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OUTLOOKS ON PEST MANAGEMENT

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COVER PHOTOS: Cotton bollworm (*Helicoverpa zea*) (Photo by Scott Bauer) *and Aedes* (*Ochlerotatus*) *sp.* mosquito on human skin both reproduced courtesy of USDA-ARS; Cocoa showing both frosty pod rot (*Moniliophthora roreri*) and witches' broom (*M. perniciosa*) on the same branch (Ecuador) (Photo by Roy Batemen); Unsprayed strip in sugarbeet showing poppies (*Papaver* spp.) (Photo by Alan Dewar)

EDITORIAL

WELCOME TO 2019 – HOW MUCH HAS CHANGED OVER THE LAST 29 YEARS?

Leonard G. Copping, Executive Editor

Key words: Crop protection; animal and human health; changing emphasis; public understanding of science; GMOs; glyphosate, statistics

When looking back over 2018 and the key issues in the world of crop protection and animal and human health that have hit the headlines, that have been a source of good news or that have been misrepresented, it is, perhaps, useful to look back over the first 28 years of *Outlooks on Pest Management* (originally *Pesticide Outlook*) and see what were the issues then.

Perhaps the place to start is the change of title around the time when it was generally agreed that the word 'Pesticide' was a word that conjured up bad things such as poisons, contamination, loss of species and pest resistance. You may well remember that around this time the word chemical (and chemistry) was equally denigrated with the industry adopting its usual position of keeping its head down and hoping that it would all go away. BASF was an unusual champion of chemistry in its advertising, but how successful was this approach in maintaining the company's profile and reassuring the general public that chemistry was not going to lead to death and destruction? The company's current success would indicate that it took the correct approach (or perhaps shows that the general public do not watch television advertisements).

In issue 1 (1990), the first herbicide-based topic was 'Wheat herbicides – emerging resistance' written by Steve Lisanksy. The next two were on 'Weed Societies' and 'Changing the Latin Names of Weeds'. These were the only three herbicide articles that were published in 1990. Perhaps this was a reflection of the considered importance of weed control in the UK, the increasing dominance of glyphosate as the herbicide of choice or (more likely) the technical expertise of the Editorial Board. By 2005 herbicide papers totaled 11 and in 2018 there were five (not including those in the Glyphosate Special Issue which contained seven).

The numbers for fungicide articles in the same years were four for 1990, four for 2005 and only two for 2018. Insecticides numbers in these years were seven for 1990 (the first being on DDT by Busvine), 10 for 2005 and five for 2018.

I admit to being surprised at the low numbers of article published in the crop protection area, but public health and animal health numbers are even lower being 2, 0 and 0 and 4, 4 and 3 (all three on rat eradication).

So what topics dominated over the 28 years of publication? This very brief survey suggests that there are many aspects to crop protection and animal and public health which have been addressed throughout the history of *Outlooks* and there has been no great change in the topics reported with the possible exception of more articles from and about the less developed world. This is not a bad thing, but the key factor is the maintenance of balance and scientific integrity – for which I have to thank my hard working Editorial Board.

Topics that have appeared recently within the crop protection press include a USDA report on the voluntary sampling of foods representing geographically about 50% of the US population and major agricultural areas. The foods include imports and those labelled as organic. Samples were collected at points close to consumer purchase, like warehouse distribution centres and handled as recommended, washed gently in water for about 20 seconds. The 521 pesticides and 21 environmental contaminants to be identified and the commodities included are determined by the EPA and take into account "types and amounts of food consumed by infants and children." In 2017, they looked at 10,541 samples of food, 83% fresh and processed fruits and vegetables, 7% milk, 7% bottled water and 3% honey. US samples predominated at 72.4%, 26% were imported, and the rest were mixed or of unknown origin. Laboratory methods were "geared to detect the lowest possible levels of pesticide residues, even when those levels were well below the tolerances established by EPA." In 2017, over 99% of the samples tested had residues well below these tolerances with 53% having no detectable pesticide residue. Residues exceeding tolerance were found in 0.59% of samples reasonably well distributed between domestic and imported sources. Residues with no established tolerance were found in 3.3% of samples again well distributed between domestic and imported sources. "The data reported corroborate that residues found in agricultural products sampled are at levels that do not pose risk to consumers' health and are safe according to EPA and FDA." Good news, but who knows about it? (Source: USDA Annual Pesticide Data Program 2017.)

As the New Year starts newspapers are full of calendars of last year's events and predictions (many tongue in cheek) of what we might expect for 2019. Traditionally, I have always avoided this approach as my highs may well be another reader's lows and what I dream of may be considered nightmares by others.

I have often written about the general public's lack of understanding of science and have been persuaded more and more that much of this is driven by social media – a system whereby any fool (or wise man – though these are sadly few in number) can espouse a belief which is rarely based in scientific fact but which is a 'pet theory'. What damage can this do, you may well ask. I do remember reading a very lengthy review that claimed that the use of glyphosate as a wheat desiccant had led to a massive increase in celiac disease. This reminded me of a case beautifully portrayed by Sir Colin Berry where he showed perfect correlation between the number of storks and the number of live births in Poland. That you can plot two

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variables and show these clearly unrelated items show a close correlation is not a condemnation of statistics, it is a demonstration of poor science, poor judgement, poor interpretation and poor understanding of the natural world. I was once told by a distinguished statistician that if you have to use statistics to show a relationship, there probably is no relationship.

Talking about statistics, a recent report published in the *Annals of Internal Medicine* concluded that researchers often make "inappropriate requests" to statisticians. By "inappropriate," the authors were not referring to accidental requests for incorrect statistical analyses; instead, they were referring to requests for unscrupulous data manipulation or even fraud. The authors surveyed 522 consulting biostatisticians and received sufficient responses from 390. Then, they constructed a table that ranked requests by level of inappropriateness. For instance, at the very top is "falsify the statistical significance to support a desired result," which is outright fraud. At the bottom is "do not show plot because it did not show as strong an effect as had been hoped," which is only slightly fraudulent.

The authors reported how often the biostatisticians estimated that they received such requests over the past five years. The worst offense (i.e., being asked to fake statistical significance) occurred to 3% of the survey respondents. Another 7% reported being asked to change data, and 24% said they were asked to remove or alter data. Unequivocally, that is a request to commit scientific fraud. Of the less serious offenses, 55% of biostatisticians said that they received requests to underreport non-significant results.

It is quite remarkable that a scientist would have the audacity to ask another professional to fudge data. While there is simply no excuse for the flagrant offenses (e.g., falsifying statistical significance), some of the other lesser offenses may not reflect an intention to commit fraud, but ignorance. Scientists often are not very good at statistics, and they may make inappropriate requests simply because they do not know any better. This study should serve as a reminder that the ongoing reproducibility crisis may have, at least in part, a more sinister explanation. (Source: Min Qi Wang, Alice F. Yan, Ralph V. Katz. 2018. Researcher Requests for Inappropriate Analysis and Reporting: A U.S. Survey of Consulting Biostatisticians. *Ann Intern Med* **169**(8): 554–558. DOI: 10.7326/M18-1230).

Many of us continue to contest the claims of the so called Greens. I am sure that nearly all of us want to see an environmentally safe world that produces enough food to feed an ever increasing population from diminishing agricultural land. One stance here is to argue that all chemical inputs are bad and are damaging the environment irreversibly (for example – see www.panna.org '*PAN North America is one of five regional centers worldwide. We link local and international consumer, labor, health, environment and agriculture groups into an international citizens' action network. Together, we challenge the global proliferation of pesticides, defend basic rights to health and environmental quality, and work to ensure the transition to a just and viable food system.*') No one could argue with the recognition of the need for basic rights to health and environmental quality, but the link to pesticide use is tenuous and there is never any consideration of the impact of reduced yields on human health as a consequence of famine.

So what else has caught my attention in 2018? The biggest example of the impact of a lack of the understanding of science has to be the California judgement against glyphosate in a case brought by Dewayne Johnson claiming that glyphosate gave him non-Hodgkin's lymphoma (NHL), a cancer that occurs when the immune system goes awry. Even the judge acknowledged that there was no evidence of harm. Yet, trial lawyers manipulated a jury's emotions and the public's misunderstanding of science to score another jackpot verdict awarding the plaintiff $289 million. The verdict is under challenge. However, Bayer failed to persuade a California state judge to set aside a jury's verdict in the first trial over allegations that its Roundup weed killer causes cancer, but the judge said damages should be 'slashed' to $78.6 million from $289 million. San Francisco Superior Court Judge Suzanne Ramos Bolanos rejected Bayer's arguments that the jury did not have any basis to conclude that the herbicide caused a former school groundskeeper's cancer. The decision is not a legal precedent for thousands of related lawsuits across the US, but it will encourage plaintiffs to press forward with their claims. Bayer said it plans to appeal the ruling. This case interests me for several reasons the first being that I have used glyphosate in my garden for many years and intend to continue using it – if I can find a shop that will sell it to a home owner. The second is that my best man died of NHL. He was an accountant and only came across pesticides when we met and these were only those found in my clothes and, being a very careful applicator, these levels were undetectable. Would the California jury find me guilty of killing my very good friend? In the current situation who knows? And now increasingly politicians are jumping on the bandwagon of supporting anything their voters believe – even if these beliefs are fantasy, misinterpretations or just lies.

A recent entry in *American Council on Science and Health (3rd December 2018) asked* 'How can you identify a scientifically ignorant person?' Ask them if they are concerned about the health effects of GMOs. If the answer is yes, it is likely that the respondent has no scientific understanding, training or knowledge according to Pew, which just released the results of a survey that showed that 49% of Americans said GMOs are bad for your health. The survey finds a 10-percentage-point increase in the share of adults who say foods with GM ingredients are worse for one's health from a 2016 Pew Research Center survey, when the share was 39%. The increase in concern has come primarily among those with low levels of science knowledge; there has been no shift in this belief among those with high levels of science knowledge (based on a nine-item index of factual knowledge across a range of topics). It is argued that this shows that the scientifically ignorant are driving society's science debates.

A few years ago, a study found that people who were uninterested in science were the ones who were most fearful of it. They "believe that science causes more problems than it solves, believe that humans should not tamper with nature, and feel that technology advances too quickly for them to understand." One of the biggest threats to science comes from a society that remains wilfully ignorant about it. How can we educate people about science if they do not want to be educated? This point is demonstrated by such things as conversations with friends at the dinner table. When is science

ever a topic of these conversations and how many individuals wear their dislike and lack of understanding of things scientific as a 'badge of honour'? Meanwhile anyone stating a lack of appreciation of art or literature is deemed ignorant with no soul. Even worse, there are plenty of people who are willing to make a quick buck by cashing in on the public's ignorance. That is why products like gluten-free water and GMO-free salt are on store shelves (in the USA). The makers of those products know full well that they are deceiving a public that largely does not know what gluten and GMOs actually are. And because junk science itself has become a profitable industry, there is little financial incentive to educate customers properly. It is simply a truth of human nature that we are far more motivated by fear than by gratitude. That is why political campaigns are almost universally about how horrible the other candidate is. It is much easier to get a person to vote against someone (out of fear) rather than for someone (out of gratitude). The bottom line, then, is that science debates are actually a struggle against human nature. And that is one tough thing to overcome, but it can be done.

Finally, thank you for reading *Outlooks on Pest Management*. Please remember that there is always an opportunity to write in to support or challenge anything that you read via the *Letters to the Editor* section (sadly undersubscribed). I do hope that 2019 is good to you and that all governments around the world begin to govern for the benefit of all.

PATHOGEN POPULATION BIOLOGY RESEARCH CAN REDUCE INTERNATIONAL THREATS TO TREE HEALTH POSED BY INVASIVE FUNGI

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Trees contribute significantly to the benefit of all living species, but are under a great threat from a number of sources including invasive pathogenic fungi. The nature of the threat of invasive pathogens is considered with examples from three major tree diseases

Key words: Ash dieback, *Fraxinus* spp, *Hymenoscyphus* species, Dutch elm disease, *Ulmus* spp., *Ophiostoma ulmi* and *O. novo-ulmi*, Dothistroma Needle Blight, *Pinus* spp., *Dothistroma* spp.

Kevin King

Introduction

Humankind owes much to trees, given their major role in sequestering carbon and providing oxygen, sugars and much of the energy on which ourselves and terrestrial ecosystems depend. Trees and forests are important culturally, economically, environmentally and socially. And yet, despite this, trees throughout the world are currently facing an increasing number of serious challenges. On a global scale, Curtis *et al*. (2018) report most forest loss is due to commodity driven deforestation through permanent conversion to non-forest land uses including agriculture (e.g. palm oil production), energy production and mining. The other main drivers of global forest loss, that might instead be considered less permanent and associated with subsequent regrowth, include forestry, shifting agriculture and wildfire. Additional threats to forests include those posed by climate change, and invasive biotic agents such as insect pests and pathogens. Most new tree disease outbreaks are due to introduction events (Anderson *et al*., 2004), with a potential pathogen introduced from their endemic centres of origin (where they generally cause little or no disease on their plant host due to long-term coevolution) into a new geographic location, in which a naïve host has not previously been exposed and can thus be highly susceptible. The incidence of such 'new encounter' diseases is increasing at an unprecedented rate due to globalisation with increased international trade in plants and travel (cf. Brasier, 2008), a scenario potentially exacerbated by a changing climate better suited to establishment of a pathogen once introduced.

Identification of the centres of origin of fungal pathogens can be important for several reasons. First, given that the original host-fungus interaction will have typically stabilised over long periods of time, such geographic regions could be useful sources of host genetic resistance. Moreover, the longer time periods involved will have likely resulted in greater genetic diversity accruing in such endemic populations. More diverse pathogen populations have greater evolutionary potential, with increased genetic variation available for response to environmental change (McDonald & Linde, 2002). This could enable host tolerance to be overcome, unexpected 'jumps' onto new hosts, increased risk of fungicide resistance, and better adaptability to changing environmental conditions (e.g. temperature). Thus, strategies to reduce introduction of additional genetic variation from source to sink regions can reduce tree health threats.

In this article, such introduction events are considered in the context of three devastating tree diseases, namely ash dieback, Dutch Elm Disease (DED) and Dothistroma Needle Blight (DNB, mainly on pine). On all these tree hosts, multiple closely-related fungal species have now been associated with each of these different diseases. Such related species are often morphologically very similar or even indistinguishable by eye, and consequently this can result in taxonomic confusion and species misidentification, leading to delayed diagnosis of the true causal agent of a given disease outbreak. Research into such related species is important as they might pose very different plant health threats that require distinct disease management strategies. These differences might relate to pathogenicity, geographic distribution, host range, effectiveness of host resistance, sensitivity to fungicides, temperature optima, reproductive strategy and so on. Furthermore, when related fungal species come into physical contact with each other after a long period of separation, for instance via an introduction event, various outcomes are possible including: (1) replacement (and possible extinction) of one species by the other; (2) coexistence of the species; or (3) cross-species hybridisation.

The remainder of this article focuses, using three major tree disease case histories, on how fundamental research on pathogen biology can provide new insights into the genetic

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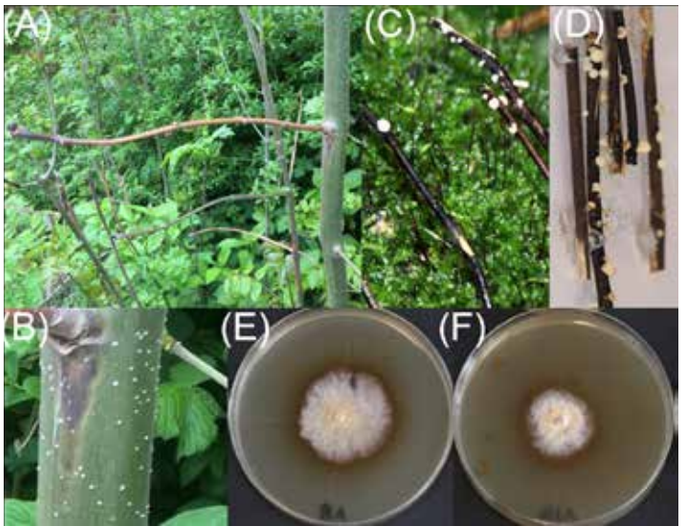

Figure 1. Ash dieback disease symptoms on young European ash trees with (A) withered and dying shoots and (B) a close-up of a stem with purple diamond-shaped stem lesion. (C) Blackened sclerotized ash rachises with white apothecia of the ash dieback pathogen *Hymenoscyphus fraxineus*. (D) Ash rachises with patchy less extensive sclerotization and white apothecia of non-pathogenic *H. albidus*. (E, F) Isolates of *H. fraxineus* and *H. albidus* respectively on agar plates. Figure (1C) is crown copyright. Figure (1D) courtesy of Dr J. Webber and Prof C. Brasier.

structure of related pathogen populations that can be usefully applied to reduce the threat to tree health posed by invasive fungal species

Case history 1 – Ash Dieback

Symptoms of ash dieback disease (Figure 1) were first seen in Poland in the early 1990s. Subsequently, westward spread of the disease was observed across Europe, and in early 2012 it was first reported in the UK (Gross *et al*., 2014). Typical ash dieback symptoms include blackened foliage and diamond-shaped, typically purple stem lesions (Figure 1). The disease results in reduced tree vigour and, in particularly severe cases, tree death may occur. In Europe two closely-related *Hymenoscyphus* species, readily distinguished by comparison of various gene sequences, are presently known to occur on European ash (*Fraxinus excelsior*) and narrow leaved ash (*F. angustifolia*) – *H. albidus* (a non-pathogenic fungus reported in Europe for >150 years) and *H. fraxineus* (a recently arrived alien invasive species from Asia that is highly pathogenic).

Initially in Europe, the sexual fruiting bodies (apothecia) of *H. fraxineus* were at first mistaken for those of *H. albidus*. This is because apothecia of the two species are morphologically very similar (pure white on blackened sclerotized rachises) and cannot readily be discriminated by eye (Figure 1 C,D), although there are some differences (e.g. *H. fraxineus* possesses croziers at the base of the apothecia, and overall produces greater numbers of larger apothecia) (Baral & Bemmann, 2014). The ash dieback fungus *H. fraxineus* was only formally recognised, based on molecular analyses, as a new species by Queloz *et al*. (2011). Unfortunately, two *H. albidus* apothecial herbarium specimens (collected from Switzerland in 1978 and 1987) in the study were initially incorrectly assigned (based on DNA sequence analyses) to *H. fraxineus*, mistakenly indicating the latter species to have been resident in Europe for several decades as opposed to a recently arrived non-native invasive. Interestingly, *H. albidus* appears to be outcompeted by *H. fraxineus* on its ash rachis niche in Europe (cf. Baral & Bemmann, 2014), although whether it is at risk of at least local extinction or might perhaps persist to some extent is unclear (King & Webber, 2016).

It is now widely considered that *H. fraxineus* originates from Asia, where it occurs as a mostly harmless endophyte on ash in China, Japan, Korea and Russia (cf. Orton *et al*., 2018). Such knowledge regarding the origins of a pathogen can help inform disease management strategies. For example, long-term coevolution between *H. fraxineus* and its ash hosts has likely occurred in Asia, suggesting the region might have sources of resistance that could be usefully deployed into breeding programmes. Moreover, several recent studies have revealed that Asian *H. fraxineus* populations have much greater genotypic diversity than European populations (cf. Orton *et al*., 2018). Additional introductions of novel *H. fraxineus* genotypes into Europe could therefore increase the genetic diversity, and hence evolutionary potential of the pathogen population in Europe. This is of concern, not only due to the potentially increased threat to ash, but also the potential threat to other related tree species in the family Oleaceae; indeed, in the UK in 2018, *H. fraxineus* was confirmed for the first time on a small number of diseased trees of three other non-ash species (mock privet, narrow-leaved mock privet, fringetree) (Forestry Research website, accessed November 2018). Furthermore, four other *Hymenoscyphus* species that are closely related to *H. fraxineus* / *H. albidus* have also recently been identified in Asia, including in China (*H. albidoides* on quassia), Japan (*H. linearis* on ash), and Korea (*H. koreanus* and *H. occultus* on Chinese ash) (cf. King & Webber, 2016). Indeed, yet another closely related species, *H. pusillus*, has been identified very recently in Poland on green ash (Kowalski & Bilański, 2018). Accidental introduction of related *Hymenoscyphus* species into Europe should be avoided given the possible plant health implications. Finally, although hypovirulence-inducing mycoviruses have previously been applied as biocontrol agents for other major tree diseases such as chestnut blight, *Cryphonectria*, a similar approach for ash dieback control in Europe appears unlikely to be successful given that mycoviruses associated with *H. fraxineus* (e.g. HfMV1) already appear prevalent across various European pathogen populations without any apparent adverse impact on the fungus (e.g. Orton *et al*., 2018).

Case history 2 – Dutch Elm Disease

Dutch elm disease (DED), so named because much of the early research on the disease was undertaken in the Netherlands, is an important vascular wilt pathogen of elms (*Ulmus*). Disease symptoms include yellowing and browning of leaves which are then lost with accompanying reduction in crown area, and mortality of seriously diseased trees occurring within a year (Figure 2). The related pathogen species responsible for DED outbreaks, most likely of Asian origin (Brasier, 1990), are *Ophiostoma ulmi* and *O. novo-ulmi* (although the latter

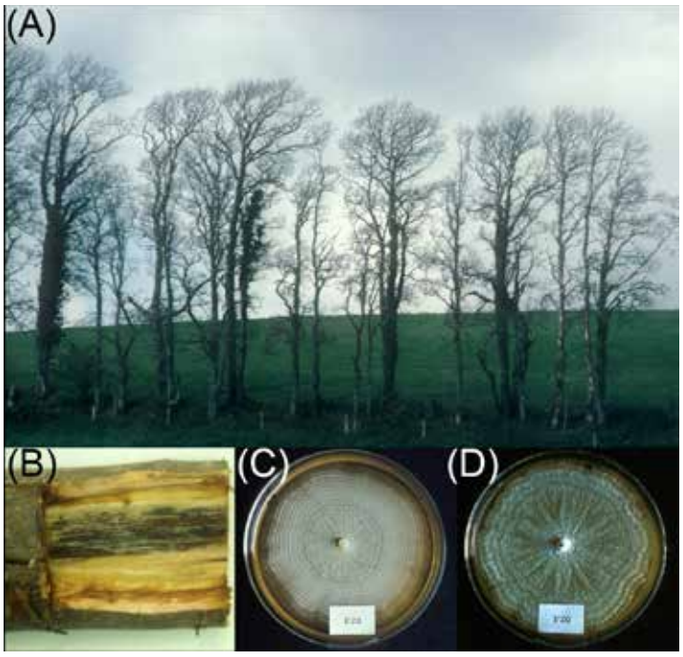

Figure 2. Dutch elm disease, caused by the fungal pathogens *Ophiostoma ulmi* / *O. novo-ulmi*. (A) The severe impact of the disease on elm trees and (B) symptomatic twigs with outer bark removed to reveal streaks of dark brown staining of the inner wood. (C, D) Fungal isolates of *O. ulmi* and *O. novo-ulmi* respectively on agar media. Figures (2A, B) are crown copyright. Figures (2C, D) courtesy of Prof C. Brasier.

of these is itself comprised of two distinct subspecies) and are vectored from tree to tree by bark beetles. Multiple DED pandemics have occurred in the last century with millions of elm trees killed across both Europe and North America (a sequence of events comprehensively reviewed by Brasier & Buck (2001)). However, underlying this environmental devastation is a fascinating case history of fungal warfare between related fungal pathogens, featuring introductions, invasions, displacements and extinctions, along with the emergence of novel variants through hybridisation.

