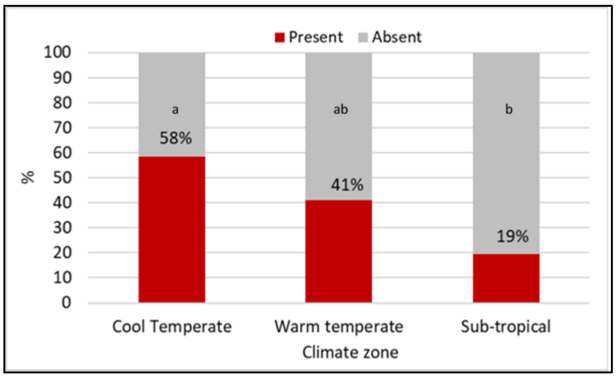


Figure 5: Occurrence of damage caused by *L. invasa* in the cool-temperate, warm-temperate, and sub-tropical climate zone. Pearson's Chi-squared indicates a significant difference at p<0.01

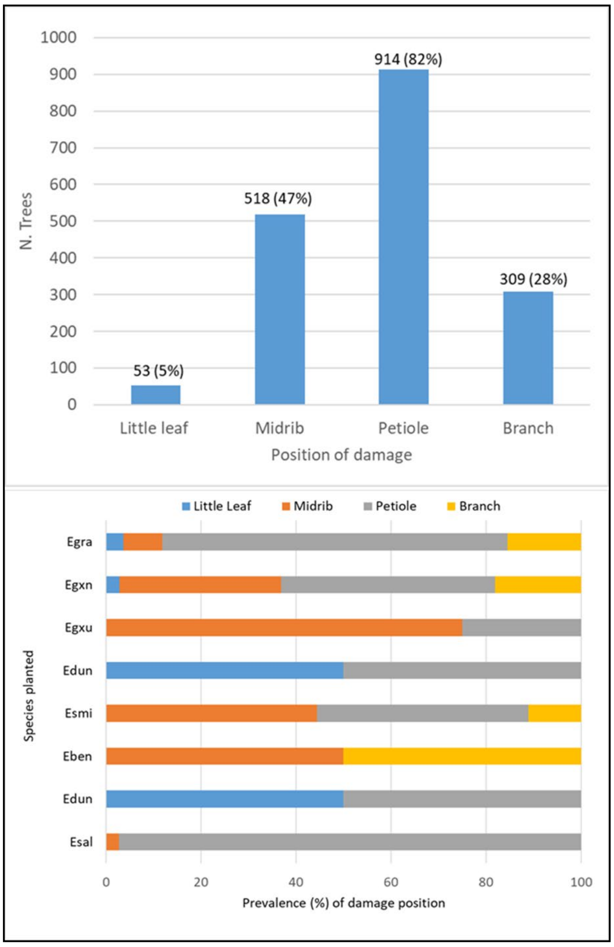


Figure 6: Symptoms and position of *L. invasa* -caused damage on affected trees (A) and by spe-cies/genotype (B). Species/genotype abbreviations: *E. dunnii*: Edun; *E. grandis*: Egra; *E. grandis* x *E. nitens*: Egxn; *E. grandis* x *E. urophylla*: Egxu; *E. saligna*: Esal; *E. smithii*: Esmi

