Neonicotinoids and their Impact on Ecosystem Services for Agriculture and Biodiversity in Africa

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The Academy of Science of South Africa (ASSAf) was inaugurated in May 1996. It was formed in response to the need for an Academy of Science consonant with the dawn of democracy in South Africa: activist in its mission of using science and scholarship for the benefit of society, with a mandate encompassing all scholarly disciplines that use an open-minded and evidence-based approach to build knowledge. ASSAf thus adopted in its name the term 'science' in the singular as reflecting a common way of enquiring rather than an aggregation of different disciplines. Its Members are elected on the basis of a combination of two principal criteria, academic excellence and significant contributions to society.

The Parliament of South Africa passed the Academy of Science of South Africa Act *(No 67 of 2001)*, which came into force on 15 May 2002. This made ASSAf the only academy of science in South Africa officially recognised by government and representing the country in the international community of science academies and elsewhere.

This report reflects the proceedings of the *Neonicotinoids and their Impact on Ecosystem Services for Agriculture and Biodiversity in Africa* workshop held from 14 – 16 November 2018 in Pretoria, South Africa, unless otherwise stated.

Views expressed are those of the individuals and not necessarily those of the Academy nor a consensus view of the Academy based on an in-depth evidence-based study.

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List of Acronyms

AASSA	Association of Academies and Societies of Sciences in Asia
AMEPH-CI	L'Association des entreprises nationales phytosanitaires de Côte d'Ivoire
ASSAf	Academy of Science of South Africa
AU	African Union
BUAN	Botswana University of Agriculture and Natural Resources
BMBF	*Bundesministerium für Bildung und Forschung*
CAPL	Central Agricultural Pesticide Laboratory
CCD	Colony collapse disorder
CNRA	National Centre for Agronomic Research
CNRS	*Centre National de la Recherche Scientifique*
DDT	Dichlorodiphenyltrichloroethane
DWV	Deformed-wing virus
EASAC	European Academies Science Advisory Council
EC	European Commission
ECOWAS	Economic Community of West African States
EFSA	European Food Safety Authority
EPA	Environmental Protection Agency
EU	European Union
GDP	Gross domestic product
GNP	Gross National Product
IANAS	InterAmerican Network of Academies of Sciences
IAP	InterAcademy Partnership
ICIPE	International Centre of Insect Physiology and Ecology
IPBES	Intergovermental Panel on Biodiversity and Ecosystem Services
IPM	Integrated Pest Management
IPPM	Integrated pest and pollinator management
IUCN	International Union for Conservation of Nature
JMPR	Joint Meeting on Pesticide Residues

JMPS	Joint Meeting on Pesticide Specifications
LANADA	Laboratory for Analysis and Support to Agricultural Development
LAPPAB	Laboratory of Bees Pathology, Parasitology and Plant Protection
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MAGREB	Northwest Africa
NAADS	National Agricultural Advisory Services
NASAC	Network of African Science Academies
NDA	National Drug Authority
NEMA	National Environment Management Authority
NEPAD	New Partnership for Africa's Development
NGOs	Non-governmental organisations
OIE	World Organisation for Animal Health
REC	Regional Economic Communities
SA	South Africa
SADC	Southern African Development Community
SDGs	Sustainable Development Goals
SMEs	Small and medium enterprises
TFSP	Task force on systemic pesticides
TPRI	Tropical Pesticide Research Institute
UP	University of Pretoria
USA	United States of America
WHO	World Health Organisation
WIA	World Impact Assessment

Background to the Workshop[1]

The neonicotinoids class of systemic pesticides have become the most widely used insecticide since their introduction to the market in the 1990s. They are registered in more than 120 countries, have a global turnover of €billions and are the dominant agent used on insecticide-treated seeds. The systemic mode of action renders plant tissue toxic and blocks the neural pathways in insects which consume parts of the plant. However, their systemic nature means that the insecticide gets into pollen and nectar, as well as plant residues, and non-target species, such as pollinators and predators, are also exposed. Moreover, when applied as dressings on plant seeds, the majority of the active ingredient enters the soil and aquatic systems, broadening the potential exposure to other non-target and non-insect species. Research has identified many potential effects on honeybees and other pollinators (e.g. bumble bees, solitary bees, flies, beetles or butterflies). Concern over the effects on individual species has also been associated with findings of substantial declines in insect populations overall, particularly honeybees, resulting in a pollinator global crisis. Especially in Africa subsistence farmers and rural communities rely directly and indirectly on the services provided by pollinators, either as hive products, like honey, or by pollinating the crops.