The first European DED pandemic, caused by *O. ulmi*, was reported in 1910 but had declined by ~1940 (by which time 10–40% of elms in many European countries were dead), most likely due to hypovirulence induced by deleterious mycoviruses (cf. Brasier & Buck, 2001). Later in the 1940s a second more severe DED pandemic outbreak in Europe began, but was this time caused by invasive *O. novo-ulmi*. At first it was not realised that another related but distinct invasive pathogen was the true cause of this later outbreak, and the causal agent was misidentified as *O. ulmi*. It was only later that two distinct pathogen groups (termed 'aggressive' and 'non-aggressive') were distinguished (Gibbs & Brasier, 1973), and later still until *O. novo-ulmi* was formally recognised as a new species (Brasier, 1991). Following the introduction of *O. novo-ulmi* into Europe, *O. ulmi* rapidly declined (by ~10% each year) before becoming virtually extinct there (although there is evidence for genetic exchange and rare interspecific hybridisation between *O. ulmi* and *O. novo-ulmi*, e.g. Brasier *et al*., (1998)). Interestingly, two distinct *O. novo-ulmi* subspecies (subsp.) were involved in this second European invasion, with subsp. *novo-ulmi* entering from the east (Romania/Maldova) in the 1940s, and subsp. *americana* arriving from the west (UK) in the 1960s (cf. Brasier & Buck 2001). These two *O. novo-ulmi* subspecies subsequently spread across Europe, and in 'overlap zones' readily hybridised yielding hybrid offspring that were just as pathogenically fit as their 'pure' subspecies parents (e.g. Brasier & Kirk, 2010).

Pathogen population biology research has provided several insights into management of DED. For example, in field expeditions in the Himalayas in 1993, a new related *Ophiostom*a species was discovered and named *O. himal-ulmi* (Brasier & Mehrotra, 1995). This new species is highly pathogenic to elms in experimental testing, but little or no disease symptoms were observed in elm disease surveys in the Himalayas. This stable fungus-host coexistence suggests that *O. himal-ulmi* may be endemic to elms in the region having coevolved over a long period of time. Thus, the region might be a useful source of elm host resistance or biological control agents including deleterious mycoviruses (or d-factors) (Webber, 1993). The potential use of such d-factors in DED management is more likely to be successful in pathogen populations that currently have more limited d-factor diversity and that are comprised of only a single or limited number of vegetative compatibility groups (i.e. greater chance of successful hyphal anastomosis and thus d-factor transfer).

Case history 3 – Dothistroma Needle Blight

Dothistroma needle blight, disease has emerged to become the most important disease of pine trees (*Pinus* spp.) worldwide (Drenkhan *et al*., 2017). The origins of the DNB pathogens are not conclusively known but it has been postulated that they might be endemic to pine in the northern hemisphere (cf. Adamson *et al*., 2017). The disease causes needle defoliation and a corresponding reduction in yield, and in severe cases even tree mortality (Figure 3). DNB previously used to be referred to as red band needle blight (Barnes *et al*., 2004), given the red/brown lesions that developed on the sympto-

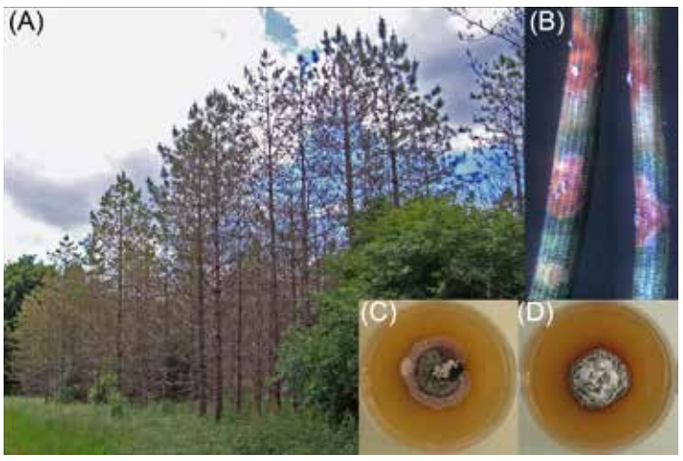

Figure 3. Dothistroma needle blight, caused by the fungal pathogens *Dothistroma pini* / *D. septosporum*, with (A) extensive defoliation of pine trees and (B) symptoms on pine needles that can include red bands and tiny black fungal fruiting bodies. (C, D) Isolates of *D. pini* and *D. septosporum* **respectively** on agar media. Figures (3A, B) are crown copyright. Figures (3C, D) courtesy of Dr I. Barnes.

matic needles (Figure 3), although these are normally green earlier on in the infection process. Drivers of increased DNB outbreaks have been suggested to include introduction events of the causal pathogens on infected planting material as well as changing climatic conditions.

Prior to 2004, the taxonomic status of the causal *Dothistroma* agent had been "beset with confusion" and three different morphological 'varieties' of *D. septosporum* had been proposed that could be discriminated based on differences in conidial size. However, this classification was rejected by Barnes *et al*. (2004) who found that, based on multilocus phylogenetic analysis, the disease was in fact caused by two related pathogen species, namely *D. septosporum* and *D. pini*. Both *Dothistroma* species are now known to co-occur in several European countries and the USA, and can coexist on the same DNB symptomatic trees and even needles (Drenkhan *et al*., 2017). Both species are thought to be dispersed mainly by rain-splash of asexual inoculum. A sexual stage producing wind-dispersed ascospores has been identified for *D. septosporum,* although it is found infrequently and only in some parts of the world; but not *D. pini* (Groenewald *et al*. 2002); for both *Dothistroma* species, however, both *MAT1-1* and *MAT1-2* genotypes have been identified suggesting similar heterothallic mating type gene organisation (Groenewald *et al*., 2007).

The genetic structures of DNB pathogen populations have now been characterised for numerous countries and such work suggests a range of practical DNB disease management strategies. Firstly, *D. septosporum* is globally more widespread (confirmed in Africa, Asia, Europe, Oceania, across the Americas) than *D. pini* (only in Europe and North America), hence additional introductions of *D. pini* into other regions should be prevented (Drenkhan *et al*., 2017). Secondly, different 'races' of *D. septosporum* have recently been described and care should be taken to prevent transfer of these between different geographic regions. Thirdly, *D. septosporum* populations in several countries in the southern hemisphere (e.g. Australia, Chile and New Zealand) have been found to be comprised of a single *MAT1-2* mating type, and in these countries no sexual stage has yet been identified for this species. Given that both mating types are required for sexual reproduction to occur, preventing introduction of the *D. septosporum MAT1-1* genotype into these regions would essentially 'lock' pathogen populations resident there into exclusively asexual reproduction, blocking any increase in evolutionary potential associated with a sexual stage (Groenewald *et al*., 2007). Fourthly, identification of the centre of origins of the *Dothistroma* species might yield useful sources of host resistance that could be incorporated into breeding programmes. Lastly, *D. septosporum* has recently been found to also harbor a mycovirus that might, subject to additional research, be of some use in biological control of DNB.

Concluding remarks

Fundamental research into plant pathogen population biology can be applied to help reduce / manage biotic threats to tree health. Knowledge gained in such research can also be used in the development of new molecular diagnostics (e.g. PCR or loop-mediated isothermal amplification (LAMP)) that can rapidly target specific pathogen genotypes and hence reduce the risk of accidental introduction events. The scenario described here with examples from tree pathology is also directly relevant to reducing risks to animal and plant health posed by other diseases involving complexes of fungal species, (see Table 1), including those causing diseases of animals (including humans), arable crops, fruit, ornamentals and vegetables. In many of the cases listed there are significant differences between the related pathogens in their pathogenesis, epidemiology and sensitivity to fungicides, so that accurate discrimination is needed to ensure optimum disease control.

Table 1. Examples of related fungal pathogens causing diseases of arable crops, vegetables, fruits, horticultural ornamentals, amphibians and humans.

Main hosts	Common disease name	Related pathogen species responsible
Cereals (wheat, barley, rye)	Eyespot, strawbreaker	*Oculimacula yallundae, O. acuformis*
Brassicas (oilseed rape)	Phoma stem canker	*Leptosphaeria maculans, L. biglobosa*
Vegetables	Sclerotinia rot	*Sclerotinia sclerotiorum, S. subarctica* (provisional name)
Soft fruits and vegetables	Grey mould	*Botrytis* species (e.g. *B. cinerea, B. fragariae* + others)
Fruit (Bananas)	Sigatoka leaf diseases	*Mycosphaerella musicola, M. fijiensis, M. eumusae*
Boxwood ornamentals	Boxwood blight	*Calonectria pseudonaviculata, C. henricotiae*
Amphibians	Chytridiomycosis	*Batrachochytrium dendrobatidis, B. salamandrivorans*
Humans	Aspergillosis	*A. fumigatus, A. lentulus + others*

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Kevin King is a post-doctoral plant pathologist employed at Rothamsted Research, UK. His PhD (2013) focused on further understanding the genetics and epidemiology of the barley leaf scald pathogen *Rhynchosporium commune*. From 2013–15, he worked at Forest Research (UK) on the major tree diseases 'Chalara' ash dieback and sudden larch death. He then re-joined Rothamsted in the Department of Biointeractions and Crop Protection, and his current projects include development of an automated spore trap for real-time monitoring of pathogens in the air, and investigating shifts in fungicide sensitivity in pathogens of arable crops.

Similar articles that appeared in *Outlooks on Pest Management* include – **2010 21(2) 64;** 2012 **23(2)** 72; 2014 **25(3)** 230

Soybeans Rise on US-China Trade Hopes

Chicago soybean futures edged up as investors saw signs of thawing relations between Washington, DC, and Beijing in the trade dispute that has disrupted flows of the most valuable US agricultural export to China, according to a Reuters report. Soybeans were poised to end 2018 with an annual decline after the plunge in exports to China coupled with big harvests in the United States and Brazil weighed on prices. A resumption in Chinese imports of US soybeans in December as part of a negotiated truce between the world's two largest economies has helped Chicago prices rebound from a decade low in September. Wheat, in contrast, was set to notch up its biggest annual rise since 2012 after a sharp fall in production in major exporters Russia, the European Union and Australia, making it one of the biggest gainers in commodity markets this year. (For more information: TheGazette.com)

Europe

Stockholm University Scientists Discover Gene that Helps Submerged Plants

A study from Stockholm University reveals that special genes keep plants from withering, staying healthy despite the lack of oxygen when they are underwater for extended periods of time. Sylvia Lindberg, professor at Stockholm University, looked at how plants become more resistant to oxygen deficiency. During this period, special genes signal danger and the plant activates other genes to help defend itself. One of these genes is PLD, which forms the enzyme phospholipase D. Until now, the key role it plays in the plants' oxygen deficiency signal systems was unknown. Lindberg and her research team used mutant plants lacking the potentially protective gene to see how they would perform during a simulated flood. The leaves of the mutant plants turned yellow and died, meaning that the gene plays a role in keeping the plants in good condition. Some of the mutant plants produced less calcium and less phosphatidic acid, substances that signal stress in plants. (For more information: www.su.se/english/research/research-news)

Herbicides

BASF registers two new herbicides

BASF's new herbicides Luximo and Tirexor (protoporphyrinogen oxidase (PPO) inhibitor) are being registered in Australia and the EU. Luximo contains an active ingredient that offers pre-emergence, residual control against a wide range of grasses such as ryegrass (*Lolium* spp.) and blackgrass (*Alopecurus myosuroides*) in winter cereals. It exhibits a novel mode of action (MoA) to address resistance. Tirexor is a fast acting herbicide against weeds that are resistant to PPO including ragweed (*Ambrosia* spp.) and pigweed (*Amaranthus* spp.) species. The product is expected to be used on soybeans, corn, small grain cereals, oil palm, pulse crops, tree fruit and nut crops, among others. Subject to regulatory clearance, BASF anticipates to launch Luximo-based products by 2021 in the UK and 2020 in Australia at the earliest. The company also expects the Australian launch of Tirexor-based formulations from 2020 onwards. (For more information: BASF SE, D-67056 Ludwigshafen, Germany; Tel: +49 (0) 621 600; Website: http://www.basf.com) **CBNB**

Insecticides

ANSES will withdraw AMMs from metam-sodium

The National Agency for Food Safety, Environment and Labor (ANSES) in France aims to remove all marketing approvals for metam-sodium products due to human health and environment issues. These products are utilised in horticulture or gardening to disinfect soils. **CBNB**

North America

USDA to Release Final 'Bioengineered' Food Labelling Standard

After a comment period of two years, the rule that requires companies to label genetically modified foods is being finalised. The White House Office of Management and Budget approved the Obama-era legislation industry site IEG Policy reports, marking its last step before publishing. According to the US Department of Agriculture, the new standard is expected to increase consumer confidence and understanding, but will not affect any advantages in human health or the environment. When the proposal was released, several environmental groups commented that the design and language might confuse the consumers. Thus, a new and improved design was proposed to be starting in 2020. (For more information: https://geneticliteracyproject.org)

Fungicides

EPA Approves Arysta LifeScience's New Fungicide

Arysta LifeScience recently announced that the US Environmental Protection Agency (EPA) has approved ZOLERA FX Fungicide for use in wheat production. The fungicide combines fluoxastrobin, a fast-acting, highly systemic strobilurin, with tetraconazole, a highly systemic triazole. In both early season and flag leaf applications, it is effective against Stripe rust (*Puccinia striiformis*), Leaf rust (*P. triticina*), Tan spot (*Pyrenophora tritici-repentis*), Spot blotch (*Cochliobolus sativus*), Septoria leaf and glume blotch (*Stagonospora nodorum*) and other diseases. Featuring the best plant uptake and mobility within the plant for maximum plant coverage, ZOLERA FX brings multiple modes of action in a single application for stronger plant health plus preventative and curative disease control.

FMC Gets EPA Approval for Lucento Fungicide

FMC Corp. has reported that the US Environmental Protection Agency has granted registration for Lucento fungicide in corn, soybeans, peanuts, sugarbeet and wheat. Lucento fungicide is a new tool that provides long-lasting preventive and curative activity for a wide range of foliar diseases and reduces dependence on strobilurins, for the 2019 growing season. Lucento fungicide encompasses two separate modes of action (flutriafol, FRAC Group 3, and bixafen, FRAC Group 7) to deliver broad-spectrum disease effi-

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cacy, fungicide resistance management, plant mobility and long-lasting residual control. Lucento fungicide is the only proven tank-mix of SDHI bixafen and FMC-patented flutriafol active ingredients (AI), offering novel disease control not previously available to US row crop growers. Additionally, Lucento fungicide is very active on diseases that have developed resistance to strobilurins, like late leaf spot in peanuts (*Phaeoisariopsis personata*) and frogeye leaf spot in soybeans (*Cercospora sojina*). (For additional information: https://www.agprofessional.com/article/fmc-introduce-lucento-fungicide)

Herbicides

Corteva Details Enlist E3, Qrome Corn Launches

Corteva Agriscience, Agriculture Division of DowDuPont, has announced plans for commercial launches of Enlist E3 soybeans in Brazil, Canada and the United States, beginning in 2019. The company also announced plans to expand the launch of Qrome corn products across the US Corn Belt. Enlist E3 soybeans incorporate advanced herbicide tolerance through three modes of action and enable use of its proprietary Enlist One (2,4-D choline) and Enlist Duo (2,4-D choline plus glyphosate) herbicides to provide more complete solutions to farmers. (For more information: CropLife.com)

EPA green-lights dicamba until 2020

On 31 October 2018, the US Environmental Protection Agency (EPA) reported that farmers in the country may continue using the herbicide dicamba on cotton and soybeans genetically engineered to tolerate the chemical, until 20 December 2020. It added new restrictions on the application of the weed killer to growing plants to avoid the chemical from drifting onto nearby properties. Dicamba drift has been a huge concern since it was first approved by EPA for use on cotton and soybeans in 2016. EPA implemented some restrictions to prevent this phenomenon in 2017 but state agencies continue investigating criticisms again in 2018. **CBNB**

US judge reduces punitive fine at Bayer glyphosate trial

A California judge decreased by over $200 M a jury verdict associating Bayer AG's Roundup glyphosate weedkiller to cancer but maintained the jury's ruling that the firm acted with malice. The San Francisco Superior Court Judge stated that the $250 M in punitive damages awarded by the jury must be reduced to match the $39.25 M in compensatory damages that the jury determined appropriate. No new trial is needed if the plaintiff agrees to the reduction by 7 December 2018. However, Bayer already announced its intention to appeal as it is convinced that the ruling contradicts the proof presented in the case. **CBNB**

US court ruling carries risks for glyphosate

The US court judge has decided to support a jury verdict stating that the Roundup weed killer formulated by Monsanto and now owned by Bayer is carcinogenic. This move has caused greater risks to glyphosate and diethanolamines (DEA) demand. The verdict may affect future studies if it remains, with over 8000 other complainants in the US who also claim a connection between cancer and the formulation. Bayer's subsidiary Monsanto has appealed the verdict in favour of a cancer patient from California, US, who said the firm's Roundup weed killer was a key factor in his cancer. **CBNB**

Bayer Posts More Than 300 Glyphosate Safety Studies

Bayer marked the first anniversary of its Transparency Initiative, designed to enhance trust in the science behind crop protection products. As another important milestone in the company's efforts to make science more accessible, Bayer is making available more than 300 study summaries on the safety of glyphosate on its dedicated transparency platform. Similar to the other substances included within its Transparency Initiative, Bayer is focusing on safety studies submitted under the European Union (EU) substance authorisation process for plant protection products. On the website you can find the study summaries for studies on residues and metabolism (18), environmental fate (32), toxicology (180), and ecotoxicology (88) on the active substance as well as representative formulations. More information can be found on the FAQ page. Access to the much more extensive underlying safety study reports will be enabled in 2019; this will include those owned by Bayer and submitted for the review that led to the European substance authorisation renewal decision in December 2017. Over the last 40 years, glyphosate and glyphosate-based formulations have been extensively evaluated for human health and safety. Most of this scientific research on glyphosate was conducted by independent researchers. (For more information: https://www.cropscience-transparency.bayer.com For additional research conducted on glyphosate, visit the European Food Safety Authority (EFSA), the US EPA, and the glyphosate task force. Background information on glyphosate and its history as a safe and efficient weed control tool for farmers around the world is also available there)

Rest of the World

Verdeca receives approval to integrate HB4 drought tolerant soybeans with herbicide tolerance in Argentina

Verdeca, a joint venture between Arcadia Biosciences Inc and Bioceres SA, announced on 29 October 2018 that it has received approval in Argentina for its HB4 drought tolerant trait stacked with herbicide tolerant traits in soybeans. The approval allows Verdeca to incorporate tolerance to both glyphosate and glufosinate-ammonium into the trait. Verdeca's HB4 trait has already been approved in Argentina and by the US Food & Drug Administration. Regulatory submissions are currently under consideration by the US Department of Agriculture, as well as in China, Brazil, Paraguay and Uruguay. Commercial launch of the HB4 trait is contingent upon China's regulatory approval, which is expected by end-2019. In the meantime, this regulatory approval of the HB4-herbicide tolerance stack will allow broader on-farm testing. (For

more information: https://www.arcadiabio.com) **CBNB**

Australian OGTR Approves Field Trial of GM Canola

Australia's Office of the Gene Technology Regulator (OGTR) has issued license DIR 164 to Monsanto Australia Proprietary Limited, for the limited and controlled release (field trial) of canola genetically modified (GM) for herbicide tolerance. The field trial (License Application DIR 164) is authorised to take place on January 2020 to January 2024, in up to 15 sites per year for the first two years and 20 sites for the third and fourth years, to be selected from 140 possible local government areas in New South Wales, Queensland, South Australia, Victoria and Western Australia. The field trial will assess agronomic performance of the GM canola in all canola growing areas of Australia. The GM canola from this field trial will not be used for human food or animal feed. The final Risk Assessment and Risk Management Plan (RARMP) concludes that this field trial poses negligible risks to people and the environment and does not require specific risk treatment measures. The finalised RARMP, together with a summary of the RARMP, a set of Questions and Answers on this decision and a copy of the license, are available online from the DIR 164 page in the OGTR website.

Australian OGTR Receives License Application for Field Trial of GM Chickpea

The Australian Office of the Gene Technology Regulator (OGTR) has received a license application (DIR 166) from Queensland University of Technology to conduct a field trial of genetically modified (GM) chickpea with enhanced drought and other environmental stress tolerance. The trial is proposed to take place between July 2019 and December 2024, on a single site with a maximum area of 3 hectares. The trial site is located in the Tablelands Regional Council in Queensland. The trial would be subject to control measures that restrict the spread and persistence of the GM plants and their introduced genetic material. The GM chickpea would not be used for human food or animal feed. The OGTR is preparing a Risk Assessment and Risk Management Plan for the application which would be released for public comment and further advice from experts, agencies, and authorities in mid March 2019. There will be at least 30 days allowed for submission of comments. (For more information visit the DIR 166 page on www.ogtr.gov.au)

China Approves Corteva's Enlist E3 Soybeans

At long last, China has approved Corteva Agriscience's Enlist E3 soybeans for import, according to a recent Reuters report. China also approved four other GM crops for import, including Corteva's DP4114 Qrome corn, as well as the SYHT0H2 soybean developed by Bayer CropScience and Syngenta but now held by BASF. The other two newly approved products – BASF's RF3 canola and Bayer-owned Monsanto's glyphosate-tolerant MON 88302 canola – had been waiting six years for permission, Reuters said. (For more information: *CropLife.com*)

Punjab to ban sale of formulations with glyphosate

India's Punjab government has banned the sale of all glyphosate-containing formulations after the San Francisco court upheld the herbicide's carcinogenic effect in humans. On 23 October 2018, the State Agriculture Department released an order asking all pesticide producers, dealers and marketers not to commercialise formulations and concentrations of glyphosate and bring unused stock back to their suppliers. It also includes an order for licensing bodies to eliminate the entries for glyphosate from the licences they issue. The decision was recommended by the Central Insecticide Board and Registration Committee that only allows glyphosate use in tea gardens and non-cropped areas. **CBNB**

Verdeca receives approval to integrate HB4 drought tolerant soybeans with herbicide tolerance in Argentina

Verdeca, a joint venture between Arcadia Biosciences Inc and Bioceres SA, announced on 29 October 2018 that it has received approval in Argentina for its HB4 drought tolerant trait stacked with herbicide tolerant traits in soybeans. The approval allows Verdeca to incorporate tolerance to both glyphosate and glufosinate-ammonium into the trait. Verdeca's HB4 trait has already been approved in Argentina and by the US Food & Drug Administration. Regulatory submissions are currently under consideration by the US Department of Agriculture, as well as in China, Brazil, Paraguay and Uruguay. Commercial launch of the HB4 trait is contingent upon China's regulatory approval, which is expected by end-2019. In the meantime, this regulatory approval of the HB4-herbicide tolerance stack will allow broader on-farm testing. (For more information: https://www.arcadiabio.com) **CBNB**

***CBNB:** These abstracts were taken from Chemical Business NewsBase (CBNB) which is produced by Elsevier, E-mail: cbnb@elsevier.com, Website: http://www.ei.org/databases/cbnb.html

AN UPSURGE OF THE OLD WORLD DATE MITE (*OLIGONYCHUS AFRASIATICUS*) IN DATE PALM PLANTATIONS: POSSIBLE CAUSES AND MANAGEMENT OPTIONS

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Summary

In recent years, the date dust mite has emerged as a serious economic pest of date palm in many areas where it is cultivated. Damage loss due to mite infestation may reach 100% if management measures are not taken. This article investigates the reasons behind the upsurge of dust mite populations and the possible available options for its management in date palm groves.