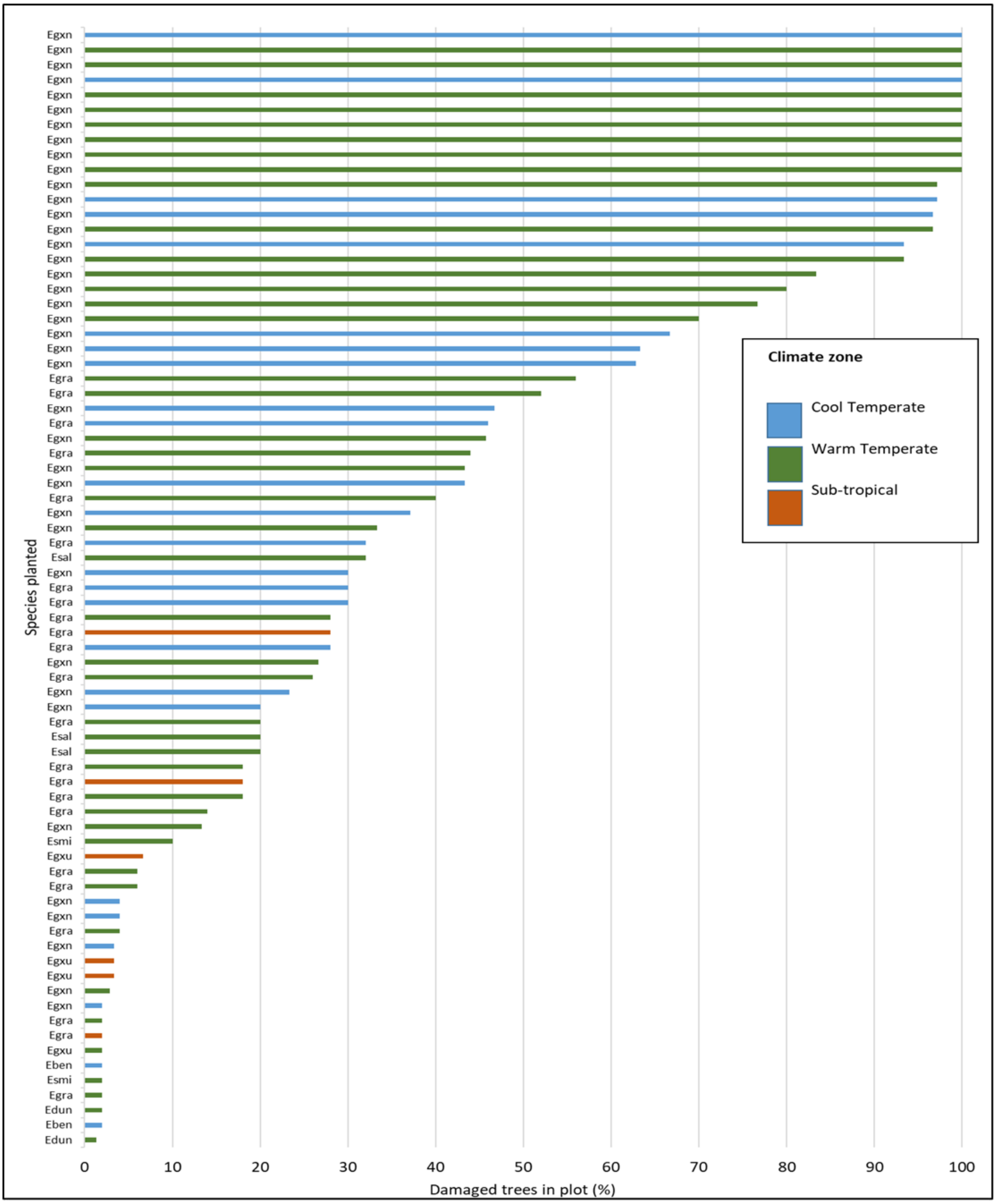


Figure 4: Percentage of trees showing damage caused by *L. invasa* at affected sites located in cool temperate, warm temperate and sub-tropical climate zones

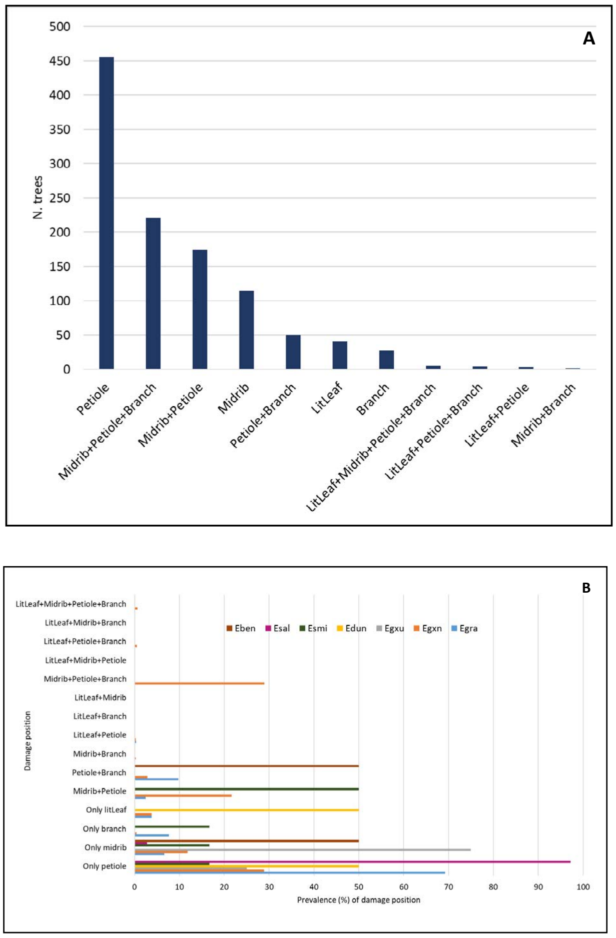


Figure 7: Co-occurrence of damage on different parts of total affected trees A) and by species/genotype. Species/genotype abbreviations: *E. dunnii*: Edun; *E. grandis*: Egra; *E. grandis* x *E. nitens*: Egxn; *E. grandis* x *E. urophylla*: Egxu; *E. saligna*: Esal; *E. smithii*: Esmi

only on the branches (2.4%). Little leaf syndrome symptoms with no other *L. invasa* -related damage was observed in 3.7% of trees (**Figure 6A**). Similar trends were observed when analysing the damage location by species and genotype (**Figure 6B**). Differences among species and genotypes were only noted when the sample size was too small for a statistical evaluation.