Keywords: date palm, *Oligonychus afrasiaticus*, Kimri stage, mite infestation

Introduction

The old world date mite, *Oligonychus afrasiaticus* has become an important pest of immature date palm fruits in recent times. The dust mite attacks the developing fruits, which represent the final yield component. Such direct damage cannot be compensated unlike damage on pinnae (leaflets) or other parts of the palm tree. Infestation by the date mite commences just after fruit set, peaks during the Kimri stage when the fruits are green with high moisture content. Mite populations decline during Khalal stage when fruit color starts to change to yellow or red depending on the date palm cultivars. During the Rutab stage when fruits start to ripen, mite populations become low and continue to decline further during the Tamr or full ripen stage (Palevsky *et al*., 2005). The world famous date palm varieties such as Medjool, Deglet Noor, Barhi, and Khalas are highly susceptible to mite infestation and estimation of damage may range between 30%–80% (Carpenter & Elmer, 1978; Ben Chaaban *et al*., 2012).

Distribution, host range, and economic importance

Oligonychus afrasiaticus is widely distributed in the old world (the Middle East and North Africa). It is reported from the following countries: Iran, Iraq, Saudi Arabia, United Arab Emirates, Bahrain, Oman, Kuwait, Yemen, Jordan, Israel, Libya, Tunisia, Algeria, Morocco, Egypt, Sudan, Chad, Mauritania, Mali, and Niger. The dust mite is oligophagous, attacking Arecaceae and few other hosts in the families Poaceae, Cucurbitaceae, Solanaceae, and Convolvulaceae. Damage loss due to mite infestation on fruits may reach 70% and sometimes a 100% loss may occur. In addition, the expenditure on purchasing acaricides, labor cost for control operations increase the cost of production, which eventually results in negative impact on growers' returns (Elwan, 2000; Blumberg, 2008; Yousef & Mahmoud, 2013).

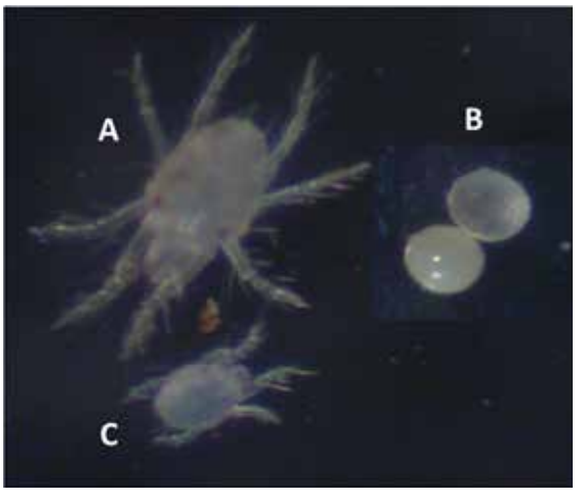

Figure 1. Old world date palm dust mite, Oligonychus afrasiaticus, life stages; (A) adult, (B) egg and (C) larva.

Biology and bionomics

The date dust mite passes through four distinct developmental stages – egg, larva, nymph, and adult (Figure 1). Adult size ranges from 0.2 mm to 0.5 mm in length and 0.17 mm to 0.2 mm width (Figure 1A). It exhibits sexual dimorphism with the end of the body being round in the female and somewhat tapering in the male. The egg is spherical and about 0.1 mm in diameter with varied colors of yellow, pink or red (Figure 1B) (Hussain, 1969). Larvae have three pairs of legs and are smaller (0.15 m–0.20 mm) as compared to the nymphs and adults (Figure 1C). The larvae assume orange, yellowish white or yellow colors. The nymphs possess four pairs of legs and their colors range from light yellow to light orange. They resemble adults morphologically; however, their sizes are usually smaller. An individual female can lay about 50–100 eggs usually in clusters on fruit strands, fruits and frond and dies after completion of egg laying process (Hussain, 1969). Eggs hatch within 2–3 days to an oval pale green tiny larva (0.2 mm) with three pair of legs as distinguishing character. The larva feeds for two days, then enters a period of quiescent (larval chrysalis) for one day before molting into a protonymph, which has a yellow color and four pairs of legs. The protonymph feeds for 1–2 days, then enters into a quiescent period (protochrysalis) of one day and molts into a deutonymph that feeds for one day and enters a period of quiescence (deutochrysalis) before finally molting into adult (Figure 2) (Hussain, 1969). The dusty silken webbings produced by the mites around the fruit and fruit strand provide a microclimate within which the mites feed and multiply, form-

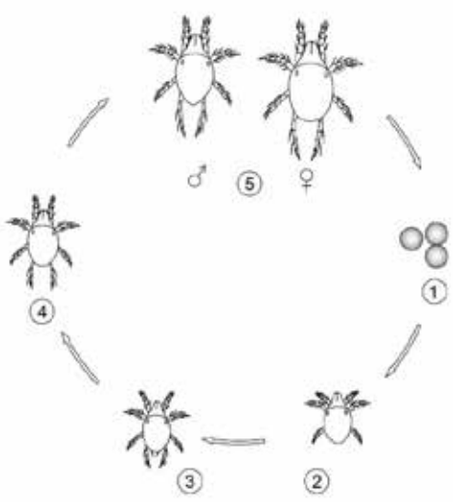

Figure 2. Life cycle of the date dust mite, Oligonychus afrasiaticus; (1) egg, (2) larva, (3) protonymph, (4) deutonymph, and (5) adult.

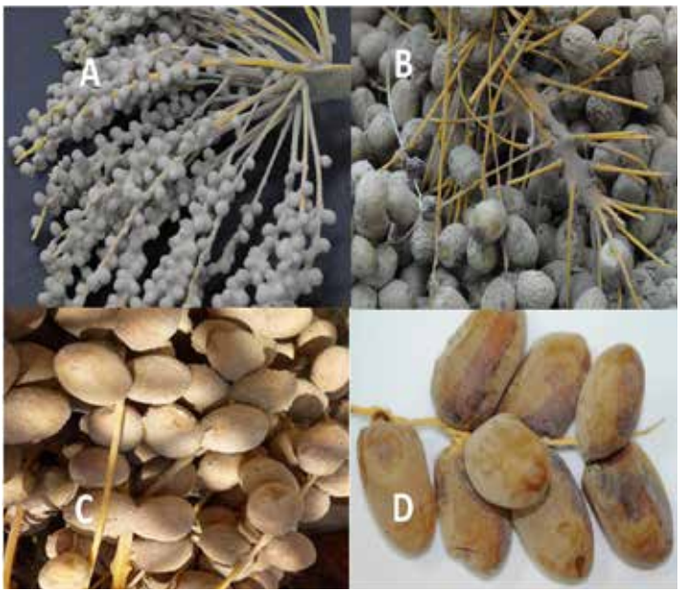

Figure 3. Date mite infestation on the different developmental stages of date fruit; Hababouk (A), Kimri (B), Khalal (C), and Tamr (D).

ing colonies away from predators and unfavorable environmental conditions (Negm *et al*., 2015). The date palm dust mite prefers hot dry weather and generation time may be two weeks depending on the prevailing temperature and accordingly, 10 generations of mite may be produced annually. After harvesting, the mites migrate to the fronds surrounding the palm heart and pass the winter between the fiber and frond bases. It can also move on the weeds around the date palm trunk presumably from fallen infested fruits.

Symptoms and damage

Date mite infestation may start immediately after fruit set, then increase gradually peaking in the Kimri and Khalal stages in mid-summer during June and July. The mite populations then decrease during the Rutab stage, and a few or no mites are found during the Tamr or fully ripened stage (Figure 3) (Palevsky *et al*., 2005; Ben Chaaban *et al*., 2011). Adults and juveniles (larvae and nymphs) feed upon developing fruits by lacerating the skin with their chelicerae (stylets) and then sucking the sap that oozes out thereafter. This feeding behavior initially produces a silvery appearance (symptoms) on the infested fruit due to the presence of air bubbles in the damaged cells and then the fruit color changes gradually to brown (Figure 4). Mite infestation usually starts at the calyx end of the fruit and then progresses towards the fruit tip. The fruits shrivel, harden, stop development, produce gum-like exudates, and their content of water and sugars are largely reduced (Palevsky *et al*., 2005). Heavily infested fruits become covered with fine dust and sand particles which render them unfit for human consumption (Ben Chaaban *et al*., 2012). The pattern of mite infestation on fruit bunches can be clumped i.e. heavy infested bunches may be found adjacent to non-infested ones (Figure 5). This phenomenon might be explained by the arrival of air-borne mites and their limited mobility after the initial establishment of the colony. Infestation by the dust mite become severe in date palm trees grown adjacent to dusty roadways and the margins of the orchards (Negm *et al*., 2015). The population dynamics of date dust mite in date palm groves are affected by weather, chemistry of date fruits, cultural practices adopted on farm, predators, and chemical treatment for mites and for other date palm pests (Ben Chaaban *et al*., 2012).

Figure 4. Immature date fruits showing progressive discoloration, starting from silver to dark brown (Bottom) as compared to the normal green color of healthy fruits (top).

Possible causes of outbreaks

Excessive use of insecticides particularly organophosphorus and carbamates for the control of major date palm pests may change mites from a secondary pest to a primary one due to the killing of its natural enemies. Different products representing four insecticide classes – organophosphates, synthetic pyrethroids, carbamates, and neonicotinoids – have been used for the control of the red palm weevil (*Rhynchophorus ferrugineus*) in date palm groves in the eastern region of Saudi Arabia during the period from 2007 to 2012. Nine different active ingredients including chlorpyrifos, cypermethrin, malathion, deltamethrin, carbaryl, beta-cyfluthrin, fenitrothion, and imidacloprid were applied (Hoddle *et al*., 2013).

Figure 5. Clumped dust mite infestation showing heavily infested bunch adjacent to non-infested one.

Figure 6. An army of car-mounted sprayers (top) and preventive spraying operations to combat the red palm weevil in date palm groves (bottom).

These insecticides were used with high frequencies (three time a year) for both preventive (prophylactic) and curative treatments.

Insecticides may also cause the dispersal of mites by exciting established colonies. The selection pressure arising from the heavy use of synthetic acaricides with the same active ingredients to combat populations of this mite in specific geographic area may induce emergence of resistant mite individuals in these populations. The rapid development of pesticide resistance in mites as compared to other arthropods could be attributed to their arrhenotokous reproduction, rapid reproductive rate, and different genetic mechanisms to the same chemical product (Croft & Van de Baan, 1988).

The mono-cropping (low palm diversity) of a single susceptible cultivar may be one of the reasons behind the rapid buildup of the date dust mite. Modern large scale date palm plantations grow one or two popular cultivars over large areas. Climate change and the increase of annual global temperatures may be another factor in the upsurge of mites. The overall effect of temperature on the life cycle parameters of mite, such as the net reproductive rate, intrinsic rate of population growth, and shortening of the mite doubling time may also contribute to the mite outbreaks (Ben Chaaban *et al*., 2012). Additionally, climatic conditions affect the phenology of both mite and date cultivar resistance through changing the physiochemical characteristics of date fruits which include osmotic pressure, soluble solids, and water content. The availability of different alternative hosts may increases the chance of mite survival and dispersal in the absence of immature date fruits. This is presumably one possible cause of dust mite outbreaks (Palevsky *et al*., 2003).

Management options

Sampling and monitoring are essential for developing effective management programs for date dust mite. For monitoring date mites, 10 palms from a plantation (2 located on each cardinal direction north, south, west and east and 2 in the middle) can be selected for sampling. Ten fruits and ten pinnae from each palm (100 fruits and 100 pinnae) can be collected at weekly intervals from the time of fruit setting until harvest (Palevsky *et al*., 2003). If infestation is restricted to only few bunches (clumped), then stratified sampling procedures can be followed i.e. categorizing infested bunches into different strata according to the level of infestation, then making random fruit selection from each stratum (Latifian *et al*., 2014). The percentage of infested fruits as well as frequency of total palm infestation (number of infested palm/total number of date palm trees) can be calculated at each sampling date. The adult cumulative mite-days (ACMs) can be used to estimate the seasonal mite population dynamics. Mite-days are defined as one mite present per fruit strand for one day and is calculated as the mean of two successive counts multiplied by the number of intervening days (Beers & Hull, 1990). Due to the small size of the mite and the difficulty of counting, mite population on infested date palm can be monitored by the presence of webbing. The relationship between development of mite webbing and degree-days (DD) can be modeled and used to monitor mite populations. A sampling plan for the date palm dust mite based on economic threshold needs to be developed (Perring *et al*., 1984).

Cultural control

Several cultural practices may be adopted against date palm dust mite to alleviate its negative impact on fruit quality (Palevsky *et al*., 2003; Latifian *et al*., 2014). These practices can be summarized as follows:

1. Establishment of an inter-palm spacing of 8–10 m, which provides good aeration and allows sun radiation sufficient to kill all stages of the mite.
2. Removal of old bunches and remains of spathe, old fronds and fibers, which act as overwintering sites for hibernating mites
3. Removal and destruction of fallen fruits in the leaf axil and on the ground
4. Phytosanitation of the orchards, involving removal of weeds around the palm trunk, which act as alternative hosts for the mite during the absence of fruits
5. Enclosure of date bunches using suitable paper or plastic bags to prevent colonization by airborne mites. Bagging might not prevent mite infestation, but at least it can lessen the spread of initial infestation
6. Control of birds, wasps, and other insects by bunch bagging that mechanically transport the mites through their movement from one palm to another
7. Maintenance of healthy palms through balanced irrigation and nutrition
8. Spraying of infested bunches with cold water (4°C) to remove the webbings and dislodge the mites at different developmental stages, particularly the eggs, which usually adhere to the webbings.
9. Fruit thinning, which helps to reduce contact between fruits and thus prevent the crawling of mites from infested fruits to uninfested ones.

Host plant resistance

Some date palm cultivars may exhibit different levels of resistance to infestation by the dust mite (Ben Chaaban *et al*., 2012). However, until now this resistance has not been exploited for field management of this pest. Seasonal pests such as date mites usually synchronize their abundance with the time when most of the date fruits are in the kimri stage. The asynchrony between the pest and host plant makes it possible for the latter to escape attack by completing the development of its susceptible stage before the pest appears or after it has disappeared. In this respect, late or early maturing date palm cultivars may escape mite attacks and thus show some degrees of resistance ((Palevsky *et al*., 2005). The synchronization between the peak of mite population and the susceptible stage of date fruits is an important aspect in the biology of this mite. The variation in flowering phenology of the different date palm cultivars may be responsible for the asynchrony between the peak population of mite and the susceptible stage of fruit development (Palevsky *et al*., 2005).

Biological control

Many attempts have been made to utilize natural enemies for control of the dust palm mite. The high rate of multiplication of this species may exceed the potential of native predators; nevertheless, the preservation and encouragement of these indigenous predators may give promising results. This strategy may seem better than introduction of exotic predators that may not be able to adapt well to the harsh summer conditions that coincide with the peak population of the dust mites (Negm *et al*., 2015). Potential predators for biological control of date dust mite include the predatory phytoseiid mites, *Phytoseiulus persimilis* and *Neoseiulus californicus* which are commercially available. Moreover, the adults and larvae of the coccinellid ladybird beetle, *Stethorus* spp. and the green lacewing, *Chrysoperla carnea* can feed on dust mite. Continuous application of insecticides could also lead to the development of resistance among mite predators. High resistance to pyrethroids and organophosphates was detected in populations of the predatory mites, *Typhlodromus pyri* and *Amblyseius andersoni* in France which could be used to control the populations of tetranychid mites in grape fields (Bonafos *et al*. 2007).

Chemical control

The application of sulfur as a dust or wettable spray has been the common practice to control date dust mite (Carpenter & Elmer, 1978; Palevsky *et al*., 2004). Now, many commercial acaricides are available in the market and can be used against date palm dust mite. These including hexythiazox, amitraz, abamectin. Botanical acaricides such as neem oil are also available (Palevsky *et al*., 2004; Aldosari, 2009). Dusting sulfur on fibers between the frond and the trunk where large colonies of overwintering mites exist would reduce mite population in the following season. This preventive treatment is used at a rate of 50–100g/palm depending on the age of the tree. Male date palms and infertile female palms should also be treated because the mites may migrate to them. Since mite infestation occurs simultaneously with fruit insect pests, abamectin, which acts as both an insecticide and an acaricide, can be used. Synchronizing management measures of many date palm pests will save growers efforts, ensure healthy date fruits for consumer and lessen the adverse impact of pesticides on the date palm agroecosystem. As a remedial measure, infested bunches can be dusted with agricultural sulfur at a rate of 100–150/palm tree or sprayed with micro-fine sulfur, two weeks after fruit setting. The treatment of date dust mites with sulfur can be employed in organic date production where synthetic acaricides are not permitted.

Conclusions

In recent years, the date dust mite has become a major pest in many areas around the globe where the date palm is grown. The heavy application of synthetic insecticides to control other date palm pests may have had an adverse effect on the natural enemies of dust mite which were responsible for regulation of mite populations. The wide use of many synthetic acaricides may have exerted a high selection pressure on the mite populations resulting in the emergence of mite resistance. Thus, a holistic approach for the management of date palm pest complex should be considered to avoid the emergence of secondary pests. Date dust mite could effectively be managed through an integrated program including cultural, biological, and chemical management. To avoid the development of resistance in mite populations, biorational acaricides can be employed.

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Similar articles that appeared in *Outlooks on Pest Management* include – 2016 **27(2)** 111

IMPRESS: IMPROVING EXPOSURE ASSESSMENT METHODOLOGIES FOR EPIDEMIOLOGICAL STUDIES ON PESTICIDES

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Abstract

This article introduces 'IMPRESS: Improving exposure assessment methodologies for epidemiological studies on pesticides', a new research project focussed on better understanding the performance of exposure assessment methodologies in pesticide epidemiology studies.

Keywords: epidemiology, pesticide exposure, exposure assessment

Exposure to certain pesticides is suspected to result in several chronic diseases such as cancers, reproductive effects (e.g. reduced semen quality, low birth weight) and Parkinson's disease. Studying chronic health diseases requires the assessment of historical exposures. However, exposure measurement data are rarely available. Therefore, assessment of historical exposures frequently needs to be based on self-reported information such as a person's job title, duration of employment, and/or whether they were ever exposed (yes/no) to pesticides or registered data like spray calendars. Naturally, such exposure measures suffer from some limitations (e.g. the ability of a person to remember their exposure history over a long time-period), which may affect the conclusions of a study. The large number of pesticides and pesticide mixtures involved, and the seasonality and broad range of characteristics regarding their application and use further complicates matters. With an increasing number of studies on occupational exposure to pesticides conducted each year, bias associated with respective exposure assessment methods may aggregate over time leading to potentially spurious associations or associations going undetected. Understanding the performance of the applied surrogate measures in exposure assessment is therefore important to allow proper evaluation of the involved risks.

The IMPRESS 'Improving exposure assessment methodologies for epidemiological studies on pesticides' project aims to understand better how well the existing methods of exposure assessment for pesticides perform when applied within epidemiological studies (i.e. studies looking to identify the causes of health effects within a human study population) of chronic health outcomes. IMPRESS is funded by the European Crop Protection Association (ECPA) and involves researchers from the Institute of Occupational Medicine (IOM), the Health and Safety Laboratory (HSL) and the University of Manchester in the UK as well as the Institute of Risk Assessment Science (IRAS) from the University of Utrecht in the Netherlands. In addition, the project has convened an independent Advisory Board, whose role is to provide advice to the project team on scientific quality and transparency regarding the research, its progress, and publication of the results.

This ongoing 4-year project, which started in September 2017, is split into four key activities and will involve the collection of data and biomonitoring samples from pesticide applicators working in the UK, Ethiopia and Malaysia.

Activity 1 aims to identify the most important and commonly used exposure assessment methods in occupational epidemiological research by reviewing available scientific literature systematically.

Activity 2 aims to evaluate the ability of workers to remember their pesticide exposure history. This will be achieved by comparing responses between the same questionnaires administered now and several years ago. Professional applicators and farmers from the UK and Ethiopia will participate in this activity.

In Activity 3, the adequacy of previously established mathematical models that can be used to estimate the exposure of workers to pesticides will be evaluated. For this, the questionnaire information on pesticide usage collected from UK, Ethiopian and Malaysian workers will be compared with the results from measurements of exposure in urine samples collected from the same workers. The results of these comparisons will be used to modify and improve the performance of the mathematical models.

In the fourth and final activity, the performance of some of the most important methods of exposure assessment identified in Activity 1 as well as of the improved mathematical models from Activity 3 will be assessed in a risk analyses. A range of different work populations will be used in this study.

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The IMPRESS team consider that the project results will be of importance to scientific and regulatory communities, as they will help inform future research regarding the preferred and most reliable exposure assessment methods to be applied in epidemiology studies focussed on pesticides.

Visit the project website for further information and updates on the project progress, http://www.impress-project.org/

Karen S. Galea is Head of the Exposure Science Section at the Institute of Occupational Medicine (IOM), Edinburgh. She has nearly 20 years' experience as a human exposure scientist, and has led a range of research and consultancy projects focussed on occupational, residential and consumer exposure. She is the Principal Investigator of the IMPRESS project.

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John W. Cherrie is Professor of Human Health at Heriot Watt University and Principal Scientist at the IOM in Edinburgh. He has been a member of the Advisory Committee on Pesticides and is currently a member of the HSE Workplace Health Expert Committee and the Industrial Injuries Advisory Council. John's research is concerned with understanding the links between human health and exposure to chemicals, pesticides, asbestos, air pollution and other risk factors. He is also interested in improving occupational and environmental exposure assessment for epidemiological studies of neurodegenerative disease and modelling exposure to welding fume.

Samuel Fuhrimann is a Post-Doctoral fellow at the Institute for Risk Assessment Sciences at Utrecht University in the Netherlands. His research focus is on risk assessment of microbial and chemical environmental contamination in the context of agricultural systems in low- and middle-income countries with a specific focus on epidemiological transition. His current research projects are mainly focusing on risk assessments related to pesticide use in Uganda and Costa Rica (PESTROP project), South Africa (CapSA project), and Ethiopia, Malaysia and the UK (IMPRESS project).

Anne-Helen Harding is an epidemiologist/statistician with the HSE, where she has worked for over 10 years. She is Principal Investigator on two cohort studies: the Prospective Investigation of Pesticide Applicators' Health (PIPAH) Study and the GB Asbestos Workers Survey. In addition Anne-Helen provides statistical support to colleagues across the organisation and is the Epidemiology Team Technical Lead. Anne-Helen is an expert member of a National Research Ethics Committee and a Member of the UK Government Statistical Group.