SPECIES AND HYBRID SUSCEPTIBILITY

Eucalyptus grandis and *E. grandis x E. nitens* showed the highest susceptibility to *L. invasa* **(Figure 8**). Only 3 plots were located in *E. saligna* stands, hence the very high (100%) incidence observed must be considered with caution. Damage caused by *L. invasa* in *E. grandis x E. urophylla* plots has been consistently moderate through the years in comparison to *E. grandis* and *E. grandis x E. nitens*, and particularly low this year, with damage being detected at only 10% of the sites (**Figure 8**). Damage presence in plots planted to this hybrid were similar in warm temperate and sub-tropical climate zones (8% and 11% respectively) (**Figure 9B** and **C**). Twenty-three of the 28 *E. grandis* sites (82%) showed damage caused by *L. invasa* (**Figure 8**), and susceptibility was high in all temperature zones (**Figure 9A**, **B** and **C**) (Cool Temperate: 100%; Warm Temperate: 75%; Sub-tropical: 100%). Sites planted to *E. grandis x E. nitens* clones also showed very high susceptibility, with 39 of the 54 sites (72%) surveyed showing damage caused by *L. invasa*. The high susceptibility of *E. grandis x E. nitens* to *L. invasa* was similar in the cool temperate and warm temperate climate zones (74% and 71% respectively) (**Figure 9 A** and **B**)

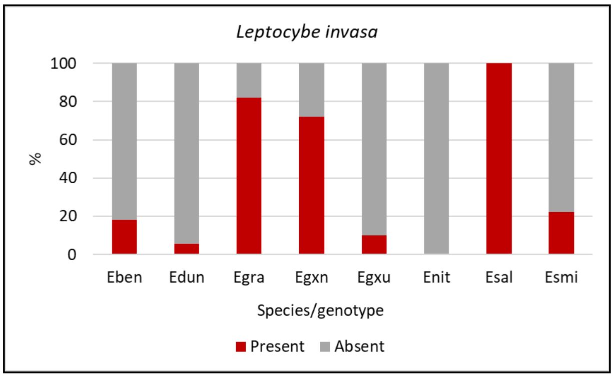


Figure 8: Presence of *L. invasa* by species/genotype. Labels on bars indicate the percentage of sites where *L. invasa* was detected. Species/genotype abbreviations. *E. benthami*: Eben; *E. dunnii*: Edun; *E. grandis*: Egra; *E. grandis* x *E. nitens*: Egxn; *E. grandis* x *E. urophylla*: Egxu; *E. nitens*: Enit; *E. saligna*: Esal; *E. smithii*: Esmi

SPATIAL AND TEMPORAL TRENDS: 2019-2021

LEPTOCYBE INVASA

During the past three years, the presence of *L. invasa* has been overall declining **(Figure 14A**), with damage being detected at 55% of sites in 2019, 51% in 2020, and 42% in 2021. However, regional trends differ, with Limpopo, Northern KZN, Southern KZN, and Eastern Cape having experienced in 2021 an increase in the occurrence of this insect pest (**Figure 10**). A steady decline in the incidence of *L. invasa*'s damage has been recorded in the KZN Midlands (2019: 67%; 2020: 45%; 2021: 30%), while the remaining regions have shown mixed trends for this three-year period (**Figure 14A**). In 2021, Limpopo showed the highest occurrence of *L. invasa* followed by Eastern Cape, with respectively 93% and 70% of the plots surveyed having signs of its presence (**Figure 10**).

Changes in species and hybrid clone susceptibility to *L. invasa* were also noted during the 2019-2021 period (**Figure 15**). Of particular interest is the decreasing susceptibility of *E. grandis x E. urophylla*. The percentage of sites planted to this hybrid showing signs of presence of *L. invasa* decreased from 33% in 2020 to 10% in 2021 (**Figure 15**). The high incidence of *L. invasa* in plots planted to *E. dunnii* observed in 2020, when 44% of incidence was recorded, was no longer evident in this year survey, with only 6% of these plots showing damage attributable to this wasp (**Figure 15**). The high susceptibility of *E. grandis* and *E. grandis x E. nitens* remained similar during the 2019-2021 period (**Figure 15**).

GONIPTERUS SP. N.2

A steady rise in the occurrence of *Gonipterus* sp. n. 2 symptoms during the period 2019-2021 was observed in Mpumalanga North (2019: 0%; 2020: 27%; 2021: 60%) and Mpumalanga South (2019: 5%; 2020: 3%; 2021: 40%) (**Figure 11**); *Gonipterus* sp. n. 2 symptoms were also recorded for the first time in Limpopo (14%) and Northern KZN (43%) (**Figure 11**). The highest presence of the snout beetle was recorded once again in the KZN Midlands, where its symptoms were detected in 77% of the plots (**Figure 11**). *Eucalyptus dunnii* was by far the most susceptible species, with a recorded incidence of 77% (**Figure 17**). The increasing presence of damage attributable to the snout beetle in *E. dunnii* and *E. grandis x E. nitens* stands reflects the increasing prevalence of this insect pest observed in the last three years. (**Figure 14B** and **Figure 16**).

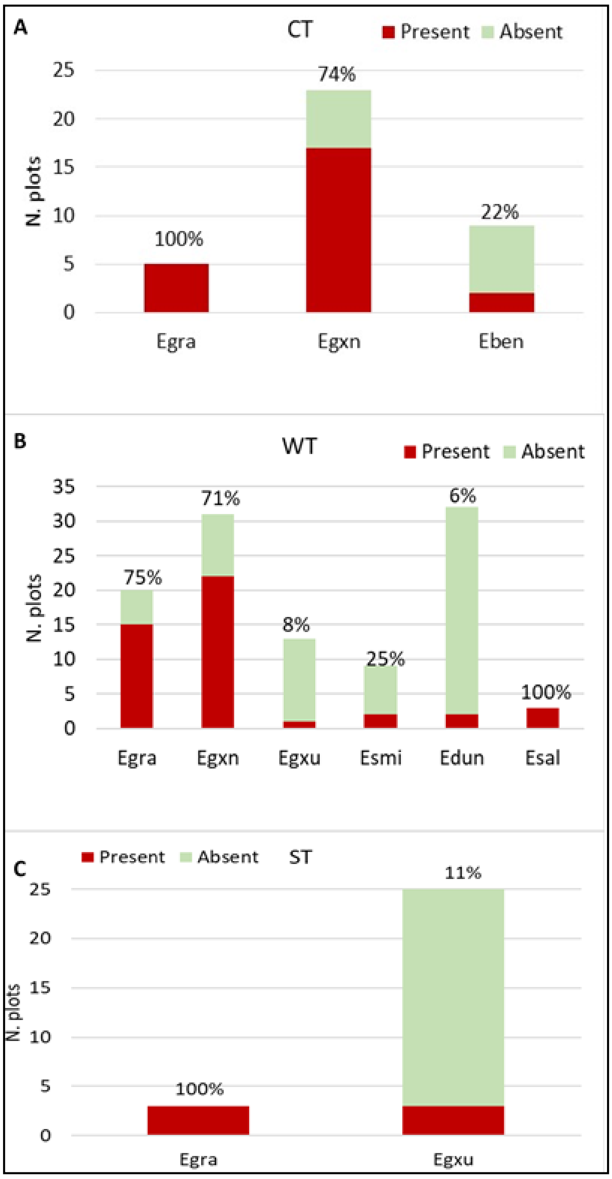


Figure 9: Presence of *L. invasa* by species/genotype in (A) Cool Temperate (MAT 10-16 °C), (B) Warm Temperate (MAT 16-19 °C) and (C) Sub-Tropical (MAT 19-22 °C) sites. Labels on bars indicate the percentage of sites where *L. invasa* was detected. Species/genotype abbreviations. *E. benthami*: Eben; *E. dunnii*: Edun; *E. grandis*: Egra; *E. grandis* x *E. nitens*: Egxn; *E. grandis* x *E. urophylla*: Egxu; *E. nitens*: Enit; *E. saligna*: Esal; *E. smithii*: Esmi

TERATOSPHAERIA DESTRUCTANS

Symptoms attributable to *T. destructans* continued to increase across the forestry landscape (2019: 14%; 2020: 28%; 2021: 32%) (**Figure 14C**). The disease was detected for the first time during the annual survey in Northern KZN, and Eastern Cape (36%, and 20% respectively) (**Figure 12A**). Except for Southern KZN, *T. destructans* symptoms were observed in all the regions surveyed. A steady increase in symptoms was noticed in Zululand (2019: 20%; 2020: 40%; 2021: 68%) and Mpumalanga South (2019: 3%; 2020: 26%; 2021: 43%; **Figure 14C**).

Eucalyptus grandis and its hybrids, *E. smithii* and *E. saligna* were the most affected species (**Figure 17 A**), while symptoms were only detected in 3% of *E. dunnii* plots.

GLYCASPIS BRIMBLECOMBEI, SPONDYLIASPIS CF PLICATULOIDES AND THAUMASTOCORIS PEREGRINUS

A slight decrease in the occurrence of *G. brimblecombei* was noted in Limpopo, Mpumalanga North, KZN Midlands, and Zululand (**Figure 12B**). In Mpumalanga South and Southern KZN, its presence was undetected this year, and it continues to be undetected in Northern KZN and Eastern Cape (**Figure 12B**; **Figure 14D**). The incidence of *G. brimblecombei* in the areas surveyed was once again very contained. *E. grandis*, *E grandis* x *E. urophylla*, and *E. dunnii* were the species affected (**Figure 17B**). Signs of presence of *S. cf. plicatuloides* were recorded in Zululand, Limpopo, and Mpumalanga North, while it was undetected in KZN Midlands and Southern KZN (**Figure 13**). As for 2020, its presence was undetected in Mpumalanga South, Northern KZN, and Eastern Cape (**Figure 13**). Susceptible species were *E. grandis* and *E. grandis* x *E. urophylla* (**Figure 17C**). It is important to highlight the detection of S. cf. plicatuloides at 22% of the *E. grandis* x *E. urophylla* sites, as this insect was mostly undetected in the past surveys. The bronze bug *T. peregrinus* was detected for the first time in 2021; spatio-temporal trends are hence not available. Its presence was minimal and recorded on *E. grandis* and its hybrids, and *E. dunnii* (**Figure 17D**).