Kate Jones is an analytical chemist working as the Team Lead for HSL's Biological Monitoring team. She has wide experience and expertise in the biological monitoring of organic compounds and particularly pesticides. She has also overseen a number of human volunteer studies involving pesticides. She is currently Chair of both the Royal Society of Chemistry's Toxicology group and the International Commission on Occupational Health's scientific committee on Occupational Toxicology.

Hans Kromhout is an international authority on occupational and environmental exposure assessment and epidemiology based at the Institute for Risk Assessment Sciences at Utrecht University in the Netherlands. His work has covered the health effects of chemical and physical agents in the workplace and general environment. He has been responsible for large international studies in among others the asphalt industry, the rubber manufacturing industry, the industrial minerals industry, the health sector and within agriculture and community based studies on cancer, respiratory diseases, neurodegenerative diseases and reproductive health effects.

Johan Ohlander is a Post-Doctoral fellow at the Institute for Risk Assessment Sciences at Utrecht University in the Netherlands. He has several years of experience in planning, executing and analyzing epidemiological studies, particularly focusing on occupational risk factors in the automotive industry. As part of his work on the IMPRESS project he has conducted a systematic review of exposure assessment methods used in studies of occupational pesticide exposure.

Andrew Povey is a Reader in Molecular Epidemiology at the University of Manchester. He has been a member of the Advisory Committee on Pesticides and is currently a member of the Committee Mutagenicity of Chemicals in Food, Consumer Products and the Environment. He has co-authored more than 110 peer-reviewed papers.

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Similar articles that appeared in *Outlooks on Pest Management* include – 2016 **27(2)** 70; 2017 **28(2)** 86; 2018 **29(1)** 43

Research Reveals MON 810 and NK603 GM Maize Have No Effects on Rat Health or Metabolism

A new, unprecedented study conducted by a large research consortium led by INRA reports that a diet based on MON 810 or NK603 transgenic maize does not affect the health or metabolism of rats. Under the conditions of GMO 90+1 project, the researchers did not detect any harmful effects of the MON810 and NK603 maize diets on the health and metabolism of rats, even after a lengthy exposure period. For six months, rats were fed a diet that contains either genetically modified (GM) maize (MON 810 or NK603) or non-GM maize, in varying concentrations. Using high-throughput biology techniques, the researchers did not find any significant biological markers related to the transgenic maize diet. Neither did anatomic pathology examination reveal any alteration of the liver, kidneys, or reproductive system of the rats whose diet contained GM maize. The period of six months, which is double that of the test required by European regulations, is equivalent to one third of the average lifespan of rats. (For more information: See *Toxicological Sciences*)

Iowa State University Study Says Anti-GMO Sentiment Has Repercussions for Developing World

A study conducted at the Iowa State University analysed dozens of previous scientific studies on the safety of Bt corn and provides an overview of the risk assessment process applied to genetically modified (GM) crops. Walter Suza, an adjunct assistant professor of agronomy at Iowa State and a co-author of the study, said that Bt corn could help farmers in Africa to combat an emerging pest capable of devastating their crops, but fear of GM crops has slowed adoption of the technology in the continent. He cites the problem of fall armyworm (*Spodoptera frugiperda*), an emerging pest spreading rapidly though Africa. He said Bt corn could help fight the pest immediately, while developing resistance through traditional plant breeding will take years. The review found that delaying the adoption of GM crops such as Bt corn in less developed countries presents risks to both humans and the environment. The paper published in the journal *Global Food Security* upholds the conclusion that GM crops are safe for humans and the environment, and that risks associated with GM crops have proven to be low to non-existent. It concludes that GM technologies can be used to develop stress-tolerant and more nutritious crop varieties, and to protect natural resources and human health. It also states that while each new GM product is evaluated on a case-by-case basis, approved commercial products, such as those containing Bt genes, have been subjected to rigorous scientific scrutiny. GM traits, including but not limited to plant-incorporated Bt protection, should be considered as a tool for improving crop yields, food safety, and income for food-insecure farmers. (For more information read the open access paper which is available at *Global Food Security*)

Fear of GM Crops Prevents Society from Benefiting from the Technology

The 2018 winners of the Nobel Prize for Chemistry, Professor Frances Arnold from the United States and Sir Gregory Winter of the United Kingdom, say that excessive concerns about genetically modified (GM) foods are preventing society from benefiting from the technology. Professor Arnold argued that GM crops could make food production more environmentally sustainable and help feed the world's growing population. Sir Gregory Winter, however, said that the current regulations on GM crops need to be "loosened up." The Nobel Laureates made the comments on December 10, 2018, during the presentation of the prize. Professor Frances Arnold and Sir Gregory Winter received the Nobel Prize in Chemistry this year, together with American scientist George Smith, for their work in harnessing evolution to produce new enzymes and antibodies. Their work led to the development of new fuels and pharmaceuticals by making use of nature's evolutionary processes themselves, leading to medical and environmental advances. (For more information: Central Maine and The Guardian)

OECD Study Provides New and Detailed Evidence on Market Concentration in Seed and GM Technology

The results of a study conducted by the Organisation for Economic Cooperation and Development (OECD) are now available. The book *Concentration in Seed Markets* provides an in-depth assessment of structural changes in global markets for seed and biotechnology based on new data on market concentration across a broad range of countries and crops, and considers potential policy responses. Recent mergers in the seed industry have led to concerns about market concentration and its potential effects on prices, product choice, and innovation. The OECD study provides new and detailed empirical evidence on the degree of market concentration in seed and GM technology across a broad range of crops and countries, and analyses the causes and potential effects of concentration. It also explains how competition authorities have responded to recent mergers, and suggests policy options to help safeguard and stimulate competition and innovation in plant breeding by avoiding unnecessary regulatory barriers, by facilitating access to genetic resources and intellectual property, as well as by stimulating public and private R&D. As this study shows, policymakers have several levers besides competition policy to ensure an innovative and competitive seed industry. (For more information: https://www.oecd-ilibrary.org)

Biotechnology Possibly to Address Forest Health Problems

The US National Academies of Sciences, Engineering and Medicine released a report that states that biotechnology may be part of the means in protecting forest trees against destructive pests and disease outbreaks. By using biotechnology to introduce pest-resistant traits to trees, threats such as the introduction of non-native tree pests and diseases hastened by climate change and global trade and travel may be mitigated. Two tree species, the American Chestnut and hybrid poplars, are currently under field trials to address forest health issues. The report also recommends further research

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to improve the use of biotechnology as a forest health tool. Challenges such as the poor understanding of how the trees' genetic mechanisms resist pests, the delay of identifying genetic changes in trees due to complex genomes, and the lack of information on the effects of releasing new tree genotypes to the environment were identified. The report also stated the importance of studying the societal responses to the use of biotechnology to address forest health threats for sound decision making. Furthermore, respectful, deliberative, transparent, and inclusive processes of engaging with people to increase understanding of forest health threats and biotechnology were pointed out. If pursued, the development of these biotech trees can decrease the severity of threats to the North American forests, therefore increasing the chances of having and retaining a healthy forest ecosystem. (For more information: dels.nas.edu/Study-In-Progress/Potential-Biotechnology-Address/DELS-BANR-16-02)

Argentina One Step Away from GM Wheat Commercialisation

The development of HB4 wheat, a transgenic wheat variety with drought tolerance trait started in the mid 1990s when Raquel Chan and her team identified the *HB4* gene that confers sunflower seed with drought tolerance. In 2003, Bioceres reached an agreement with Conicet to develop it commercially. In 2007, HB4 was transferred to other crops such as soybean, maize, and wheat. To date, the technology is one step away from being available to Argentinean farmers. The developers are just waiting for the findings about the impact of HB4 wheat on the markets (domestic and foreign) to be released by the Ag-Industry Secretariat. (For more information: see the Genetic Literacy Project)

Research Finds Extreme Opponents of GM Foods Know the Least but Think They Know the Most

People with the most extreme views opposing genetically modified (GM) foods think they know most about GM food science, but actually, they know the least, according to new research published in *Nature Human Behaviour*. The research was a collaboration between researchers at the Leeds School of Business at CU Boulder, Washington University in St. Louis, the University of Toronto, and the University of Pennsylvania. Marketing and psychology researchers asked more than 2,000 US and European adults for their opinions about GM foods. The surveys asked the respondents how well they thought they understood GM foods, then tested how much they actually knew with a battery of true-false questions on general science and genetics. The researchers found that despite the scientific consensus that GM foods are safe for human consumption, many people oppose their use. More than 90% of the respondents reported some level of opposition to GM foods. Nicholas Light, a Leeds School of Business PhD candidate in marketing suggests that changing people's minds first requires them to appreciate what they do not know. He added that without this first step, educational interventions might not work very well to bring people in line with the scientific consensus. (For more information: https://www.colorado.edu/today)

GM Maize (MON 89034×1507×MON 88017×59122×DAS-40278-9) and Soybean (A2704-12) are Safe for Release

The European Food Safety Authority (EFSA) released scientific opinions on the assessment of GM maize (MON 89034×1507×MON 88017×59122×DAS-40278-9) and soybean (A2704-12) concluding that both are safe for release. The five-event stack GM maize and their subcombinations were subjected to molecular characterisation, comparative analysis (agronomic, phenotypic and compositional characteristics) and toxicological, allergenicity, and nutritional assessments, and found that the GM maize does not give rise to food and feed safety and nutritional concerns. It was proven to be as safe and nutritionally equivalent to its non-GM counterparts. The herbicide tolerant soybean (A2704-12), which was submitted for renewal of authorisation, was evaluated based on post-market environmental monitoring reports, a systematic search and evaluation of literature, updated bioinformatic analyses, and additional documents or studies performed by or on behalf of the applicant. Based on the results, EFSA concluded that there are no new hazards, modified exposure or scientific uncertainties that would change the conclusions of the original risk assessment on the GM soybean. (For more information see the EFSA scientific opinions of GM maize and GM soybean)

Gene Improves Heat and Drought Tolerance in Wheat and Arabidopsis

Drought and heat stress highly affect yield in wheat and other crops around the world. Thus, genes that respond to these stresses are important in developing plants that can withstand such environments. In a gene expression study by researchers from China Agricultural University, the gene *TaPEPKR2* from the wheat variety TAM107 is found to be responsive to heat and drought stress and can be found in chromosome number 5B of wheat. In a subsequent study, the same group of researchers transferred the gene into another wheat cultivar Liaochun10 and into *Arabidopsis* via *Agrobacterium*-mediated genetic transformation. This step was done to determine the gene's function in wheat and dicots further. Through thermotolerance assay, ion leakage assay, and dehydration tolerance assay, the researchers determined response of the transformed plants to heat and drought stress. Results showed higher expression of the gene in stressed plants than normal plants. Heat and drought tolerance are also enhanced in both wheat and *Arabidopsis* in the presence of the gene. The researchers concluded that *TaPEPKR2* may have a role in the regulation of abscisic acid signalling and heat shock proteins during stressed conditions. (For more information see *Frontiers in Plant Science*)

Cotton Gene Enhances Brown Fibre Quality

Brown-coloured cotton fibre is increasing in importance because it skips dyeing and bleaching during textile processing. This characteristic makes it more eco-friendly than white cotton and chemical fibres. However, studies have shown that the brown pigment is associated with low yield and low fibre quality. Thus, studying the biochemical and molecular basis of pigmentation is important to improve the colour, productivity, and fibre quality of brown-fibre cotton and broaden its applications. Researcher Qian Yan from Southwest University in China and colleagues perform gene expression and transgenic analyses of a cotton version of an *Arabidopsis* gene *TT2*, which is involved in the synthesis of the brown pigment in cotton fibre. This cotton gene called *GhTT2-3A* is observed to be involved in the activation of genes involved in brown pigment synthesis. The researchers also find that increasing the amount of this gene during the stage of secondary wall thickening resulted in brown mature fibres with fibre quality and lint percentage almost the same as the white fibre counterpart. Therefore, this gene may be a key to improve the yield and quality of brown fibre cotton. (For more information see *Plant Biotechnology Journal*).

Development of 3rd Generation Climate Resilient and Dry Direct Seeded Rice Varieties

Rice, the most important staple food crop in Asia is commonly grown by transplanting seedlings into puddled soil and standing water. Despite the multiple benefits of manual puddled transplanted rice (PTR), it is a highly labour-, water-, and energy-intensive system, making it less sustainable, less profitable, and less attractive to farmers. In the face of changing climatic conditions, global water scarcity and escalating labour rates, when the future of rice production is under threat, dry direct seeded rice (DDSR) offers a viable alternative to PTR. Lack of suitable rice varieties for DDSR has been a major constraint for adoption in rice growing areas. A successful transition of rice cultivation from PTR to DDSR will rely on the development of new nutrient efficient-high yielding climate resilient rice varieties possessing better adaptability to DDSR. At International Rice research Institute (IRRI), traits and the QTLs associated with the traits that increase adaptability to dry direct seeded cultivation conditions such as root traits [nodal root number ($qNR_{4.1}$, $qNR_{5.1}$) and root hair density ($qRHD_{1.1}$, $qRHD_{5.1}$, $qRHD_{8.1}$)] leading to higher nutrient availability under dry direct-seeded conditions, early vegetative vigour ($qEVV_{9.1}$), early uniform emergence ($qEUE_{1.1}$, $qEUE_{11.1}$), and grain yield under direct-seeded conditions ($qGY_{1.1}$, $qGY_{8.1}$, $qGY_{10.1}$) have already been identified. The polymorphic markers for early vigour, nodal roots, early and uniform emergence, drought tolerance, and grain yield under direct seeding, and gene-specific markers for blast, bacterial blight, and gall midge have been identified. In this context, a marker-assisted breeding program combining several genes for biotic and abiotic stresses and traits required for DDSR situation in many elite genetic backgrounds utilising trait linked markers has been initiated at IRRI (Philippines) and Punjab Agricultural University, Ludhiana (India). (For more information see the *Journal of Experimental Botany*.)

Gene Editing for Developing GM Spicy Tomatoes

With the development of gene editing tools, experts from the Federal University of Viçosa in Brazil explored the possibility of engineering spicy tomatoes. The paper is published in *Trends in Plant Science*. The primary goal of developing spicy tomatoes was to mass produce capsaicinoids easily. These are secondary metabolites that give chilli peppers their spicy flavour and have been proven to have health benefits and industrial applications. According to the researchers, two genome editing techniques could be used together to turn on the capsaicinoid biosynthesis in tomato. The first one is the transcriptional activator-like effectors (TALEs), a set of proteins secreted by pathogenic bacteria, *Xanthomonas* spp., when they infect plant hosts. Rapid assembly of the TALE genes into a single T-DNA vector would allow simultaneous upregulation of the expression of some key capsaicinoid biosynthesis genes. Actual experimentation would further exhibit whether the transcript levels achieved will be enough for the capsaicinoid pathway to be functional. The second technique is the use of genome engineering for targeted replacement of promoters. This was proven to be effective in tomato using a constitutive 35S promoter inserted in *ANT1* gene, which encodes a transcription factor involved in regulating anthocyanin production. Promoter regions of the inactive genes in the capsaicinoid pathway could be replaced with endogenous tomato fruit-specific promoters to produce cisgenic plants with transcriptionally active genes. Actual testing will reveal if the products are fully functioning, biochemically active, and catalyse the right reactions. (For more information see the article in *Trends in Plant Science*)

Researchers Use CRISPR-Cas9 for Gene Editing of Cavendish Banana

Cavendish banana takes almost half of global banana production worldwide. However, improvement of this cultivar is difficult because it is essentially sterile. Thus, scientists from Queensland University in Australia used CRISPR-Cas9 gene editing system to deliver a self-cleaving guide RNA designed to target the Phytoene desaturase (*PDS*) gene in the Cavendish cultivar *Williams*. The researchers reported that genotyping of 19 various events showed the successful modification of the *PDS* gene through insertions or deletions at the target cleavage site. Disruptive changes were observed in 63% of the plants, which was characterised by albinism and dwarfing. Editing efficiency was observed to be dependent on both target site selection and Cas9 abundance. The results of the study show that the CRISPR-Cas9 modification system could be used to develop better Cavendish banana with favorable traits such as disease resistance and other important agro-traits. (For more information: see *Transgenic Research*)

Europe Grants CRISPR-Cas9 Patent to Calyxt

A patent has been issued by the European Patent Office to Calyxt, Inc. which gives them permission to create gene-edited plants by the transient delivery of sequence-specific nucleases, including CRISPR-Cas9. Calyxt has been using TALEN in developing better food products, but the company is continuously trying out new gene editing technologies and approaches to edit plant genes. Calyxt's intellectual property portfolio is also strengthened by having licensed from Cellectis two patents of a family claiming the uses of chimeric nucleases, such as TALEN and CRISPR-Cas9, for gene editing in any type of cells. (For more information: www.calyxt.com/newsevents)

CRISPR-Cas9 Used in Breeding Indica Glutinous CMS Line WX209A

Glutinous cytoplasmic male sterile (CMS) line is vital for the selection of hybrid glutinous rice combination with high yield and quality. To develop glutinous CMS with low amylose content, researcher Xin Wang and team knocked out the granule-bound starch synthase OsWaxy in 209B using CRISPR-Cas9-mediated genome editing technology and successfully obtained a glutinous maintainer line WX209B. When compared with maintainer line 209B, WX209B exhibited reduced amylose content and similar agronomic characteristics. After one generation of hybridisation and two generations of backcrossing with WX209B as the male parent and 209A as the female parent, the glutinous CMS line WX209A was successfully achieved. The results of the study provide a strategy to breed for the glutinous cytoplasmic male sterile line efficiently by combining CRISPR-Cas9-mediated gene editing technology with conventional backcross breeding method in a short period, which prepares the ground for further breeding of hybrid glutinous rice variety. (For more information: read the research article from *Czech Academy of Agricultural Sciences*)

WRI Report Says GMOs and Gene Editing Can Help Improve Crop Breeding to Boost Yields to Feed the World

A new report, *Creating a Sustainable Food Future*, published by the World Resources Institute (WRI) suggests ways of feeding the planet's almost 10 billion people by 2050 when food demand is set to rise by over 50%, and demand for animal-based food products (meat, dairy, and eggs) likely to grow by almost 70%. The report states that the world must boost food production on existing agricultural land and that genetically modified organisms (GMOs) and gene editing can help improve crop breeding to boost yields. According to the report, there is no evidence that GMOs have directly harmed human health. The report says that there is no silver bullet in producing enough food sustainably, but it offers a five-course menu of solutions to ensure feeding everyone without increasing emissions, fuelling deforestation, or exacerbating poverty. WRI estimates that feeding the world sustainably while reducing agricultural land use and greenhouse gas (GHG) emissions by 2050 will mean the whole world: reducing demand by cutting food loss and waste, eating less beef and lamb, using crops for food and feed rather than biofuels, and reducing population growth by achieving replacement fertility levels; increasing crop and livestock productivity to higher than historical levels, but on the same land area; stopping deforestation, restoring peatlands and degraded land, and linking yield gains to the protection of natural landscapes; improving aquaculture and managing wild fisheries more effectively; and using innovative technologies and farming methods that lower agricultural GHG emissions. *Creating a Sustainable Food Future* has been produced by WRI in partnership with the World Bank, UN Environment, UN Development Programme, and the French agricultural research agencies CIRAD and INRA. (For more information download the report from WRI - https://www.wri.org/our-work/project/world-resources-report/wrr)

Japan May Allow Genome-edited Food Sale

Japan's Ministry of Health, Labour, and Welfare Expert Committee announced their proposal to allow most of the genome-edited currently under development to be marketed without safety screening by the state. It is expected that the proposal that would accelerate the creation of more nutritious and improved crops. In the draft report of the Committee, the method to destroy target genes, including livestock products and fishery products, as well as agricultural crops was excluded from the regulation such as sales. Those products cannot be distinguished from traditional breeding improvement, because it occurs also in nature and regulation is difficult. However, even in this case, they will demand for notification. Penalties such as notification contents and notification can be set in fiscal 2019. Meanwhile, the method of adding genes from the outside is subject to the same regulation as those of genetically modified foods, requiring safety review by the Ministry of Health, Labour, and Welfare. Products can be marketed after passing examination. The new regulation is applied to domestic products or imported items in the same way. Individual safety assessment will be conducted by the Foods Safety Committee of the Cabinet Department upon request of the Ministry of Health, Labour, and Welfare. The final decision is expected to be released by the end of March 2019. (For more information, contact Fusao Tomita at ftomita@a-hitbio.com)

Study Shows Inheritance of Transgenes in Bt Cotton Lines Resistant to Bollworm

A total of six transgenic Bt cotton lines (GKsu12, GK19, MR1, GK5, 109B, and SGK1) exhibit high resistance to cotton bollworm (*Helicoverpa armigera*) from the seedling to boll-setting stages in bioassays with detached cotton leaves. Scientists from Nanjing Agricultural University in China conducted genetics analyses which revealed that the resistance to bollworm in these six Bt cotton lines is controlled by a pair of dominant genes, thus their resistance levels vary as well as Bt toxin content. More tests showed some populations

follow the Mendelian segregation for two non-allelic genes, i.e., the inserted Bt gene in GKsu12 is non-allelic to that of SGK1, GK5, 109B, and GK19, and Bt genes in GK19 and SGK1 are likely inserted in the same or in close proximity (genetically closely linked), while some F2 produce abnormal segregation patterns, with a segregation of resistance to cotton bollworm which vary between 15:1 and 3:1, though their Bt segregation fit into 15:1 by Polymerase Chain Reaction analysis, which imply Bt gene silence in these populations. Two genes silence may occur in these populations due to the homologous sequence by crossing since the silenced individuals accounted for 1/16 of the F2 populations for allelic test. The silenced populations further showed that one of their parents all showed high resistance to bollworm. (For more information see the research article in *Transgenic Cotton*)

Aarhus University Researchers Release New Insights in Rust Resistance in Wheat

One of the devastating diseases that threaten the world's wheat production is yellow rust, caused by *Puccinia striiformis* f. sp. *tritici* (*Pst*). Approximately 88% of wheat production is susceptible to yellow rust and estimates say that the disease ruins at least five million tons of the global annual wheat harvest. A large international group of researchers zoomed in on the gene sequence of the *Yr15* resistance gene in wheat. *Yr15* is a broad-spectrum R-gene derived from wild emmer wheat and is known for being one of the most effective resistance genes against yellow rust due to its unique mode of action. The international group of researchers mapped the gene sequence of *Yr15* and investigated how the resistance gene prevents fungal growth inside the infected wheat plant. According to Professor Mogens Støvring Hovmøller from the Department of Agroecology at Aarhus University, *Yr15* works differently than other resistance genes. They have discovered that *Yr15* produces defense responses early in the infection process, and there is only one single case where the fungus could bypass this defense. (For more information: *Nature Communications*)

Transgenic *Pm3e* Wheat Show High Resistance to Powdery Mildew

Pm3 from wheat confers resistance to powdery mildew caused by fungal pathogen *Blumeria graminis* f.sp. *tritici* (*Bgt*). Researchers have identified 17 working Pm3 alleles that confer resistance to *Bgt* isolates. One of the variants, *Pm3e*, was found in wheat donor line W150 and similar to non-functional variant Pm3CS except for two amino acids. To evaluate the capability of *Pm3e* to confer powdery mildew resistance, scientists from the University of Zurich and Agroscope in Switzerland developed transgenic Pm3e lines by biolistic transformation of the powdery mildew susceptible spring wheat cultivar Bobwhite. Results of the field trials showed significant and strong powdery mildew resistance of the *Pm3e* transgenic lines, while the non-transformed lines were severely powdery mildew infected. Thus, it was confirmed that *Pm3e* alone is responsible for the strong resistance phenotype. The field grown transgenic lines showed high transgene expression and Pm3e protein accumulation with no fitness costs on plant development and yield associated with Pm3e abundance. Based on the study, *Pm3e* can provide strong powdery mildew field resistance, making its use in wheat breeding programs very promising. (For more information: *Transgenic Research*)

GM Pigs Resist Infection from Classical Swine Fever Virus

Researchers have developed genetically modified (GM) pigs that are resistant to the classical swine fever virus (CSFV), a widespread, highly contagious, often fatal disease that causes significant economic losses. The study, led by Hongsheng Ouyang and colleagues from Jilin University, is published in the open-access journal *PLOS Pathogens*. The researchers investigated the biology of CSFV extensively, as there is an urgent need to develop effective approaches to eradicate CSFV. Ouyang and colleagues generated CSFV-resistant pigs by combining the gene-editing tool CRISPR-Cas9 with RNA interference (RNAi), a technique that silences gene expression. The researchers showed that the GM pigs could effectively limit the replication of CSFV and reduce CSFV-associated clinical signs and mortality. Disease resistance could also be stably transmitted to first-generation offspring. Currently, the researchers are conducting long-term studies to monitor the safety and effectiveness of this approach as these animals age. (For more information: read the open access paper in *PLOS Pathogens*)

Gene-edited Tilapia Not Classified as GMO in Argentina

Gene-edited tilapia (FLT 01) will not be classified as genetically modified organism (GMO) in Argentina, according to the National Advisory Commission on Agricultural Biotechnology (CONABIA). The new line of tilapia was developed by Intrexon and its subsidiary AquaBounty Technologies, which is known for its AquaAdvantage salmon. FLT 01 has been developed to demonstrate a 70% improvement in fillet yield, a 16% increase in growth rate, and a 14% improvement in feed conversion ratio. According to CONABIA, FLT 01 was developed using gene editing techniques and do not contain a foreign DNA or a new combination of genetic material, thus it is not considered as a GMO. (For more information: https://thefishsite.com)

***CBNB:** These abstracts were taken from Chemical Business NewsBase (CBNB) which is produced by Elsevier, E-mail: cbnb@elsevier.com, Website: http://www.ei.org/databases/cbnb.html

PROSPECTS FOR INTEGRATED PEST MANAGEMENT OF BROWN MARMORATED STINK BUG IN WASHINGTON TREE FRUITS

Elizabeth H. Beers, Adrian Marshall, Jim Hepler and Josh Milnes, Tree Fruit Research & Extension Center, 1100 N. Western Ave., Wenatchee, Washington, USA there is grave concern that the brown mamorated stink bug will disrupt decades of progress in IPM in tree fruits, and force producers to return to a regimen of broad-spectrum, non-selective insecticide use

Keywords: invasive species, biological control, landscape ecology

Elizabeth Beers Adrian Marshall Jim Hepler Josh Milnes

Brown marmorated stink bug (BMSB, *Halyomorpha halys*) is one of several new invasive pests that threaten tree fruit production in the western US. Based on the experience in the eastern US, there is grave concern that this pest will disrupt decades of progress in IPM, and force producers to return to a regimen of broad-spectrum, non-selective insecticide use.

The western US has had over 20 years of warning as BMSB has gradually spread across the US from the original find in Pennsylvania (Leskey *et al.*, 2012). However, microsatellite analysis (Valentin *et al.*, 2017, Xu *et al.*, 2014) indicates that western populations are the result of multiple independent introductions from Asia and the eastern US.

Since its initial detection, research efforts in the eastern US have been launched to meet the challenge of this new pest by establishing the fundamentals of BMSB biology, ecology and management. Previous Asian literature was also made available to English-speaking researchers by Lee *et al.* (2013), who translated and reviewed many formerly inaccessible studies. Despite this progress, re-establishing IPM in eastern orchards has proven difficult. Similar challenges are predicted for the west.

Invasive pests of tree fruits – past and present

Invasive pests are often considered the "new reality" for tree fruits, but in fact, they are also our old reality. Two more recent arrivals, BMSB and spotted wing drosophila (*Drosophila suzukii*), currently receive high levels of attention. However, a glance at the list of tree fruit pests not native to western North America includes almost all significant pests we deal with today (Table 1). In this sense, the invasion of BMSB is business as usual.

The longer an invasive pest has been in a new area, the greater the opportunity for study and finding pest management solutions. However, those solutions may still represent only a temporary truce in the ongoing and dynamic interaction of pest and crop. A notable example is codling moth (*Cydia pomonella*), the key pest of pome fruits in western North America (if not the world). This species has held key pest status for well over a century in Washington. The first 'solution' to the problem was the arsenical pesticides. These were followed by DDT and then by the organophosphates, but resistance occurred to a greater or lesser extent to all of these groups. In the early 1990s, both sterile insect release (Dyck *et al.*, 1993) and mating disruption for codling moth were implemented (Brunner *et al.*, 2002). Both of these novel and non-insecticidal methods of control have strengths and weaknesses, and future improvements are likely. In contrast, we still struggle with another invader, pear psylla (*Cacopsylla pyricola*), in a cycle of new insecticide introductions followed by resistance. Familiarity with a pest does not a guarantee a permanent solution.

The arrival of a new invasive pest initiates a somewhat predictable sequence of events (Figure 1). The east has already passed through all the early stages of the invasion sequence. Here in the west we are in the Expansion/Crop Damage

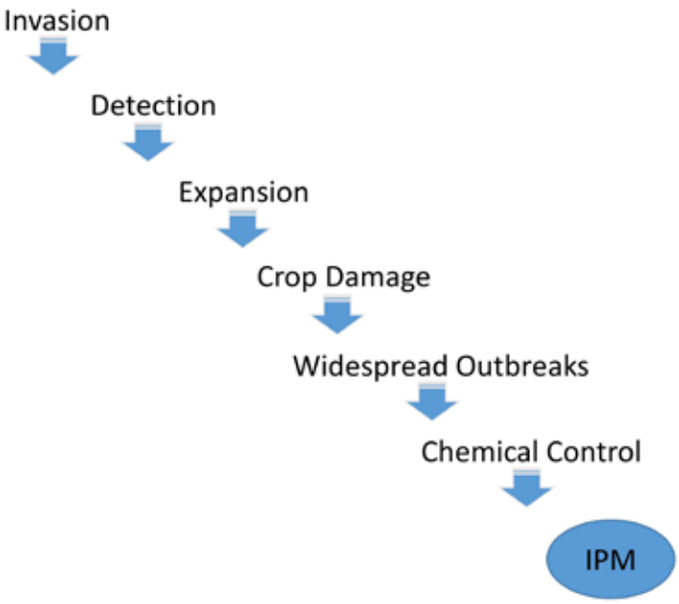

Figure 1. Stages of IPM following invasion of a new pest species.

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Table 1. Invasive pests of western tree fruits, 2018.

Pest		Place of Origin	Time of Introduction/ detection
Codling moth	*Cydia pomonella* (L.) (Lepidoptera: Tortricidae)	Asia Minor	1700's
Oriental fruit moth	*Grapholita molesta* (Busck) (Lepidoptera: Tortricidae)	China	ca. 1913
Eyespotted bud moth	*Spilonota ocellana* (Denis & Schiffermüller) (Lepidoptera: Tortricidae)	Europe	<1840
European leafroller	*Archips rosanus* (L.) (Lepidoptera: Tortricidae)	Europe	1800s
Peach twig borer	*Anarsia lineatella* Zeller Lepidoptera: Gelechiidae	Europe	<1860s
Pear psylla	*Cacopsylla pyricola* (Foerster) (Hemiptera: Psyllidae)	Europe	1932
Campylomma	*Campylomma verbasci* (Meyer) (Hemiptera: Miridae)	Europe/Asia	<1886
Pear slug	*Caliroa cerasi* (Linnaeus) Hymenoptera: Tenthredinidae	Europe	[Colonial]
Dock sawfly	*Ametastegia glabrata* (Fallén) (Hymenoptera: Tenthredinidae)	Europe	<1862
European earwig	*Forficula auricularia* (L.) (Dermaptera: Forficulidae)	Europe	
European red mite	*Panonychus ulmi* (Koch) (Acari: Tetranychidae)	Europe	<1911
Pear rust mite	*Epitrimerus pyri* (Nalepa) (Acari: Eriophyidae)	Europe	1800s
Prunus rust mite	*Aculus fockeui* (Nalepa & Trouessart) (Acari: Eriophyidae)	Europe	1800s
Pearleaf blister mite	*Phytoptus pyri* Pagenstecher (Acari: Eriophyidae)	Europe	<1900
Rosy apple aphid	*Dysaphis plantaginae* Passerini (Hemiptera: Aphididae)	Europe	ca. 1870
Green peach aphid	*Myzus persicae* (Sulzer) (Hemiptera: Aphididae)	Europe	
San Jose scale	*Quadraspidiotus perniciosus* (Comstock) (Hemiptera: Diaspididae)	China	1870s
Oystershell scale	*Lepidosaphes ulmi* (Linnaeus) (Hemiptera: Diaspididae)	Europe	<1850
European fruit lecanium	*Parthenolecanium corni* (Bouché) (Hemiptera: Coccidae)	Europe	
Shothole borer	*Scolytus rugulosus* (Müller) (Coleoptera: Scolytidae)	Europe	early 1900s
Cherry Bark Trotrix	*Enarmonia formosana* (Scopoli) (Lepidoptera: Tortricidae)	Europe	<1990
Apple ermine moth	*Yponomeuta malinellus* (L.) (Lepidoptera: Yponomeutidae)	Eurasia	ca. 1985
Pear leafcurling midge	*Dasyneura pyri Bouché* (Diptera: Cecidomyiidae)	Europe	1931
Apple leafcuring midge	*Dasyneura mali* (Diptera: Cecidomyiidae)	Europe	1912/1994
Apple clearwing moth	*Synanthedon myopaeformis* (Borkhausen) (Lepidoptera: Sesiidae)	Europe	2005
Spotted wing drosophila	*Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae)	Japan/Korea	2008
Brown marmorated stink bug	*Halyomorpha halys* (Stål) (Hemiptera: Pentatomidae)	China/Korea	1996
[Apple maggot]	*Rhagoletis pomonella* (Walsh) (Diptera: Tephritidae)	eastern US	1980s
[Woolly apple aphid]	*Eriosoma lanigerum* (Hausman) (Hemiptera: Aphididae)	eastern US	1800s

Pests listed in brackets are invaders of the western US from eastern North America.

Stage, but have not yet experienced any major Widespread Outbreaks. We hope to by-pass some of the intermediate steps and transition smoothly into the IPM phase. While the goal is laudable, the path forward is uncertain.

Progress in BMSB research in the Eastern US

From initial studies of BMSB distribution and biology, researchers in the eastern US have made significant progress in many areas of research. Chemical control was initially a top priority to prevent damage in the early phases of pest management (Kuhar & Kamminga, 2017, Nielsen *et al.*, 2008). In the course of these studies it became clear that broad-spectrum pesticides, especially the pyrethroids, were the most effective in preventing damage (Bergh *et al.*, 2016). Contact mortality rates were acceptable, but their short residual efficacy meant frequent re-applications were necessary. This temporary solution was largely responsible for the secondary pest outbreaks seen in high pest pressure situations. Work on the ecology of BMSB characterized it as a 'landscape-level' pest (Aigner *et al.*, 2017, Bakken *et al.*, 2015), based on its behavior of moving through both managed and unmanaged vegetation and using multiple hosts to complete its development. It has also been characterized as a border pest, building up in nearby host plants (often in deciduous wooded areas) and invading orchards over a prolonged period of time. This type of orchard invader has proven challenging to manage with the current native pests, as the bulk of the life cycle may be spent outside the orchard in areas inaccessible to control operations.

Monitoring and thresholds

Monitoring methods were established during this period of intensive research with the development of an aggregation pheromone lure and several trap options. The dual lures (murgantiol and methyl (*E*,*E*,*Z*)-2,4,6-decatrienoate (MDT)) are now considered standard and are available from commercial suppliers. Trap body styles include the 1 m tall black pyramid (staked to the ground), smaller multi-pane traps that may be suspended, and a clear sticky panel on a stake. The pyramid trap tends to capture the highest numbers, but the sticky panel trap has found favor due to lower expense and relative ease of use. BMSB is attracted to lights of various wavelengths (Leskey *et al.*, 2015), but the use of light traps is limited by the need of a power source.

The primary need for monitoring tools (after detection of range expansion and phenology studies) is for use in developing decision-making thresholds. Work on thresholds in tree fruit has been conducted (Short *et al.*, 2017), but will need continual refinement as control practices develop.

Alternative control methods

The next evolutionary step toward IPM is behaviorally based control, focused on attract-and-kill strategies using the new pheromone lures. This approach involves baiting a tree with the newly developed pheromone lure and spraying it frequently to kill immigrating BMSB (Morrison III *et al.*, 2018). While effective in reducing damage, it is also quite expensive because of the high density of lures and frequency of sprays required. The tendency of BMSB to move from unmanaged vegetation into orchard borders also suggests a behaviorally based tactic – perimeter sprays (Blaauw *et al.*, 2015). In this method, only a fraction of the total surface area of the orchard need be treated to minimize damage, resulting in considerable cost savings.

A relatively recent approach proposed is insecticide-infused netting (IIN) (Kuhar *et al.*, 2017). Such netting has been widely used as mosquito nets in sleeping areas as part of malaria prevention efforts. While their uses in these situations have been well studied, their applications in agriculture are still in their infancy. The active ingredient, deltamethrin, has proven quite toxic to all stages of BMSB, and only a few seconds of contact with the netting is sufficient to induce high levels of mortality (Kuhar *et al.*, 2017). Squares of IIN are now used as kill strips in pheromone traps to help improve capture/retention. This approach translates readily to crops where row covers have been used for other purposes, and the engineering requirements (compared to covering orchards) are minimal.

Intermediate between the behavioral control and the INN control methods are the so-called 'ghost traps' (G. Krawczyk, personal communication). These are pieces of netting draped over a pole about 2 m high (providing a large toxic surface area), and baited with one or more pheromone lures. These traps may be used for monitoring or (potentially) control, and have the advantage of placement outside the orchard, so there is no sacrificed pheromone-baited tree.

Biological control

Lastly, biological control has been intensively studied in the areas where BMSB has caused damage. This has focused largely on predators and parasitoids of the eggs, which appear to be a vulnerable stage. In some situations, predation causes significant mortality, but the native North American parasitoids have difficulty attacking BMSB egg masses. Not only are BMSB eggs not preferred by many species, but the rate of successful development is low, constituting an 'evolutionary trap' for the parasitoid (Abram *et al.*, 2017). BMSB eggs are presumed to have some defensive mechanism that prevents the native parasitoids from developing to adulthood.

In contrast, several species of Asian egg parasitoids (in the genus *Trissolcus*) (Hymenoptera: Scelionidae) have been identified in foreign exploration for classical biological control agents as likely candidates for BMSB biocontrol. These were imported to the US and placed in quarantine facilities starting in 2007 (Talamas *et al.*, 2015) to determine the extent of non-target effects on North American stink bugs. While there was a distinct preference for BMSB egg masses, the exotic parasitoids were not quite as species-specific as had been hoped,

Figure 2. Detections of adventive *Trissolcus japonicus* populations in the continental United States, 2014-2018.

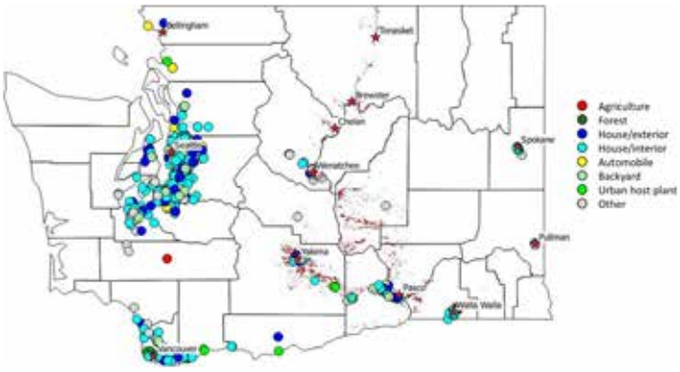

Figure 3. Distribution of BMSB in Washington State as determined by citizen reports and targeted pheromone sampling, 2018 (small red dot indicate apple orchards).

and at this writing, researchers are still awaiting permission to release them from quarantine.

In the meantime, one species of Asian parasitoid, *Trissolcus japonicus* was detected in the eastern US (Maryland) in 2014 (Talamas *et al.*, 2015), and in the western US (Washington State) in 2015 (Milnes *et al.*, 2016). Within a few years, such adventive populations were found in a number of nearby sites; to date a total of 10 states and Washington DC have detected *T. japonicus* within their boundaries (Figure 2). The success of this parasitoid in suppressing BMSB in its native range (Zhang *et al.*, 2017) and its serendipitous spread in North America led the research community to focus on this species as key to future biological control efforts of BMSB (Walgenbach *et al.*, 2016). Detections have been made in a variety of climates, indicating *T. japonicus* may adapt readily to new areas, a perennial problem with classical biological control.

Current distribution and pest status in Washington

The expansion of BMSB in the continental US in the past few years has made it easier to name the few states (MT, WY, SD, OK, LA) where it has not yet been detected. Most states track the expansion within their borders, and Washington is no exception (Figure 3). The pattern of spread has followed predictable lines given the propensity of this species to

hitchhike on vehicles (in addition to its considerable flight capacity) (Wiman *et al.*, 2014). The first detection occurred in 2010 in Vancouver, WA, across the Columbia River from Portland, OR, where it was well established. From there, detections spread northward along the I–5 corridor west of the Cascade Mountains and east along the Columbia River. Detections in the arid interior regions east of the Cascades are increasing, primarily (if not exclusively) in urban/suburban areas. This likely reflects both movement by human agency and the presence of favored host trees planted in urban landscapes and parks. The general absence of deciduous forests in eastern Washington, as occur in the eastern US, may restrict the number of suitable habitats. Like many states, Washington currently employs a combination of citizen reports (verified by a photo or specimen) and active trapping with pheromone lures to determine the range and population density in the state.

The pest status of BMSB in Washington is currently listed as 'Agricultural and nuisance problems' (http://www.stopbmsb.org/where-is-bmsb/state-by-state/). The nuisance problems are (for the moment) confined mostly to western Washington, where homeowners report invasions of houses and structures by overwintering adults (Figure 3) and the destruction of produce in backyard gardens. Damage to commercial agriculture has only been verified in western Washington from small, diversified farms in the Vancouver area. Damage to crops in the primary fruit-growing districts of eastern Washington has not been verified, although several reports have been noted. BMSB infestations in this area are expected to occur eventually, although the level of risk is unknown, and may be different than that experienced by orchards in the mid-Atlantic area.

Research Focus for Washington Tree Fruits: Building on the Eastern Foundation

Phenology

After expansion and distribution of BMSB in Washington, the next task is to establish seasonal phenology, which will inform IPM decisions. Most areas of the US report 1–2 generations per year, but there is a surprising degree of ambiguity about this. Phenology data are currently being gathered using pheromone traps to clarify this important aspect, as future IPM programs will need this to time sampling and control measures. A phenology model specific to the Pacific Northwest is planned (V. Walton, personal communication) to complement the model developed by Nielsen *et al.* (2016). Phenology data are being gathered from several sites in Washington and Oregon, with representation from both mild winter temperate climates and the arid interior.

Alternative controls

Given that the pesticidal options for BMSB control are well explored and less appealing from an IPM standpoint, control research in Washington has focused on alternative measures. Preliminary work by Krawczyk in Pennsylvania indicated some potential benefit from net barriers interposed between an unmanaged source (e. g., woodlots) and a sink (an orchard). He noted that such barriers to immigration appeared to be more effective if the height of the source (e.g., corn) was similar or lower than the sink, whereas barriers between 40 ft deciduous trees and 12–15 ft orchard trees did not appear to provide much benefit. This observation gave rise to the hypothesis that Washington orchards near unmanaged habitats, which are composed largely of grasses, herbaceous flowering plants, and small shrubs, might benefit from exclusion barriers. Because BMSB has not yet become established in tree fruit growing districts with this type of environment, native stink bugs (especially *Euschistus conspersus*) are being used as model systems to study the efficacy of barriers (Figure 4).

Because our assumptions were based to some extent on the relative height of source and sink, more detailed observations were clearly in order. Studies are underway that look at the height of stink bug capture from extra-orchard habitat into orchards. These migrational studies have revealed a much longer period of movement than previously realized, and a more bi-directional exchange between the two areas.

The next evolutionary step from a single wall barrier is a complete net enclosure (Figure 5), which is a growing trend in Washington orchard production. This is the functional equivalent of a row cover in vegetable crop, but with a much greater investment in engineering and infrastructure. The cost of installation (estimated at ca. $10,000/acre; (Hansen, 2014)) is daunting, but provides multiple benefits to the fruit grower. The building of such structures began many years ago in Europe with the goal of preventing hail damage (Scott, 1988); more recent applications involve the control of codling moth (Alaphilippe *et al.*, 2016) . In Washington's arid climate, the primary impetus has been sunburn prevention, which can damage >40% of the crop (Kalcsits *et al.*, 2017). Even if this is the most compelling economic argument in our climate, benefits of a complete enclosure include reduced off-target drift of sprays, reduced wind damage of fruit, fewer incursions of pest vertebrates (rodents, deer, birds), reduced heat stress of orchard workers, and insect exclusion. Unsurprisingly, natural enemies may be among the insects excluded, and secondary pest outbreaks have been noted inside the cages, especially woolly apple aphid. Finding a way to restore biological control inside complete net enclosures has become an additional objective of this research.

As shade netting was being explored both for its horticultural and entomological uses, the concept of IIN became more widely recognized, and the similarity of these approaches suggested combining the two. One potential problem of IIN that was recognized at the outset was the non-target effects on beneficial species, especially pollinators. Such studies are in progress in Washington and elsewhere. Our compromise was to reduce the total surface area of the IIN to just a series of flaps in the barrier (Figure 6), with plain netting comprising the majority. In theory, this will target only those insects that walk upward after encountering the net, rather than killing all that alight for more than a few seconds.

Biological control

The detection of *T. japonicus* in Vancouver, WA (Milnes *et al.*, 2016) (Figure 7) made it possible to pursue research on biological control using this Asian parasitoid. Sentinel egg mass surveys (Figure 8) were continued to determine the

Figure 4. Single wall net barrier (ca. 3.7 m high) between unmanaged vegetation and an apple orchard, Manson, WA.

Figure 7. *Trissolcus japonicus* female ovipositing in a BMSB egg mass.

Figure 5. Complete net enclosure over an orchard, north-central Washington, 2018.

Figure 8. Sentinel egg mass survey for BMSB parasitoids.