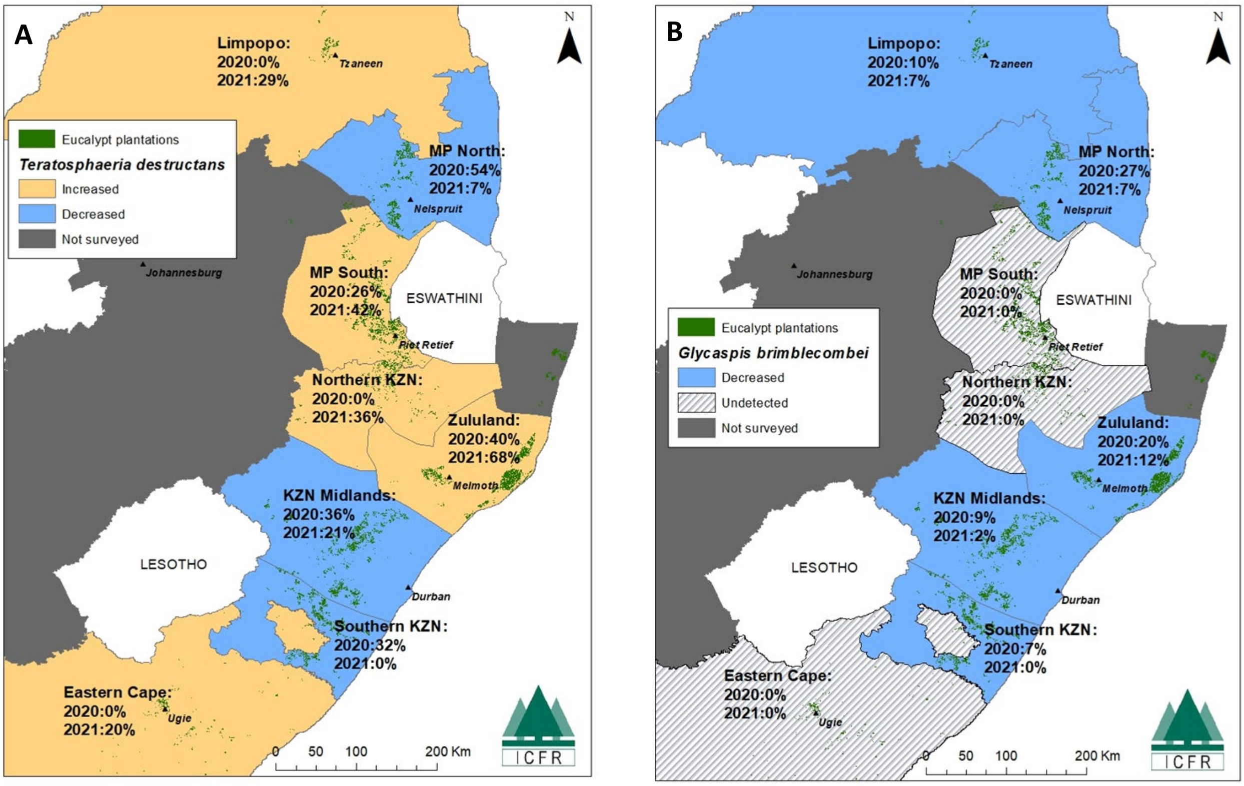


Figure 12: Spatial and temporal changes in occurrence of (A) *Teratosphaeria destructans* and *Glycaspis brimblecombei*; 2020 – 2021

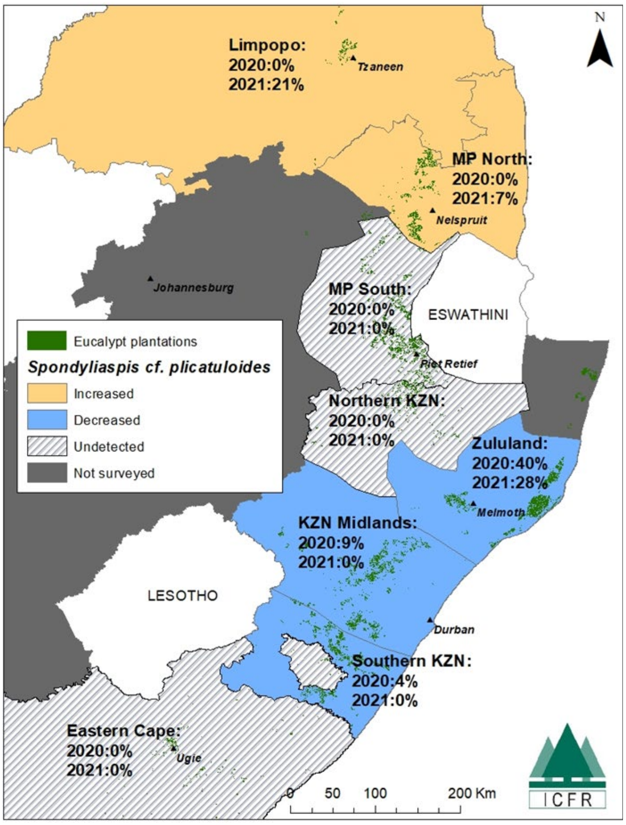


Figure 13: Spatial and temporal changes in occurrence of *Spondyliaspis cf plicatuloides*: 2020 – 2021