Figure 6. Flaps of black INN retrofitted to a single wall barrier.

distribution in the state. In 2017, an intensive survey of established urban populations of BMSB revealed the presence of *T. japonicus* in the town of Walla Walla, WA, over 200 miles east of the Vancouver sites. This discovery in the arid growing districts east of the Cascades, where the vast majority of Washington's tree fruits are grown, was a hopeful indicator that *T. japonicus* could establish in this climate (as BMSB had already done).

Climate control?

The heat and aridity of eastern Washington have led to speculation that BMSB will be unable to thrive here as a landscape-level pest. The deciduous forests and summer humidity characterizing its current range are absent here, and the plant communities typical of the region are xerophytic and foreign to BMSB. However, the ubiquity of irrigation and riparian corridors along the many waterways draining into the Columbia River provides elements of a more temperate environment amenable to invasion. Even the vast stretches of presumably inhospitable grassland, shrub-steppe, and basalt are interspersed with surprisingly diverse pockets of plant life (Figure 9) that vary with slope, aspect, elevation, and proximity to water. Indeed, the prevalance of BMSB on shade trees planted in urban areas indicates that the desert climate in of itself will not restrain its spread. Thus, the million-dollar question presents itself: what is the risk of mid-Atlantic-style buildups of BMSB populations in unmanaged habitats and subsequent

Figure 9. Plants common to eastern Washington's shrub-steppe.

Figure 10. BMSB feeding on *Amelanchier alnifolia*, a small-fruited Rosaceous shrub common on the slopes of the Columbia River.

invasions of cropland? Preliminary investigations indicate that a number of native plants species commonly found near orchards are potential hosts for BMSB (Figure 10), and ongoing research is investigating the suitability of key arid-adapted plant species for BMSB feeding and reproduction.

Prospects for IPM

Washington is home to a vibrant tree fruit industry, crops which are recognized as being among those at the highest risk to BMSB damage. As BMSB inexorably spreads throughout our state, we are motivated to take any steps possible to prepare for managing this pest. Preserving and perpetuating the current level of IPM begun in the 1990s with the implementation of codling moth mating disruption (Brunner *et al.*, 2002) is one of the highest priorities. Invasive species represent a clear and present danger to IPM programs, especially when they entail the use of broad-spectrum pesticides. While these will still be in our toolbox in case of need, we focus our research on non-pesticidal strategies: *biological control*, which should help prevent the outbreak conditions experienced in the mid-Atlantic region in 2010, and *physical exclusion*, which may minimize damage for conventional and organic growers alike. For now, we plan to continue releases of *T. japonicus* in

urban areas and orchard borders, where they are less likely to be impacted by routine sprays, in order to suppress outbreaks proactively. As we modify our orchards to cope with sunburn, net structures will become more common, and can be adapted for BMSB control. BMSB's presence in the Central Valley of California indicates it can tolerate conditions that are even hotter and drier than those in central Washington. If BMSB proves as adaptable to the sagebrush steppe as it has to other environments, then the risk of damage may still be considerable.

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Adrian Marshall is a Ph.D. candidate in WSU's Department of Entomology. His dissertation research focuses on physical exclusion of stink bugs and other pests, and the non-target effects of netting, both with and without insecticide infusion. He also studies the immigration behavior of stink bugs to inform how netting could be most effectively deployed.

James Hepler is a Ph.D. candidate in WSU's Department of Entomology investigating landscape ecology and host plant preference of brown marmorated stink bug, using a combination of observational studies and gut content analysis. He is also investigating the complex of native stink bug species to aid in determining the effects of the invasion of this new exotic species, and exploring monitoring and control with insecticide-infused netting.

Joshua Milnes is a M.S student in WSU's Department of Entomology with a focus on classical biological control. He discovered the first known population of *Trissolcus japonicus*, an important exotic parasitoid of brown marmorated stink bug, on the west coast of America. His thesis research investigates the natural and artificial spread of this parasitoid in the state, and the non-target effects of *T. japonicus* on native stink bug species.

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REGEV™ – A NEW POTENT HYBRID PRODUCT FOR THE CONTROL OF PLANT DISEASES: A MINI REVIEW

Moshe Reuveni, STK, bio-ag technologies, Petah Tikva, Israel and Shamir Research Institute, University of Haifa, Israel describes a combination product containing a chemical fungicide and a natural plant extract as an effective way to combat plant disease and the onset of resistance

Keywords: Difenoconazole, disease control, *Melaleuca alternifolia*, resistance management, tea tree oil

Moshe Reuveni

Introduction

The global search for plant-protection solutions that are both environmentally safe and efficacious is driven by the need to supply food to the ever-growing world population. The call for chemical load reduction is an important aspect of sustainable agriculture. The natural extract of the tea tree plant (*Melaleuca alternifolia*), i.e. tea tree oil (TTO), contains many components – mostly terpenes and their alcohols – and has been shown to be an effective antiseptic, fungicide and bactericide (Carson *et al*. 2006; Carson *et al*. 2002; Cox *et al*. 2001; Hammer *et al*. 2004). It was found to be effective against a broad range of plant-pathogenic fungi in numerous crops, including vegetables, herbs, grapevines, bananas and fruit trees (Reuveni *et al*. 2009; Vardi & Reuveni 2009; Reuveni & Tirosh, 2012).

New effective alternatives to existing products, that can provide different and multiple modes of action with a lower risk for fungicide resistance and which place a smaller chemical load on the environment concomitantly with consistent disease control, are required to increase options for the control of plant diseases. The newly developed Regev™ EC (STK, Petah Tikva, Israel), a hybrid formulation containing 200 g/L difenoconazole plus 400 g/L tea tree extract, is a unique formulation which provides various mechanisms of action for improved efficacy.

Activity and MOA

Regev, at suitable concentrations, significantly inhibited spore germination or lesion development on treated leaves, and limited the expansion of lesions caused by various fungi. Diseases effectively controlled by Regev include powdery mildews (caused by fungi in the order Erysiphales), apple scab (*Venturia inaequlis*), Black Sigatoka in banana (*Mycosphaerella fijiensis*), species of *Alternaria*, *Cercospora*, *Botrytis*, *Rhizoctonia*, *Pyricularia*, *Helminthosporium*, *Sclerothium* and more.

The fungicidal and antimicrobial activities of the tea tree oil against fungal pathogens are derived from its ability to inhibit respiration and disrupt the permeability barrier presented by the membrane structures of living organisms (Carson *et al*. 2006; Carson *et al*. 2002; Cox *et al*. 2001). Tea tree oil was found to disrupt the fungal cell membrane and cell wall in plant tissue infected with phytopathogenic fungi (Reuveni *et al*., 2012, Reuveni & Tirosh, 2012). This explains why it exhibited outstanding curative activity against fungal pathogens, making it a unique product and enabling growers to use it even when the disease is already visible on the tissue.

Difenoconazole affects the fungal cell membrane by inhibiting ergosterol biosynthesis. The mode of action of sterol biosynthesis inhibitors, including difenoconazole, has been investigated extensively: they inhibit C-14 demethylation of lanosterol or 24-methylenedihydrolanosterol, a biosynthesis step that occurs during conversion of lanosterol to ergosterol, the final product of fungal cell membrane sterol synthesis (Koller & Scheinpflug 1987). The different modes of action of TTO and difenoconazole, i.e. a combination of a natural product with broad-spectrum activity (TTO) and a traditional site-specific chemical, makes Regev an effective and unique tool for resistance management which is suitable for Integrated Pest Management (IPM) programs. This combination results in a reduced synthetic chemical load on the environment compared to other mixtures based on two traditional chemicals.

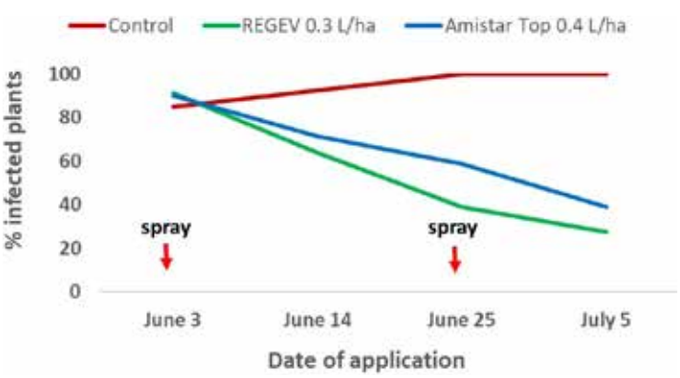

Figure 1. Efficacy of two foliar applications of Regev against *Rhizoctonia solani* in rice.

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Figure 2. Infected plants of control untreated (right) and Regev-treated plants (left).

Resistance management

Because Regev has a unique multiple functional activity and presents a very low probability for development of resistance or cross-resistance in plant pathogens, it could be an important tool in preventing the development of resistance during the growing season. Its application can be rotated with products that exhibit different modes of action and to which fungal pathogen populations have shown a loss of sensitivity, so that the population of individuals that are less sensitive to chemical products can be reduced. Studies have also shown that a combination of TTO together with difenoconazole improved the efficacy of difenocanozole, including against fungal populations which exhibited a lower sensitivity to difenoconazole.

Field trials

Regev is currently used for controlling a broad range of diseases on arable crops, cereals, fruits and vegetables. Numerous trials have been conducted with various crops and pathogens and in different countries.

Figure 1 presents an example of excellent Regev activity against *Rhizoctonia solani* in rice. This trial was conducted in Colombia in 2016 under high disease pressure, and included two foliar sprays of either Regev or the ready-mixed fungicide Amistar Top (azoxystrobin plus difenoconazole), at the recommended rates. Both products effectively controlled *Rhizoctonia* following the spray applications and significantly reduced the number of infected plants compared to an untreated control. However, Regev provided better disease control (Figures 1 and 2).

Registration

Regev is already registered in Israel, Serbia and various Latin American countries for various crops and diseases. It is currently in the process of registration in Brazil, the USA and the EU.

Summary

The preventive and curative activity of Regev, together with the indirect activity via the host plant either by systemic resistance or enhancing plant growth and hence yield, and the fact that it is reliable, leaves little residue and provides significant added value to growers, make Regev an important component in plant disease control. Its activity has been shown on a wide range of plant diseases and can be an attractive alternative for controlling various diseases.

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Professor Moshe Reuveni received his Ph.D. in Plant Pathology from the Department of Life Sciences of Bar-Ilan University in Israel in 1982. As a post-doctoral research fellow and associate, Moshe spent four years at the Plant Pathology Department at the University of Kentucky, USA. He continued to work for three years as a senior scientist for Plant Biotechnology Industry in Israel. In 1990, Moshe joined the Golan Research Institute of Haifa University as senior plant pathologist; in 2000 he was appointed as the head of the Institute.

Since 2002 he has been involved in developing new bio-pesticides based on plant extracts, including Timorex Gold, in the STK Group, where he holds the position of Chief Scientist.

Similar articles that appeared in *Outlooks on Pest Management* include – 2012 **23(1)** 30; 2016 **27(2)** 136

Global crop protection chemicals market 2017–2018 & forecast to 2023 – market value is expected to reach $77.3 billion

The "*Crop Protection Chemicals Market: Global Industry Trends, Share, Size, Growth, Opportunity and Forecast 2018–2023*" report has been added to ResearchAndMarkets.com's offerings. The global crop protection market reached a value of $57.7 billion in 2017. The market value is further expected to reach $77.3 billion by 2023, exhibiting a CAGR of around 5% during 2018–2023. Based on the product type, the market has been segmented into herbicides, fungicides, insecticides and others. Currently, herbicides dominate the market, holding the largest share. Based on the origin, the market has been segmented as synthetic and natural. Synthetic crop protection chemicals currently represents a bigger segment. Based on the crop type, the market has been segmented as cereal and grains; oilseed and pulses; fruits and vegetables; and others. Based on the form, the market has been segmented as solid and liquid. On the basis of mode of application, the market has been segmented as foliar spray, seed treatment, soil treatment and others. (For more information: Research and Markets, Guinness Centre, Taylors Lane, Dublin 8, Ireland; Website: www.researchandmarkets.com)

CBNB

Biorationals

Terramera launches innovative plant-based pest control product for agriculture

Terramera, the leader in Technology for Clean Food, announced the US Environmental Protection Agency approved registration of their novel, broad-spectrum agricultural insect, fungal disease, and mite control product RANGO, which was launched commercially on 20 November 2018. RANGO contains highly effective, plant-based active ingredients built into a proprietary formulation with superior mixing and handling qualities. RANGO protects vegetables, fruits, berries/grapes, tree crops, row crops, ornamental plants and greenhouse/horticultural crops against a broad range of plant pests and diseases. RANGO is OMRI Listed for use in organic agriculture, can be used as an effective tool for conventional farming, and is essential for any Integrated Pest Management (IPM) programme. The newest product in the expanding Terramera portfolio, RANGO has a unique mode of action, superior emulsion and stability properties, a zero-day pre-harvest interval and 4-hour re-entry, protecting against and treating a wide variety of insects, including aphids, mites, thrips, caterpillars, whiteflies, and fungal diseases such as botrytis, fusarium and powdery mildew. (For more information: https://www.terramera.com)

CBNB

Global biostimulants market to exhibit 12.8% CAGR owing to strong potential in developing regions

The global biostimulants market is anticipated to grow at a stellar rate owing to rising demand of the market product during the forecast period 2017 – 2025. According to Transparency Market Research (TMR), the players in the market are likely to have numerous growth opportunities in the years to come. Major players in the market in order to expand their stretch to various parts of the world, are going into a strategic partnership such as mergers, and acquisitions. Huge market potential is drawing attention for new market players to enter in the market. Presence of numerous small, medium, and established players have resulted the market to be highly fragmented in nature. Some of the major players in the market are Syngenta, Italopolina SpA, Koppert Biological Systems, Premier Tech Ltd, Kepgrow, Agriculture Solutions Inc, and Biolchim SpA. According to TMR, the global market for biostimulants is anticipated to expand at a robust rate of 12.8% CAGR during the assessed period. The market which was valued at $5.93 billion in recent years is likely to rise and touch $20.05 billion by the end of the tenure period. (For more information: www.transparencymarketresearch.com)

CBNB

2018 bioherbicides market size, share & trends analysis report – global segment forecasts to 2024

The "*Bioherbicides Market Size, Share & Trends Analysis Report By Application (Grains & Cereals, Oil & Seeds, Fruits & Vegetables, Turf & Ornament), By Region, Competitive Landscape, And Segment Forecasts, 2018–2024*" report has been added to ResearchAndMarkets.com's offerings. The global bioherbicides market size is expected to reach $4.14 billion by 2024. The market is estimated to expand at a strong CAGR of 15.7% during the forecast period. Increasing preferences for organic farming along with rising consumption of eco-friendly weed control products is projected to drive the market in the near future. Innovations in organic farming practices for sustainable crop cultivation are also expected to bolster the market growth over the forecast period. Shifting consumer preference toward greener and nutritional diet is fuelling the demand for organically produced food grains and vegetables, which, in turn, will boost the market growth. Bioherbicide products are also used in gardening, maintenance of golf course, and clearing of railway tracks. This is expected to further contribute toward the industry development in turf and ornament sector. Various regulatory norms and policies to promote organic farming are projected to increase product demand in the North America and Europe regions. However, availability of cheap, chemical-based herbicides may hinder the market growth. Fruits and vegetables accounted for over 27% of the global industry in 2015 and emerged as the largest application segment due to extensive product usage. North America led the global market in 2015 with a demand share of 29.5%. It is estimated to expand further on account of government initiatives and high consumer awareness about health and environmental issues. Asia Pacific is anticipated to witness the highest CAGR of 16.1% in the coming years. Product demand in Australia is anticipated to significantly contribute to the growth of this region. Key companies operating in the industry are Bioherbicides Australia (BHA), HerbaNatur Inc, Hindustan Biotech Ltd, Fitz Chem Corp, Marrone

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Bio Innovations, Emery Oleochemicals, Engage Agro USA, and Mycologic Inc. (For more information: Research and Markets, Guinness Centre, Taylors Lane, Dublin 8, Ireland; Website: www.researchandmarkets.com) **CBNB**

Fungicides

Sumitomo and BASF to register Pavecto fungicide

In the EU, BASF and Sumitomo Chemical are partnering to submit a registration application for metyltetraprole, a new fungicide compound discovered by Sumitomo. The fungicide, which will be trademarked as Pavecto, is effective against a wide range of diseases like Septoria leaf blotch in wheat. Subject to regulatory clearance, the companies anticipate to launch Pavecto-based products in the EU market beginning 2022. (For more information: BASF SE, D-67056 Ludwigshafen, Germany; Tel: +49 (0) 621 600; Website: http://www.basf.com and Sumitomo Chemical Co Ltd, Sumitomo Building, 5–33, Kitahama 4-chome, Chuo-ku, Osaka 541-8550, Japan; Tel: + 81 6 6220 3891; Fax: + 81 6 6220 3345; Website: http://www.sumitomo-chem.co.jp)

CBNB

Syngenta introduces Saltro

Syngenta has launched Saltro, a new adepidyn-containing seed treatment fungicide for control of diseases including Bakanae in rice (*Gibberella fujikuroi*), Sudden Death Syndrome in soybeans (***Fusarium virguliforme***) and Blackleg in canola (*Leptosphaeria maculans*). Adepidyn exhibits succinate dehydrogenase inhibitors mode of action. Initial registrations of Saltro are anticipated in Canada and the US during 2019 and in Australia in 2020. (For more information: Syngenta International AG, Basel, Switzerland; Tel: +41 61 323 5883; Fax: +41 61 323 5880; Website: http://www.syngenta.com) **CBNB**

Herbicides

BASF releases next generation of weed control

The Pest Management Regulatory Agency registered BASF's new Heat Complete (saflufenacil plus pyroxasulfone) pre-seed/pre-emerge herbicide for use on lentils, field peas, soybeans and corn in Canada for the 2019 crop season with the label expansion of one of the components. Heat Complete's two modes of action – Group 14 and Group 15 – provide broad-spectrum burndown of tough weeds, including cleavers (*Galium aparine*), volunteer canola (*Brassica napus*), kochia (*Bassia scoparia*) and wild buckwheat (*Fallopia convolvulus*), as well as extended residual activity on key broadleaf and grass weeds such as redroot pigweed (*Amaranthus retroflexus*) and wild oats (*Avena fatua*), allowing for better efficacy of growers' in-crop applications. In addition to Heat Complete, the Advanced Weed Control portfolio includes Heat LQ (saflufenacil), Solo Ultra (imazamox plus ethoxydim), Odyssey Ultra NXT (imazamox plus imazethapyr plus sethoxydim), Viper ADV (imazamox plus bentazon), Engenia (dicamba) and Armezon (topramezone). (For more information: BASF SE, D-67056 Ludwigshafen, Germany; Tel: +49 (0) 621 600; Website: http://www.basf.com)

CBNB

Global glyphosate market will reach $10.88 billion by 2024

Zion Market Research has published a new report titled "*Glyphosate Market for Conventional Crops and Genetically Modified Crop Applications: Global Industry Perspective, Comprehensive Analysis, and Forecast, 2017–2024*". According to the report, global glyphosate market was valued at $7.24 billion in 2017 and is expected to reach $10.88 billion in 2024, growing at a CAGR of 6.2% between 2018 and 2024. In terms of volume, the global glyphosate market stood at approximately 785,300 tonnes in 2017. Emerging markets in developing countries are likely to set opportunities for the market over the next few years. Based on application, conventional crops led the global glyphosate market in 2017. It accounted for above 72% share of the total volume consumption of the market in 2017. Moreover, changing the perspective of farming coupled with escalating demand for good yield is expected to accelerate the market's growth during the coming years. In addition, the genetically modified crops segment is an important outlet that is expected to influence the market consumption over the next few years due to the rising massive demand for genetically modified crops in the emerging markets of less developed countries. The Asia Pacific was the dominating market of glyphosate during the past decades. India is likely to augment the exponential growth of the glyphosate market over the future years due to the growing agricultural activities and strong support from the government bodies in the region. North America is a second leading market for glyphosate. Government approval for the usage of glyphosate and its formulations is expected to accelerate the demand for glyphosate during the next few years. Europe is also an important outlet for glyphosate. Ongoing research and strategic innovation for product portfolio of glyphosate by major producers will trigger the market's margin within the forecast period. The Latin America market for glyphosate is expected to exhibit moderate growth over the forthcoming years. The Middle East & Africa is expected to achieve sustainable growth in the future years. Some of the major players of the global glyphosate market include Monsanto Company, DowDuPont, Nantong Jiangshan Agrochemical & Chemicals, Nufarm Ltd, Syngenta, BASF, Bayer (Monsanto), Zhejiang Xinan Chemical Industrial Group, SinoHarvest, and Anhui Huaxing Chemical Industry, among others. (For more information: https://www.zionmarketresearch.com)

CBNB

Molluscicides

$725+ M molluscicides market by type, application, form and region – global trends & forecast to 2023

The "*Molluscicides Market by Type (Chemical (Metaldehyde, Methiocarb,*

Ferric Phosphate) and Biological Molluscicides), Application (Agricultural and Non-Agricultural), Form (Pellets, and Liquid & Gel), and Region – Global Trends & Forecast to 2023" report has been added to ResearchAnd Markets.com's offerings. The molluscicides market is estimated at $587.8 M in 2018 and is projected to reach $727.8 M by 2023. It is projected to grow at a CAGR of 4.4% from 2018 to 2023. The market is primarily driven the increased commercial production of horticulture crops such as fruits, vegetables, herbs, and nuts in recent years. The demand for such crops of refined and varied characteristics has been increasing worldwide, thereby increasing the market for molluscicide products. On the basis of application, the agricultural segment is projected to grow at the higher CAGR. Snails impact most horticulture crops; this necessitates the adoption of agrochemicals for slug and snail control. Moreover, since the investment in production is usually higher in horticulture as compared to field crops, the growth in the horticulture industry becomes a driver for the market for molluscicides. Based on type, the biological molluscicides segment is projected to be the fastest-growing segment during the forecast period. The increasing awareness about biological crop protection products has not only resulted in increased use of snail and slug control products but has also led to awareness about the potential for more profitable opportunities with minimum loss. Based on form, the pellets segment is projected to be the fastest-growing segment during the forecast period. Pellet formulations are usually recommended for small as well large cures, as dusting powders are ready for use; are more easily applied compared to other methods; are easily supplied; and are available in proper small packs, which are reasonably priced and easy to use. Asia Pacific is projected to be the fastest-growing market between 2018 and 2023. The usage of molluscicides is increasing gradually in developing economies due to continued growth in the major Asia Pacific economies and the increasing awareness about the use and benefits of molluscicides. The dominant form of agriculture in this region is wet-rice cultivation. These crops require a large amount of molluscicides. Thus, as food production is projected to increase in this region, so is the consumption of molluscicides. (For more information: Research and Markets, Guinness Centre, Taylors Lane, Dublin 8, Ireland; Website: www.researchandmarkets.com) **CBNB**

Seed treatments

Global seed treatment chemicals market is projected to reach around $5500 M by 2026; high demand for seed treatment chemicals is anticipated to drive market

The global seed treatment chemicals market was valued at around $3500.0 M in 2017 and is anticipated to expand at a CAGR of more than 5.0% from 2018 to 2026, according to a new report published by Transparency Market Research (TMR) titled '*Seed Treatment Chemicals Market – Global Industry Analysis, Size, Share, Growth, Trends, and Forecast, 2018–2026*.' The global seed treatment chemicals market is driven by the rise in demand for seed treatment chemicals among farmers because of their effective usage in crop protection and yield enhancement. The seed treatment chemicals market in Asia Pacific is expected to expand at a CAGR of around 8.0% during the forecast period. Improvement in seed treatment active ingredients, advancement in farming practices, enhanced plant growth, and improvement in crops' stress tolerance are factors estimated to drive the global seed treatment chemicals market during the forecast period. The rise in prevalence of soil-borne diseases and pests causes significant yield losses. High prevalence of soil-borne diseases and pests is anticipated to boost the demand for seed treatment chemicals. Increase in demand for seed treatment chemicals owing to their characteristics of seed disinfection and seed disinfestation from seed-borne and soil-borne pathogenic organisms, and storage insects is projected to drive the global seed treatment chemicals market. A paradigm shift in utilisation rate of biostimulant seed treatment chemicals over pesticide foliar sprays is likely to boost the global seed treatment chemicals market. Implementation of stringent regulations on usage of neonicotinoid-based pesticides in EU countries is anticipated to provide an impetus to the adoption rate of biostimulant seed treatment chemicals. Based on region, the global seed treatment chemicals market can be segregated into North America, Europe, Asia Pacific, Latin America, and Middle East & Africa. In terms of value, North America was the leading region of the global seed treatment chemicals market in 2017. The US accounted for a significant share of the seed treatment chemicals market in the region, owing to the higher adoption rate of seed treatment chemicals for different crops such as wheat, corn, and soybean. Increase in agricultural activities in emerging markets such as India, China, and Australia is driving the seed treatment chemicals market in Asia Pacific. The advent of advanced farming techniques and favourable climatic conditions are anticipated to produce high crop yields in Asia Pacific. The usage of advanced farming techniques such as seed priming, seed coating, and seed pelleting using seed treated products is projected to boost the demand for seed treatment chemicals in Asia Pacific in the next few years. Furthermore, the seed treatment chemicals market in Argentina and Brazil is likely to expand at a rapid pace during the forecast period. Eminent players operating in the global seed treatment chemicals market include BASF SE, Bayer AG, DowDuPont Inc, FMC Corporation, Germains Seed Technology, Nufarm Limited, Platform Specialty Products Corporation, Syngenta AG, UPL Limited, and Valent USA LLC (Sumitomo Chemical Company Limited). (For more information: www.transparencymarketresearch.com) **CBNB**

***CBNB:** These abstracts were taken from Chemical Business NewsBase (CBNB) which is produced by Elsevier, E-mail: cbnb@elsevier.com, Website: http://www.ei.org/databases/cbnb.html

THE BCPC WEEDS REVIEW 2018

Ken Pallett, Editorial Board Member of *Outlooks on Pest Management*

The 55th Annual BCPC Weeds Review "*Building on the basics*" took place at Rothamsted Research on 7th November 2018, with an audience of over 72 invited delegates.

In his chairman's introduction, **Joe Martin**, (AHDB) introduced the review by saying that whereas the focus for 2017 had been the future for weed management, the purpose of 2018 was to look back at the basics of weed biology, some possibly forgotten, which could help address weed management issue in the future.

Prior to this there was a short synopsis of the weather in 2017/18 compared to the 30-year mean (1981-2010) by **Peter Lutman** based on the national weather data from the Meteorological Office website. This was then used to explain agricultural implications. A relatively benign August and September and warm October led to late drilling of autumn crops and favoured pre-emergence herbicides. Planting of spring crops was a challenge due to wet and cool conditions. The hot and dry summer this year has meant that many grain crops matured early, leading to yield losses (estimated at 5% for wheat and 8% for barley).

Bob Froud-Williams an independent consultant presented the 'Biology of Weeds: A ramble down memory lane'. Bob gave a generalised view of the basic life cycle of annual weed species in relation to their fecundity, dispersal, predation and incorporation into the soil seedbank. He considered soil seedbank in relation to size, distribution, persistence and seed dormancy. He also discussed the mechanisms regulating periodicity of germination through cyclic changes in dormancy and subsequent seedling emergence. Finally, Bob presented the effect of maternal environment, positional factors and somatic polymorphism on seed dormancy and germination requirements for some grass and broad-leaved weeds. Much of the data cited was from weed biology research 40-50 years ago and awareness is necessary today when dealing with weed management issues. One further take-home message from this brief review is that each weed species has its own properties and characteristics which must be taken into account in its control.

John Cussans (NIAB) presented Weed Seedbank in Practice. Practices such as spring cropping, fallowing, ploughing, delayed drilling, higher crop seed density and competitive crop cultivars have variable impacts on seedbank with reductions of 80%, 70%, 67%, 37%, 30%, and 27% respectively. Whilst spring cropping gave the highest reduction, it is not always the answer. Understanding the status of the seedbank and where the seeds are distributed within it is key for seedbank management, along with understanding its interaction with environmental conditions particularly soil moisture; the crop and its ability to suppress weeds; the interaction of agronomy, crop rotation and weed control and attention to detail.

Paul Fogg (Frontier) presented the Arable Perspective – Harvest weed seed control – the value of chaff tramlining. This harvest weed seed control (HWSC) approach was pioneered in Australia as part of an integrated approach to control herbicide resistant ryegrass populations (see Walsh 2018. Development of Harvest Weed Seed Control (HWSC) in Australian Cropping Systems *Outlooks on Pest Management* **29**(**3**) 114). Up to 95% of weed seeds can, in theory, enter the combine header and the chaff-fraction discharged at the rear of the machine. A range of approaches have been trialled and are used commercially in Australia, including chaff carts, direct baling, weed seed destruction and chaff tramlining. Using approaches to manage the chaff, rather than spreading it ahead of next season's crop clearly could have value on UK farms, particularly where black-grass (*Alopecurus myosuroides*), ryegrass (*Lolium* spp.) and brome (*Bromus* spp.) are an issue. UK trials focused on chaff tramlining given the low capital outlay, running cost and horse power requirements of the chaff deck. Three clear objectives were set at the start of the project: to investigate the relative amount of black-grass seed retained at harvest; to establish whether the chaff deck would work in a range of UK crops and to see what proportion of the weed seed fraction could be consolidated into the chaff tramlines. After two years of trials, initial results are encouraging. The amount of black-grass retained varies depending on harvest date. Data confirm that weed seeds are being effectively consolidated, such that over the course of a rotation and provided the soil seedbank is left undisturbed we should start to see fields being "cleaned up". Working on 5 farms for harvest 2018, the chaff deck has performed well in a range of combinable crops with the straw either left in the swath or chopped.

Daniel Jones (Advanced Invasives) presented the Amenity Perspective – Japanese knotweed; Ecology and Evidence. Knotweed (*Fallopia japonica*) is the most notorious invasive non-native plant in Britain. Knotweed and its close relatives impose serious management costs on homeowners, developers and large landowners alike. This presentation discussed current research on knotweed rhizome ecophysiology, exploring how this is integral to effective knotweed control and the sustainable management of other rhizome-forming species. Of the nineteen knotweed treatments investigated only 3 were statistically effective and all involved glyphosate: biannual foliar spray; stem injection; and annual foliar spray. Stem injection was dose inefficient at present requiring a much higher glyphosate dose compared to foliar spraying leading to the conclusion that more glyphosate is not better.

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The morning session was completed with the new scientist poster pitch session where students gave a short presentation on their posters.

Helen Metcalfe (Rothamsted Research) used functional traits to model plant communities in arable fields. A range of traits such as plant height, seed size, specific leaf area and flowering time were used to model multiple (136) weed species which were considered a product of environmental and management filters acting on the weed community.

Sophie Hocking (Swansea University) investigated life after knotweed and recovery of invader dominated habitats.

Laura Davies (ADAS) investigating the distribution and presence and potential for herbicide resistance of UK brome species in arable farming.

Vian H. Mohammad (University of Sheffield) demonstrated that drought stress elicited heritable herbicide resistance in the grass weed *Alopecurus myosuroides* (black grass).

After lunch, two presentations focussed on optimising herbicide performance

James Southgate (Syngenta) presented the 'slow and low' campaign for pre-emergent herbicides. Due to the increasing challenges of grassweed control, growers need to take advantage of every cultural and chemical option to keep populations in check. A particular area which can be optimised includes pre-emergent herbicide application timing. Syngenta has spent multiple years thoroughly researching the interaction of water volume, forward speeds, boom height & nozzles on herbicide efficacy. The results of which can be simplified into three key messages Go Low, Go Slow, Get Covered.

Claire Butler-Ellis (Silsoe Spray Applications Unit) reviewed how application technique can influence herbicide performance. This started by a look back in history and a 1994 review concluded a lack of consistency from studies with post-emergence herbicides and often no clear trends identified. Performance improved with reducing droplet size and was most consistent for systemic herbicides. Optimum volume rates were between 100 and 400 L/ha although this was not always clear for all herbicides, although glyphosate had consistently better performance for reduced volume. Since 1994 we have had the introduction of air-induction and angled nozzles, loss of chemicals, improved formulations but it was claimed that we know less now than we did 24 years ago. More recent findings from formulation studies suggest that firstly, low application volumes may give better efficacy performance than high, due to greater plant retention. A higher concentration may be more important than higher 'coverage'. Secondly, where a high level of coverage of the plant surface by water is genuinely beneficial, higher volumes may work best.

The final two presentations covered Weed identification

Firstly, **Stephen Moss** (Consultant) covered the identification of Brome (*Bromus* spp). Spikelet morphology aids identification. Those of sterile or barren brome (*B. sterilis*) and great brome (*B. diandrus*) are wedge-shaped whereas those of soft brome (*B. hordeaceus*), meadow brome (*B. commutatus*) and rye brome (*B. secalinus*) are more oval shaped. Sterile and great brome can be differentiated based on length of spikelet e.g. 40 – 60 mm (sterile) or 70 – 90 mm long (great) (including awns). Sterile brome has a hairless main stem of the panicle (flowering head) whereas that of great brome is hairy. Soft brome has hairy spikelets whereas those of meadow brome are hairless. Rye brome which can have either hairy or hairless spikelets can be differentiated from meadow and soft by a V- or U-shaped seed saucer, which has a white cross section in meadow and soft brome. The panicle of soft brome is compact whereas that of meadow and rye is loose.

The identification of the 5 main species was stated as being important because different control measures are necessary for sterile and great brome compared with soft, meadow and rye brome, in relation to post-harvest cultivations. Label claims for control of different brome species vary. Great brome is generally considered a more challenging species than sterile brome. Rye brome is generally considered a more challenging species than meadow or soft brome. Emergence patterns and seed survival may vary between species and populations.

Secondly, **Sarah Cook** (ADAS) covered the identification and distribution of Umbellifers (*Apiaceae*). Members of the Umbelliferae include edible plants such as carrot, celery, parsley, coriander, parsnips, poisonous plants such as hemlock, hemlock water dropwort and fool's parsley. Currently umbellifers are trending in world of floral art and are prized for their open airy flowers and foliage. There are 73 species of umbellifers described in the BSBI handbook No 2 – Umbellifers of the British Isles, of which less than 10 are commonly found in arable fields. The most likely species are *Aethusa cynapium* Fool's parsley; *Anthriscus sylvestris* Cow parsley; *Anthriscus caucalis* Bur chervil; *Daucus carota* Wild carrot; *Petroselinum segetum* Corn parsley; *Torilis arvensis* Spreading hedge parsley and *Scandix pecten-veneris* Shepherd's needle;

Joe Martin concluded the review by stating that weed control was not straightforward and that we need to learn from the past. There is a need for attention to detail, considering factors such as weather and resistance and to share this information. Finally, there is still a need for research but it was recognised that funds for this are diminishing.

Precision agriculture for sustainability
Edited by Dr John Stafford, Silsoe Solutions, UK.
Burleigh Dodds Science Publishing, Cambridge, UK.
ISBN 978-1-78676-204-7.
£180 for hard back (494pp.).
Electronic copies of Individual chapters can be purchased at £30 each.

The latest multi-author book in their Series in Agricultural Science provides a comprehensive collection of information on important aspects of precision agriculture in three sections. Part 1 has six chapters covering information gathering and processing, Part 2 four chapter on Delivery systems, while the remaining seven chapters relate to Applications. Considering the book in relation to pest management, a large part of the information gathering relates to airborne and satellite remote sensors and using unmanned aerial systems (UAS) for image acquisition. Delivery looks at variable-rate application technologies, spray technology and intelligent machinery for precision farming. Applications refers to specific systems including tillage and weed management systems. This review has concentrated on certain chapters. Each chapter has an extensive list of references and a section on where to look for further information.

The use of unmanned aerial systems (UAS) is examined in great detail concerning the different types of sensors and platforms to monitor crop conditions, soil moisture and leaf parameters as well as the requirements for flight planning and image processing. While accepting that UAS will be used for monitoring a range of crop and environmental factors affecting crops, the interpretation and analysis of data are not straightforward, so further development of such automated procedures might allow much greater adoption, as indicated by the need to define management zones with a crop.

Variable rate application systems were initially developed in the 1980s to adjust the amount of fertilizer or pesticide applied in relation to measured travel speed, but now seek to benefit from automated sensor-based systems. These real-time sensors may ultimately result in a transition from spraying a section of the field to individual nozzle control. This has been shown by laser guided sprayers for orchards, vineyards and nurseries to match spray outputs to crop structures.

Spray technology is discussed with experience from two case studies that involved spot treatment of volunteer potatoes and spraying herbicides confined to certain patches within a crop. Such systems have relied on getting data on maps and programming a sprayer with GPS to spray only in the specified places. With the development of new sensing systems, discussed elsewhere in the book, there is clearly much more research needed to deliver the appropriate dose to specific targets to maximise control of pests. This will require integrating application systems with decision support tools and improved sensing systems. Spraying using UAVs has increased especially on small-scale farms in China, but currently the limited payload has prevented more widespread adoption.

Part 3 covers many different applications, such as precision tillage, nutrient management and irrigation systems. The focus in this review is on two chapters on crop protection and weed management systems. Even with present use of pesticides, crop losses due to diseases, insect pests and weeds still occur reducing yields. In the crop protection chapter it is argued that this is due to the way they are applied uniformly across fields, which can result in over- and under-dosing which in both cases is inefficient and uneconomical and may be an environmental burden. This is undoubtedly true as most pesticides have been sprayed downwards over crops, so the distribution is affected by the umbrella effect of foliage, especially with broad-leaved crops. Thus, site-specific application of pesticides has the potential to reduce their use and may cut costs and ecological impacts. The spatial and temporal heterogeneity of pests is discussed in conjunction with sensing devices for certain types of pests and diseases. However, despite improvement in optical, mechanical and chemical sensors, these systems are not yet ready for practical applications. The situation is somewhat different when considering management of weeds. Sprayers and nozzles on sections of a boom can already be turned on or off to treat specific patches of weeds within a crop as directed by GPS information and a spray map programmed in an on-board computer. Using this technology, huge savings in herbicide can be achieved. Further studies are using UAVs with high resolution cameras to map weed distributions in maize and other crops. On-line detection of weeds is being developed to automate weed control further. Similarly, development of precision hoeing could be the basis for robotic weeders between and within crop rows.

The book ends with a look at the economics of precision agriculture, concluding that precision agriculture technology has the potential for widespread adoption over the next decade, not only on large farms, but medium and small farms will also benefit. A detailed index completes the book.

There is no doubt that technology on farms is undergoing major changes and progress in sustainable agriculture will depend on advances in technology. This book provides an excellent "state of the art" review and forecasts that implementation of precision agriculture will play a major role in helping farmers to increase crop production profitably.

Graham Matthews

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BOOK REVIEW

The UK Pesticide Guide 2019
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The latest edition of *The UK Pesticide Guide 2019* is essential for all those involved in controlling pests and diseases. The printed version, which is an excellent and comprehensive source of UK pesticide information, is ideal to keep in the office or tractor cab, but as usual it provides the information available when it went to press in October 2018, so many will now prefer the BCPC's Online *UK Pesticide Guide*, which is updated throughout the year as new approvals and Extensions of Authorisation for Minor Use (EAMUs) are announced. Subscribers to the on-line version (£70 +VAT) can purchase the printed copy with a 50% discount on the printed version available separately at £55.80 (+p&p). Members of BASIS can gain 2 Continuing Professional Development (CPD) points if they enter their British Agricultural Supply Industry Scheme (BASIS) number when purchasing the Guide and 3 CPD points when subscribing to the UKPG on-line. The online resource enables users to access additional content and links that cannot be accommodated in the book version. Thus maximum approved doses, latest approved timings, harvest intervals, mode of action codes, and Local Environment Risk Assessment for Pesticides (LERAPs) classifications are available as well as a link to the Chemicals Regulation Division (CRD) database of Maximum Residue Levels. Although the publication is aimed at UK farmers, contractors, advisors, growers and local authorities it is a valuable resource for others in many parts of the world that have similar crops and pest problems.

As previously the content is split into easy to find sections:- Crop/pest guide index, Pesticide profiles, Products Also Registered (PAR), Adjuvants, Key information for users of pesticides and Suppliers of pesticides and adjuvants. There are eight new actives, although one is listed only in the PAR section. Sulfoxaflor was introduced in Ireland in 2017 to control aphids and has a 2028 expiry date. Two of the other new insecticides – azadirachtin and buprofezin are old products that were not previously commercialised in the UK. Azadirachtin is based on an extract from the neem tree and has been used principally in India. More modern methods have presumably allowed a more consistent product to be marketed, but the Guide, that lists it to control thrips on ornamental plants, warns that it should be tried only on a small area initially, to check whether it has any adverse effect on the variety treated. The other new insecticide/acaricide is fenazaquin to control spider mites on protected ornamentals.

Two new biopesticidal fungicides are cerevisane, derived from a yeast, and cos-oga, both of which are to be used on protected cucurbits and similar crops against downy mildew and powdery mildew respectively. Oxathiapiprolin and penflufen are both recommended for use on potatoes. Oxathiapiprolin is used to control blight, but it cannot be used with hand-held equipment. Sold in a twinpack it has to be used with amisulbrom or a mixture of cymoxanil and mancozeb to combat the risk of resistance. Penflufen is used as a seed treatment against black scurf and cankers. However, it can only be used in the same field once every 3 years.

Other new products are various combinations of usually two actives, in many cases to replace older products or mixtures that are no longer available or are now listed as demoted to PAR. Significant in the demoted actives are the neonicotinoids – clothianidin and imidacloprid as the UK has followed the EU decision to ban insecticides which have been implicated in adverse effects on bees. The loss of chlorpyrifos is expected to be a problem as it has been very effective in controlling insects in turf on airports as the presence of leatherjackets attracts birds. Other changes are the result of changes in the suppliers of pesticides due to mergers and adoption of new names. Changes in the Guide since the 31st edition in 2018 are listed at the beginning of the Guide. Whether more changes will occur during 2019 will depend on the outcome of the negotiations for the UK to leave the European Union. Fortunately, a key herbicide – glyphosate – remains approved in the UK, despite the concerns raised within the EU, although in many parts of the world its overuse has already led to many important weeds becoming resistant to it. No doubt with more emphasis on integrated pest management (IPM), there will be an increase in biopesticides, but so far few have been sufficiently effective under field conditions to be more widely adopted.

As in previous issues, the Guide provides useful information on adjuvants in Section 4 and pesticide legislation in Section 5. Section 6 has lists of suppliers of pesticides and adjuvants as well as crop and weed growth stages and a key to hazard classifications and safety precautions. The Guide concludes with an index of the proprietary names of products.

Graham Matthews, IPARC

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Agreements, mergers, acquisitions and takeovers

ADM Acquires Gleadell Agriculture and Dunns Ltd, Forms ADM Agriculture Ltd

Archer Daniels Midland Co. has announced it has signed an agreement to purchase the remaining 50% stake of Gleadell Agriculture Ltd, currently jointly owned by ADM and InVivo, including Gleadell's wholly owned subsidiary Dunns (Long Sutton) Ltd. ADM will merge Gleadell and Dunns with ADM Arkady, ADM's UK destination marketing business, and ADM Direct UK, ADM's specialist combinable crop origination business to create ADM Agriculture Ltd, thus strengthening ADM's presence across the UK. The transaction will increase ADM's origination, storage and destination marketing capabilities in the UK, allowing it to serve as the trading partner of choice for even more farmers and customers. Established in 1880, Gleadell Agriculture Ltd is a leading supplier of combinable crops to UK millers, feed compounders and other consumers, and a major exporter of grains, oilseeds and pulses to EU markets and further afield. The company sources crops directly from UK farmers and supplies certified seed and fertilisers. Key assets include port storage and ship loading operations along with extensive pulse and agricultural seed processing and storage. The deal, which is subject to regulatory review, is expected to close during the first quarter of 2019.

ADAMA Moves Closer to Anpon Acquisition

Leading global crop protection company ADAMA Ltd has reported that it is making significant progress toward the potential cash acquisition of Jiangsu Anpon Electrochemical Co., Ltd (Anpon). With 2017 sales of RMB 1,643 million (approximately $234 million) and located in Huai'An City, Jiangsu Province, China, Anpon is a fully backward-integrated manufacturer of key active ingredients used in crop protection markets worldwide, most notably ethephon, pymetrozine and buprofezin, as well as intermediates such as chlor-alkali and other products, with advanced membrane production technology. Anpon is wholly-owned by ChemChina, ADAMA's controlling shareholder. In recent years, ADAMA benefited from Anpon's strong manufacturing position, enhancing its portfolio with products and differentiated mixtures based on Anpon's molecules. The company has been able to build market-leading positions in major markets such as the US, India, and Australia. In China, Anpon brings a portfolio of product registrations to the ADAMA product offering, as well as a domestic sales force. Anpon is fast becoming a key part of ADAMA's global operations, adding significant synthesis and formulation capabilities to the company's China operational hub. Anpon is located adjacent to ADAMA's new global formulation facility, facilitating robust and continuous exchange of expertise and knowledge-sharing between the teams. Work at ADAMA's state-of-the art R&D facility in Nanjing is resulting in major process improvements in the Anpon production processes. The parties have reached initial understandings on the intended transaction and are now working towards signing of a definitive purchase agreement. Any such agreement will be subject to the requisite corporate approval procedures as well as customary closing conditions, including the receipt of all required regulatory approvals. No financial details have been disclosed at this stage.

AMVAC Acquires Herbicide Product Line from Corteva Agriscience

American Vanguard Corporation has announced the acquisition of the quizalofop (QPE) product line of herbicides from Corteva Agriscience, Agriculture Division of DowDuPont. The primary markets for these products are in canola, soybeans, and pulses in the United States and Canada. This transaction includes acquisition of technical registrations, commercial sales information, and the transfer of existing product supply arrangements. Financial terms are not being disclosed. The acquisition of the QPE product line from Corteva Agriscience provides its crop protection business with a portfolio of valuable herbicide brands that hold significant leadership positions in the North American market. These products are complementary to existing glyphosate, glufosinate and 2,4-D use, and are highly regarded for weed and grass control by providing a broad window of application and excellent crop safety. In addition, the new DowDuPont Enlist seed trait technology for corn provides crop tolerance to these QPE herbicides, making them ideal for achieving improved weed management. In this acquisition, AVD has secured a license to market QPE for use alone or with Enlist herbicides over-the-top of the new Enlist corn seeds, a segment that is forecast to grow considerably in coming years. In this transaction, AMVAC also acquired the rights to market in Argentina and Chile which dovetails with its initiative to increase market access in that South American region. AMVAC will continue multiple existing supply agreements for these products and incorporate the sales & marketing of these brands into its expanding portfolio of herbicide offerings.