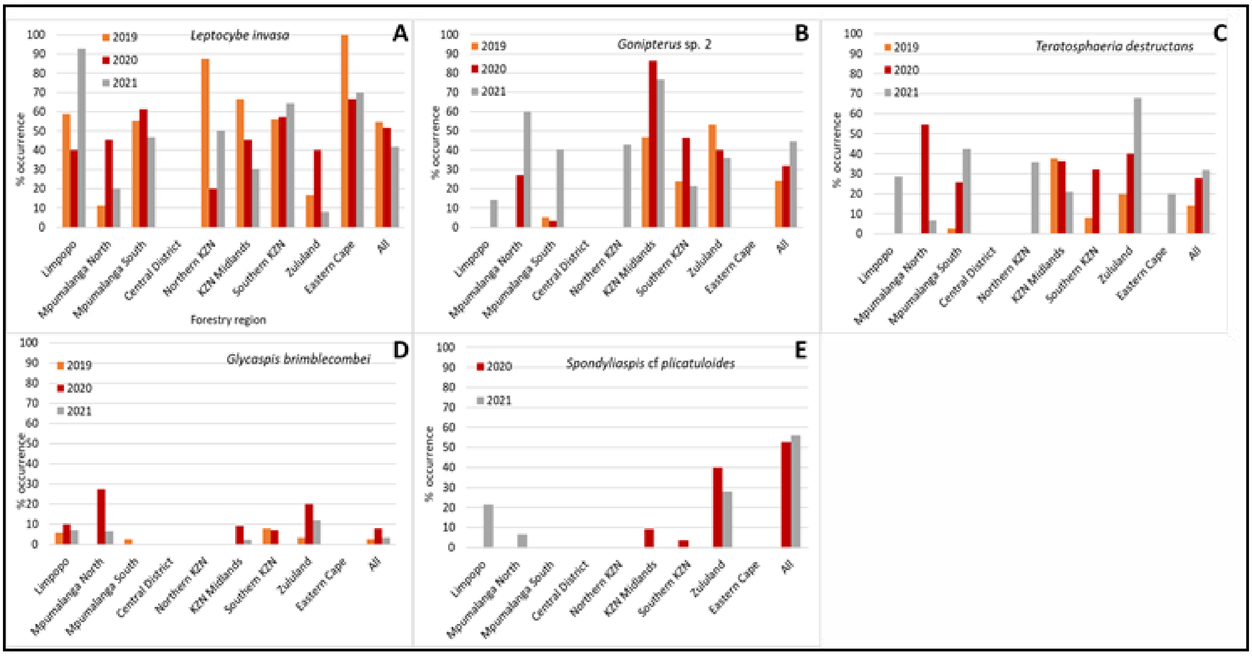


Figure 14. Spatial and temporal trends over time of *Leptocybe invasa* (A), *Gonipterus* sp. n. 2 (B), *Teratosphaeria destructans* (C), *Glycaspis brimblecombei* (D), and *Spondyliaspis cf pliatuloides*: 2018 – 2019 – 2020

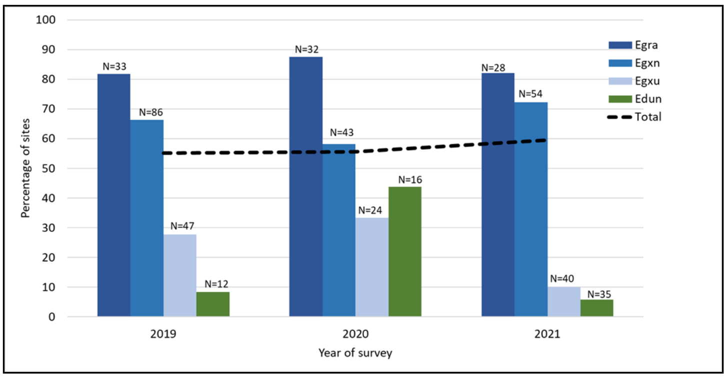


Figure 15: Temporal changes in the occurrence of damage caused by *Leptocybe invasa* in stands planted to *Eucalyptus grandis*, *Eucalyptus grandis* x *Eucalyptus nitens*, *Eucalyptus grandis* x *Eucalyptus urophylla*, and *Eucalyptus dunnii*. Species/genotype abbreviations: *E. dunnii*: Edun; *E. grandis*: Egra; *E. grandis* x *E. nitens*: Egxn; *E. grandis* x *E. urophylla*: Egxu

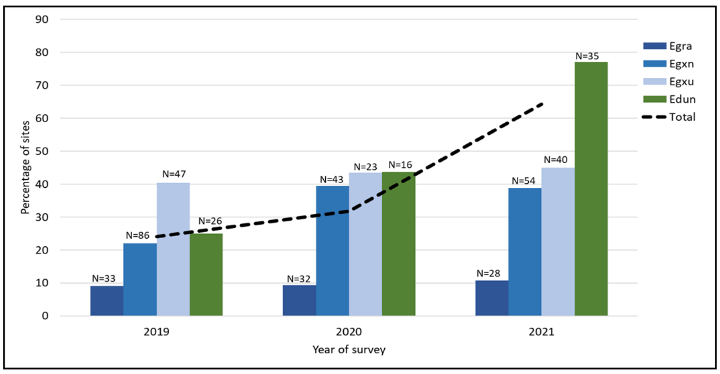


Figure 16: Temporal changes in the occurrence of damage caused by *Gonipterus* sp. n. 2 in stands planted to *Eucalyptus grandis*, *Eucalyptus grandis* x *Eucalyptus nitens*, *Eucalyptus grandis* x *Eucalyptus urophylla*, and *Eucalyptus dunnii*. Species/genotype abbreviations: *E. dunnii*: Edun; *E. grandis*: Egra; *E. grandis* x *E. nitens*: Egxn; *E. grandis* x *E. urophylla*: Egxu

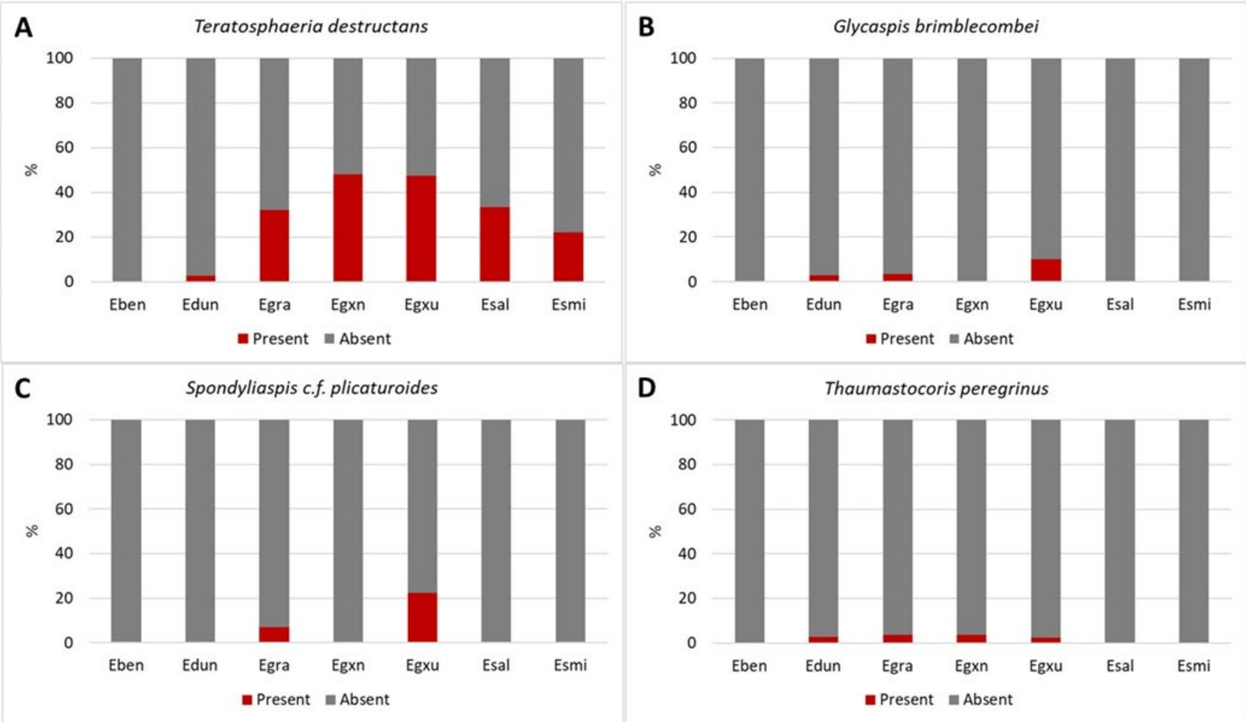


Figure 17: Presence of (A) *Teratosphaeria destructans*, (CB) *Glycaspis brimblecombei*, (C) *Spondyliaspis cf plicatuloides*, and (D) *Thaumastocoris peregrinus* by species. Species. abbreviations. *E. dunnii*: Edun; *E. grandis*: Egra; *E. grandis* x *E. camaldulensis*: Egxc; *E. grandis* x *E. nitens*: Egxn; *E. grandis* x *E. urophylla*: Egxu; *E. saligna*: Esal; *E. smithii*: Esmi