Arysta LifeScience Establishes Research Station in Vietnam

Arysta LifeScience has announced the establishment of a new field research station in Long An, Vietnam. The station will work with local agricultural researchers and agronomists to help growers improve the quality and yield of their crops. It also demonstrates Arysta LifeScience's effort to innovate and collaborate with an important strategic partner, Hokko Chemical. The new research center will accelerate the development of products to help growers protect rice crops from weeds, insects and diseases. The new station, which will begin operations in early 2019 and will serve customers throughout the world.

Cerexagri inaugurates a €15.6 M investment in Lacq in the presence of its Indian president

On 12 October 2018, Cerexagri, an offshoot of UPL, opened an additional building in Lacq, Pyrenees-Atlantiques, France. The Mourenx project is

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estimated to cost €15.6 M. With this new investment, Cerexagri boosts its copper fungicide production. The project enables each of the two copper salts to be manufactured in devoted plants using recycled copper wire. Moreover, the project allows the construction of a second spray drying tower, which is intended for microgranule fungicides. It also includes the establishment of a new storage hall. The capacity of the Mourenx site is expected to increase from 11,000 tonnes/y to 18,000 tonnes/y. The headcount is predicted to rise to 50 from 42, once the facility is operating at 100% capacity. (For more information: UPL online.com) **CBNB**

Crystal Crop Protection acquires 3 Syngenta insecticide, fungicide brands cbnb

Everstone Capital-backed Crystal Crop Protection of New Delhi, India, has purchased three fungicide and insecticide brands from Syngenta AG's Indian arm. Tilt (propiconazole), Blue Copper (**copper** oxychloride) and Proclaim (emamectin benzoate) brands together have over $20 M of market size.

Evogene announces establishment of Ag-Chemicals subsidiary – AgPlenus Ltd

Evogene Ltd, a leading biotechnology company developing novel products for life science markets, announced on 19 November 2018 the establishment of a new subsidiary – AgPlenus Ltd. All of Evogene's ag-chemical activities focusing on the design and development of effective and safe next generation agrochemical products are being transferred to the new subsidiary, along with access to Evogene's Computational Predictive Biology (CPB) platform. The ag-chemical activities being transferred to AgPlenus, which were initiated in 2014, now consist of a substantial internal and collaborative product pipeline focusing on herbicides and insecticides with a clear go-to-market strategy. This rapid product candidate discovery and early stage development was achieved through the use of Evogene's CPB platform, a well-established disruptive technology platform. AgPlenus' promising product candidate pipeline includes advanced hits for potential new Mode-of-Action (MoA) herbicides and new Sites-of-Action (SoA) for key insecticidal targets. Evogene's existing ag-chemical collaborations with world leading crop protection companies such as BASF and ICL will also be transferred to the new subsidiary. As Evogene disclosed at the beginning of 2018, in order to take full advantage of its broadly applicable CPB platform, Evogene focuses on a number of life science based industries in which its technology can serve as the key differentiator in the development of next generation products. (For more information: Website: www.evogene.com)

CBNB

Sumitomo, Nufarm partner on fungicides distribution

Sumitomo Chemical and crop protection specialist NuFarn have agreed to explore distribution of new fungicide offerings in Poland, Germany and the UK. Sumotomo's metyltetrapole fungicide compound will be branded Pavecto and will be sold along with NuFarm's current fungicide range. The firms target selling these solutions beginning 2022 after securing regulatory approval. (For more information: Sumitomo Chemical Co Ltd, Sumitomo Building, 5-33, Kitahama 4-chome, Chuo-ku, Osaka 541-8550, Japan; Tel: + 81 6 6220 3891; Fax: + 81 6 6220 3345; Website: http://www.sumitomo-chem.co.jp)

CBNB

UPL Corp buys Arysta LifeScience

UPL Corp has agreed to the $4.2 billion acquisition of Arysta LifeScience Inc and its subsidiaries. The transaction will make UPL among the biggest crop protection firms in the world. UPL Corp is UPL's limited international arm. (For more information: UPL online.com)

CBNB

United Phosphorus, Inc Changes Corporate Name to UPL NA Inc

UPL, a global leader in the production of high-quality crop protection products, announced that the company changed the name of its North American operation from United Phosphorus, Inc., to UPL NA Inc., effective January 1, 2019. UPL globally has a presence in over 130 countries on six Continents. With 33 manufacturing and formulation facilities situated in 11 countries, UPL is a leader in the manufacture of high-quality brands used to protect crops and property. UPL is focused on emerging as a premier global provider of total crop solutions designed to secure the world's long-term food supply. UPL has invested heavily in R&D activities that produce innovative solutions, leading to the global launch of more than 100 new products in the past two years.

Challenges Begin to Emerge for UPL-Arysta Combine

UPL Ltd's $4.2 billion purchase of Arysta LifeScience Inc. avoided the typical investor skepticism associated with large acquisitions. With the management convincing investors about gains from synergies, the stock has gained 36% since the acquisition announcement on 20 July. Part of the gains can be explained by the recovery in Latin America, a large market for UPL. The Arysta acquisition is expected to drive up the leverage, thanks to borrowing of $3 billion, while synergies estimated at $205-255 million per annum are expected to create value from the first year of amalgamation itself. However, these assumptions are at risk as challenges are emerging for the combined entity. The drought in Europe is one, points out CGS-CIMB Securities (India) Pvt. Ltd. Sparse rain and high temperatures impacted farm productivity. So much so that fodder for cattle is falling short in some regions. Besides, the heat waves can lower the attacks of fungal pathogens, impacting agrichemicals sales in the region, warns CGS-CIMB. (For more information: LiveMint.com)

Valent BioSciences, ADAPCO, an Azelis Company, form strategic partnership in public health

Valent BioSciences (VBC), the global leader in biorational solutions for public health, forest health, and agriculture, announced it has entered into a strategic partnership with ADAPCO, an Azelis company, the world's largest distributor of products to the professional mosquito control industry. As part of the agreement, ADAPCO will become the exclusive distributor of VBC's broad range of biological-based mosquito control technologies in the US, Puerto Rico, and the Cayman Islands. (For more information: https://www.valentbiosciences.com) **CBNB**

Vegalab announces distribution agreement with AMVAC Mexico SRL

Vegalab Inc recently finalised a distribution agreement with AMVAC Mexico S de RL de CV, a subsidiary of AMVAC Netherlands BV, for distribution of all-natural biologically derived pesticides, fertilisers and speciality products across Mexico. AMVAC Mexico is a crop protection company based in Guadalajara in the State of Jalisco, Mexico with a 22-year history of helping farmers with their crops. AMVAC Mexico has a sales organisation in place throughout Mexico. In the future, AMVAC and Vegalab will provide an extensive line of environmentally friendly products that help maximise yields. AMVAC signed a distribution agreement for Vegalab products. The agreement stipulates that Vegalab will provide the proper support to AMVAC to assure that growers can get the most out of Polen Bust, a very effective, adjuvant in the pollination process, which has been specially formulated for the Mexican market and is available for sale in Mexico. Polen Bust is the first of a family of organic materials produced by Vegalab that AMVAC will be working toward official registrations during the coming months. (For more information: https://vegalab.us/news) **CBNB**

Company performance

BASF Group increases sales – earnings below prior-year quarter: Agricultural Solutions

In 3Q 2018, BASF Group's sales of €1.2 billion in the Agricultural Solutions segment were up considerably by 26% compared with 3Q 2017. This was attributable to portfolio effects from the transaction with Bayer, a higher price level and slightly stronger volumes. Negative currency effects continued to weigh on sales development. Despite the seasonally strongly negative results of the businesses acquired from Bayer, EBIT before special items was down only €26 M on the prior-year quarter. Income generated by BASF operations excluding Bayer activities rose considerably compared with 3Q 2017. Excluding the negative currency effects, EBIT before special items also increased slightly overall. (For more information: BASF SE, D-67056 Ludwigshafen, Germany; Tel: +49 (0) 621 600; Website: http://www.basf.com) **CBNB**

Bayer: good performance in a challenging environment, group outlook confirmed: Crop Science

The Bayer Group achieved good operational performance in a challenging environment in 3Q 2018. In the agricultural business (Crop Science), Bayer registered sales of €3.733 billion. Sales were down 9.5% on a currency- and portfolio-adjusted basis due to the accounting measures taken in Brazil in 2017, which had a positive effect on sales in 3Q 2017 due to the reversal of provisions. The division also recorded lower volumes in the Europe/Middle East/Africa region. On a currency- and portfolio-adjusted basis, sales advanced year on year in North America. On a pro-forma basis, Crop Science increased sales by 1.4%, in part due to significant growth at Corn Seed & Traits and Soybean Seed & Traits. At Herbicides, pro-forma sales were higher as a result of higher prices and volumes in the Latin America and North America regions. As for Fungicides and Insecticides, pro-forma sales were down due to the effects in Brazil in the prior year and the dry weather in Europe. EBITDA before special items of Crop Science climbed by 25.7% to €386 M. (For more information: Bayer AG, 51368 Leverkusen, Germany; Tel: +49 214301; Fax: +49 214 305 8923; Website: http://www.bayer.com)

Insecticides (India) Limited: financial results for the quarter and six months ended 30 September 2018

The standalone unaudited financial results of Insecticides (India) Limited for the quarter and six months ended 30 September 2018 show that for the quarter, total income from operations amounted to Rup 45,864.00 lakhs, an increase from Rup 41,892.17 lakhs in the same quarter of 2017. Net profit for the period (after tax) amounted to Rup 4297.28 lakhs, up from Rup 3613.94 lakhs. For the six months, total income from operations amounted to Rup 77,774.80 lakhs, an increase from Rup 76,454.67 lakhs in the same period of 2017. Net profit for the period (after tax) amounted to Rup 7696.43 lakhs, up from Rup 6664.26 lakhs. (1 crore=10 M, 1 lakh=100,000). (For more information: www.insecticidesindia.com)

CBNB

Marrone Bio Innovations Inc reports 3Q 2018 financial results

Marrone Bio Innovations Inc, a leading provider of bio-based pest management and plant health products for the agriculture, turf and ornamental and water treatment markets, has provided its financial results for 3Q 2018 ended 30 September 2018. Revenues grew to $5.4 M in 3Q 2018, compared to $4.2 M in 3Q 2017. Due to the adoption of the ASC 606 accounting standard (Revenue From Contracts With Customers), 2018 over 2017 reported revenues are not strictly an apples to apples comparison. Gross margins in 3Q 2018 increased significantly to 48.3%, compared to 40.9% in 3Q 2017. Operating expenses in 3Q 2018 declined 19% to $6.8 M, compared to $8.3 M in 3Q 2017. Net loss in 3Q 2018 improved significantly to $4.4 M, compared to a net loss of

$8.5 M in 3Q 2017. Cash and cash equivalents, including restricted cash, totalled $22.1 M on 30 September 2018 compared to $24.9 M on 30 June 2018, reflecting cash usage of $2.8 M in 3Q 2018. (For more information: Marrone Bio Innovations Inc, 1540 Drew Avenue, Davis, CA 95 618, USA; Tel: 1.530.750.2800; Website http://www.marronebioinnovations.com) **CBNB**

NACL Industries Limited: financial results for the quarter and half year ended 30 September 2018

The unaudited financial results of NACL Industries Limited for the quarter and half year ended 30 September 2018 show that for the quarter, total income from operations amounted to Rup 29,092 lakhs, a decrease from Rup 30,910 lakhs in the same quarter of 2017. Net profit for the period after tax (after exceptional and/or extraordinary items) amounted to Rup 530 lakhs, down from Rup 716 lakhs. For the half year, total income from operations amounted to Rup 51,631 lakhs. Net profit for the period after tax (after exceptional and/or extraordinary items) amounted to Rup 640 lakhs. (1 crore=10 M, 1 lakh=100,000). (For more information: https://www.nagarjunaagrichem.com) **CBNB**

Sapec Agro Business 2018 financial results

Sapec Agro Business released its full-year results ending in June 2018 and posted sales of €250M, a sustained growth versus the previous year. Sapec Agro Business holds two business areas: Crop Protection and Crop Nutrition, mostly represented by Ascenza (former SAPEC AGRO) (plant protection), Tradecorp (nutrients); IDAI Nature (biopesticides), and SDP (adjuvants). In addition, the group has experienced a noticeable increase on the recurrent EBITDA contribution, which has reached €53M, a growth of more than 25% versus the previous year. This result is almost fully organic, as the recent acquisitions of the group arrived at the year end and are expected to promote substantially the group´s profitability for the future. International markets, where the group has a strong presence, continue to provide increasing opportunities for both Crop Protection and speciality Crop Nutrition businesses, especially across Latin America, Eastern Europe, and Asia regions. In November 1987, Crop Protection business communicated the rebranding of its main brand, SAPEC AGRO. ASCENZA, the new brand results from a new positioning and image. ASCENZA reflects business maturity of a company with more than 50 years and its now ready to become an off-patent leader in other markets. These notable figures are the result of Sapec Agro Business investment in research, development, and innovation for several years. The group's efforts in innovation have resulted in the launching of a large number of differentiated products, specifically adapted to the needs of the agricultural markets where the group is present, currently more than 70 countries globally. Among others, the group launched in 2018 the first biodegradable 8,2% iron chelate stable under alkaline condition, IsliFe 8.2. This launching represents a major milestone in innovation since the new IsliFe 8.2 provides enhanced product effectiveness with full respect for the environment. With the objective of enhancing its global portfolio and strengthening its position in important markets, Sapec Agro Business recently completed the acquisition of two new companies, IDAI Nature, a unique Biocontrol company based in Spain which proposes residue-free biopesticides, and SDP, a company specialised in Adjuvants and Speciality nutrition, based in France, with worldwide presence. The Group remains open to new acquisitions which may contribute to increase the product portfolio and solutions to its clients.

Tessenderlo Group 3Q 2018 trading update: solid 3Q 2018 results despite challenging market conditions

Tessenderlo Group disclosed its financial results in 3Q 2018. In 3Q 2018, its revenue increased by 2.6% (or increased by 1.3% when excluding the foreign exchange effect) compared to 3Q 2017. Excluding the foreign exchange effect, the revenue of the Agro segment slightly decreased (-2.2%). REBITDA decreased by -0.9% (or decreased by -4.9% when excluding the foreign exchange effect) and amounted to €36.8 M, compared to €37.1 M in 3Q 2017. The Agro REBITDA slightly increased, as the impact of lower Tessenderlo Kerley International volumes was compensated by the performance of the other Agro activities. At end-3Q 2018, group net financial debt amounted to €25.3 M, resulting in a leverage of 0.2x. Net financial debt as per end-2017 amounted to €58.7 M. Capital expenditure amounted to €22.5 M in 3Q 2018 (€19.5 M in 3Q17), and includes the acquisition of a new headquarters building for Tessenderlo Kerley Inc in Phoenix (Arizona, US) for approximately $10 M. Total capital expenditure of the first nine months of (9M) 2018 amounts to €54.9 M (compared to €59.0 M in 9M 2017). The group confirms its previous forecast that the 2018 REBITDA, when including the estimated 4Q 2018. REBITDA contribution of T-Power nv, is expected to be in line with the 2017 REBITDA despite the evolution of the EUR/USD exchange rate and the evolution of raw material/fat prices. (For more information: http://www.tessenderlo.com) **CBNB**

***CBNB:** These abstracts were taken from Chemical Business NewsBase (CBNB) which is produced by Elsevier, E-mail: cbnb@elsevier.com, Website: http://www.ei.org/databases/cbnb.html

CALENDAR

6 March 2019	**Climate change and agriculture: all you need to know in a day**, SCI, London, UK. What are the implications for agriculture of mitigating greenhouse gas emissions? This conference will be an overview of the impacts of climate change on agriculture and the range of options available to cope with the changes. It will address the impacts agriculture has on the climate and the options available to reduce greenhouse gas emissions. If you want to get to grips with the state of the art in agriculture, food supply and climate change, then this conference will tell you all you need to know. In a day. Contact: Tel: +44 (0)20 7598 1561; E-mail: conferences@soci.org Web: www.soci.org/events
25–28 March 2019	**International Conference on Microbes for Sustainable Agriculture**, Forman Christian College (A Chartered University), Lahore, Pakistan. Workshop themes: Plant microbiome; Microbiome in Agriculture – New Frontiers; Plant-Microbe Interactions; Soil-Microbe Interactions; and Microbes and Plant Diseases. Contact: Prof Samina Mehnaz, AvH Fellow, Humboldt Ambassador Scientist, E-mail: msa19@fccollege.edu.pk Web: http://www.isaaa.org/kc/cropbiotechupdate/files/documents/2018-12-12-Flyer-msa19.pdf
29–30 May 2019	**Biopesticides Europe 2019** – London, UK. Contact: Rohan Baryah, Tel: +48 (0)6545 79221); E-mail: rbaryah@acleu.net
25–26 April 2019	**Adding Value to Field Crop Genetic Resources,** John Innes Centre, Norwich Research Park, Norwich NR4 7UH, UK. For decades the world's genebanks have conserved genetic diversity and supplied stakeholders with the raw materials of basic research and breeding. Recent development of next generation gene discovery tools together with associated phenotypic and genotypic datasets based on genebank foundations have opened completely new opportunities for the interrogation of genebank resources, for the delivery of new and useful genetic variation to agriculture. This conference will highlight these exciting developments and map out next steps for the genetic resources community. Contact: Tel: +44 (0)1603 450000; E-mail: john@aab.org.uk Web: https://www.jic.ac.uk
21–23 May 2019	**Cultivating Healthy Food Systems**, The Royal Botanic Garden Edinburgh, Arboretum Pl, Edinburgh EH3 5NZ. This conference will discuss parallels between what is considered a healthy diet and the sustainable practice of food production and consumption. Day 1 will focus on current agri-food practice on a global scale, but with implications for local economies. It will explore current eating habits and how they relate to retailing, processing and farming. Idealised food systems is the topic for Day 2, discussing what we hope to achieve and how we realistically move towards better practice. Day 3 will explore current policy-driven approaches to achieving change. It will explore the role and scope of policies and research needed to underpin initiatives across the food supply chain and identify multidisciplinary approaches to achieving these objectives. Contact: Tel: +44 (0) 131 248 2909; Web: https://www.rbge.org.uk
29–30 July 2019	**Agribusiness Global Biostimulant CommerceCon** – Harrah's Resort Atlantic City, New Jersey, USA. The Biostimulant CommerceCon exceeded expectations in 2018's launch, and 2019's event will once again facilitate the unification of the traditional and biological crop input sectors as the integrated portfolio is the "new normal". The event will focus on actionable commercialisation strategies, providing top-tier networking amongst the industry's leading companies in this rapidly growing space. Contact: Eric Davis, Managing Director, *AgriBusiness Global*, Meister Media Worldwide. E-mail: EJDavis@meistermedia.com
30 July–1 August 2019	**Agribusiness Global World Summit** – Harrah's Resort Atlantic City, New Jersey, USA. The Trade Summit, now in its 13th year, has become known as the world's premier sourcing event in crop protection, plant health, equipment, and more. Every year, more than 800 delegates from more than 45 countries gather for what is now the largest crop input sourcing event in the Western Hemisphere. Contact: Eric Davis, Managing Director, *AgriBusiness Global*, Meister Media Worldwide. E-mail: EJDavis@meistermedia.com
10–11 September 2019	**5th Symposium of Potato Cyst Nematode Management** – Harper Adams University, Newport TF10 8NB, UK. The 5th Symposium of Potato Cyst Nematode Management will cover many aspects =including international distribution, genetic diversity, sampling and decision making, population dynamics, diagnostics, integrated management, biology and application of resistance, use of effectors, rotational control, chemical control, biological control and novel control methods such as RNAi and biofumigation. BASIS points will be applied for. Contact: Richard Whiston Tel: +44 (0) 1952 82028
13–16 October 2019	**Integrated Protection of Field Vegetables**, DoubleTree by Hilton Stratford-upon-Avon, Arden Street, Warks, UK organised by the IOBC-WPRS Working Group. The pests, pathogens and weeds infesting field vegetables are becoming increasingly difficult to manage due to the reducing availability of conventional pesticides, particularly for minor crops such as vegetables, and the very high quality standards set by retailers and consumers. For these and other reasons associated with pesticide use there is considerable interest in Europe and elsewhere in integrated approaches that minimise the use of pesticides without compromising marketable yield. The aim of this meeting, hosted jointly by the IOBC Working Group 'Integrated Protection of Field Vegetables' and the Association of Applied Biologists, is to provide crop protection specialists/practitioners with the opportunity to explore new approaches to crop protection, present the results of their recent research, and discuss ongoing research and issues that are of mutual interest and whose resolution may benefit from a multi-disciplinary approach. Contact: Web: https://www.iobc-wprs.org/expert_groups/12_wg_vegetables.html

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BIOPESTICIDES EUROPE 2019

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Exclusive Site Visit: Syngenta - Jealott's Hill International Research Centre




Last Edition's Attendees Include...

NOVOZYMES BIOAG, BIOCONSORTIA, EXPONENT INTERNATIONAL, UNIVERSITY OF VIGO, BIOBEST NV, CABI, BIONEMA, BIPA BIOLOGICAL PRODUCTS FOR AGRICULTURE, IPM IMPACT, GAB CONSULTING, LABORATOIRE MEINERS, CLIFFORD CHANCE DEUTSCHLAND LLP, RUSSELL IPM, BASF, ATLÁNTICA AGRÍCOLA, MESSINAS, LUKE - NATURAL RESOURCES INSTITUTE FINLAND, INSTITUTO DE HORTOFRUTICULTURA SUBTROPICAL Y MEDITERRÁNEA LA MAYORA(UMA-CSIC), ISAGRO S.P.A., ANDERMATT BIOCONTROL AG, SUTERRA, MATERIA-NOVA, CAIRO UNIVERSITY EGYPT, ARYSTA LIFE SCIENCE, UPL, SEPRAN S.R.L., SUMI AGRO EUROPE, NOVAFIELD, SYNTECH RESEARCH, LOUIS DREYFUS COMPANY SUISSE S.A., SAPEC AGRO, SUMITOMO CHEMICAL AGRO EUROPE, REDEBEL, TRADECORP SPAIN, BIOVITIS S.A., STOCKTON GROUP, GOWAN COMPANY, FMC AGRICULTURE, DEXTRA INTERNATIONAL, ACTION-PIN, ADP-FERTILIZANTES, BAYER SAS, ENVIGO, KENOGARD S.A., TECHNISM, BAYER CROPSCIENCE, AGROBEST GROUP, AFRASA, ENVIRONMENTAL PROTECTION AUTHORITY - NEW ZEALAND, EUROFIN REGULATORY AG, FUTURECO BIOSCIENCES S.A., SELECTIS, DOW AGROSCIENCES, IDAI NATURE, VEGENOV, EUROFIN EUROPE, BIOMAR MICROBIAL TECHNOLOGIES, ADVANTA SEEDS DMCC, JOHN INNES CENTRE, ESTICON SOBCZYK & TABOR SP. J. AND MANY MORE!

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