DISCUSSION AND CONCLUSION

The fifth *L. invasa* survey saw a substantial increase in the number of sites surveyed, with 182 plots distributed across most of the forestry areas planted to *Eucalyptus*. The main gap was in the Melmoth and Babanango areas, where no plots were surveyed due to unforeseen constraints, and Maputaland. Results showed once again important changes in the incidence of damage occurrence at regional level and prevalence of canopy pests and pathogens. Mpumalanga North, KZN Midlands and Zululand saw a remarkable decrease in the number sites affected by *L. invasa*. On the other hand, Eastern Cape, Northern KZN, and Limpopo showed a noticeable increase in its occurrence. These population fluctuations are in part natural responses to the climatic conditions experienced regionally at a given time. The steady decrease observed in the past three years in the occurrence of *L. invasa* in Zululand is also likely due to the successful breeding strategy adopted by the forestry companies, resulting in the deployment of *E. grandis x E. urophylla* clones with a high degree of resistance to the gall wasp. On the contrary, the incidence of damage caused by the gall wasp in *E. grandis x E. nitens* hybrid clones has been steadily increasing over time. The evident increasing vulnerability of *E. grandis x E. nitens* may also be related to the warmer than average weather consistently experienced in the last few years (SAWS 2019; SAWS 2020, SAWS 2021), resulting in sub-optimal climate conditions at many sites planted to this hybrid, increased levels of stress experienced by trees at these sites, and environmental conditions more favourable to *L. invasa*, which thrives in warmer climates. At most sites, levels of infestation recorded were in the lowest damage category (<25%). The use of broad categories may be misleading and, in this instance, promote the perception that *L. invasa* is currently causing minimum damage in *Eucalyptus* plantations. It is advised to consider breaking the lowest damage category into two, for example <10% and 11-25%, to gain a better understanding of the damage observed and differentiate between minimal and moderate damage.

Gonipterus sp. n. 2 was found in all regions except for the Eastern Cape, and, despite the design of the survey being developed based on *L. invasa*'s life cycle and ecology, it was overall the predominant insect pest, occurring at 45% of sites. At the regional level, *Gonipterus* sp. n. 2 was the dominant canopy pest in Mpumalanga North, KZN Midlands, and Zululand. No information on the levels of the damage caused by the snout beetle was collected, hence, the severity of infestation cannot be determined. Since 2020 its distribution and prevalence in eucalypt plantations has been increasing, making the snout beetle currently the most concerning eucalypt insect canopy pest.

This year, *T. destructans* was detected throughout the plantation forests landscape, except for Southern KZN. Its presence was recorded for the first time in Limpopo, Northern KZN and Eastern Cape; it is however important to keep into consideration that only in the last two years the recording of diseases and pests other than *L. invasa* has been formalised as part of the survey protocol, and the lack of detection particularly of diseases and less common insect pests may be partially related to an oversight. An important result is the prevalence of this disease in Zululand, where 68% of sites showed *T. destructans* symptoms.

A general decrease of *G. brimblecombei* was noticed across the eucalypt landscape, while *S. cf. plicatuloides*'s presence was detected for the first time in Limpopo and Mpumalanga North. The fluctuations in the occurrence of these less common insect pests as well as the lack of detection are strongly due to their generally more sporadic occurrence, the limited number of sites surveyed, and the criteria applied during the site selection process in terms of age class and species, which are calibrated to target *L. invasa*'s susceptible sites.

The bronze beetle *T. peregrinus* was detected for the first time this year, with its distribution confined to Mpumalanga North, Mpumalanga South and Limpopo. Its presence was still very contained, and once again, lack of detection in previous years also partially attributable to the focus of the surveyors on *L. invasa* and the other most prevalent insect pest, *Gonipterus sp. n. 2*.

As for the previous years, the survey was conducted thanks to the in-kind participation by some of the companies, rather than a sector-level, fully funded program, resulting in some areas not being surveyed with the same intensity as other areas. It is particularly concerning that small holders and community forestry areas are excluded from the annual survey, resulting in the Maputaland region being excluded from the survey, and the data pertaining particularly to the Zululand region being based only on the eucalypt plantations managed by large scale corporates. Considering that the areas excluded from the survey may act as reservoirs for insect pests and diseases, providing the population levels leading to outbreaks, the development of a sector level forest health monitoring framework is crucial for all players in the forestry sector. Lack of funding and resources is a major limitation in the implementation of the annual survey, and this year, again, restrictions due to the Covid-19 pandemic posed additional strain to this initiative. Nevertheless, thanks to the commitment by the participating companies, the 2021 survey was by far more comprehensive than the 2020 one. Spatio-temporal trends derived from the annual survey are providing important information on the occurrence and prevalence of eucalypt canopy pests and diseases within the forestry landscape; this information, together with in-house company survey, contribute towards the annual snapshot of eucalypt pests and diseases distribution, highlighting problem areas and potential new important pests and pathogens. Pest and disease monitoring is a critical input to the integrated pest management (IPM) decision process, and the lack of a co-ordinated, industry level, multi-tiered forest health monitoring program is still a major hindrance in the implementation of a solid and successful forest protection strategy in South Africa.

ACKNOWLEDGEMENTS

Merensky, Mondi, NCT, Sappi, TWK and FABI are gratefully acknowledged for their input and assistance in field data collection. Forestry South Africa (FSA) is thanked for providing some funding through the Spatial Technology Platform housed at the ICFR. Dr Ronald Heath (FSA) and Wayne Jones (Chair, Eucalypt Pests and pathogens Working Group) are also thanked for their support for this initiative.

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