Concerns over impacts on honey bee colonies grew during the 2000s and in Europe, the European Commission commissioned a review of the available scientific evidence on the effects of neonicotinoids by the European Food Safety Authority (EFSA). This identified potential risks and led to partial restrictions on the three main active agents (imidacloprid, chlothianadin and thiomethoxam) in 2013. However, this was fiercely opposed by the manufacturers and uncertainties remained over the extent and nature of effects in the field. Reflecting on this, the European Academies' Science Advisory Council (EASAC), launched a review of the evidence on the effects of neonicotinoids on ecosystem services of importance to agriculture (pollination, natural pest control and soil, as well as biodiversity). EASAC member academies nominated 14 leading independent experts who worked with EASAC's Environment Programme Director to produce a policy report, which was endorsed by all European national academies of science and publicly launched into the European Union (EU) and national policy arena in April 2015.

This report reviewed the relations between agriculture and ecosystem services and their economic value. Recent trends were considered and evidence analysed for acute, chronic and sub-lethal effects on insects from neonicotinoid use, before considering this in the wider ecosystem context. Some highlights from the EASAC report are:

- Worldwide, 75% of the crops traded on the global market and dependent to some degree on pollinators is estimated to be worth €153 billion. With trends to grow more crops that require or benefit from pollination, there is also an emerging pollination deficit. Honeybees are the most widely used managed pollinators, but a diversity of pollinators is necessary to improve crop yield or fruit quality.

- Natural pest control (parasitic wasps, lacewing and hoverfly larvae, ladybirds and other beetles, etc. as well as birds) reduces the need for chemical measures and is

[1] Background document is not part of the proceedings report.

estimated to be worth US$100 billion annually globally. Loss of natural control weakens agriculture's resilience and renders it less sustainable and more vulnerable to pests and diseases.

- Underpinning ecosystem services is biodiversity, which is an objective in its own right under both global and European international agreements.

- Honeybee colony structure provides a resilient buffer against losses of its foragers and workers that is lacking in other pollinators. Thus, protecting honeybees is not enough to protect pollination or other ecosystem services.

- Critical to assessing the effects of neonicotinoids on ecosystem services is their impact on non-target organisms, both in invertebrates and vertebrates, and whether located in the field or margins, or in soils or the aquatic environment. Here it was found:

    - There is an increasing body of evidence that the widespread prophylactic use of neonicotinoids has severe negative effects on non-target organisms that provide ecosystem services including pollination and natural pest control.

    - There is clear scientific evidence for sub-lethal effects of very low levels of neonicotinoids over extended periods on non-target beneficial organisms.

    - Current practice of prophylactic usage of neonicotinoids is inconsistent with the basic principles of integrated pest management.

    - Widespread use of neonicotinoids (as well as other pesticides) constrains the potential for restoring biodiversity in farmland.

The EASAC report attracted much attention in the media and shifted the debate from the simple argument over the fate of honeybees at a colony level, to the issue of all species of bees and pollination overall. It also added to the background concerns on other ecosystem services provided by beneficial insects, and on the wider ecosystem side-effects including loss of insect food supplies to higher trophic levels. Critically, the report influenced the choice of the terms of reference for the scientific update carried out by EFSA from the summer 2015 which looked at the effects not just on honeybees, but also bumble and solitary bees. This was published at the end of 2017 as a result of which the EU has decided to further restrict the use of the three main neonicotinoids used. On 27 April 2018, the EU decided to ban these for use outside contained facilities, such as greenhouses.

In parallel with these developments, the International Union for the Conservation of Nature (IUCN) set up the Worldwide Integrated Assessment of the Impact of Systemic Pesticides on Biodiversity and Ecosystems (WIA) project, led by a task force on systemic pesticides (TFSP). The WIA project has examined all literature on neonicotinoids (also on fipronil) and has published reviews on 1) trends, uses, mode of action and metabolites; 2) environmental fate and exposure; 3) impacts on invertebrates; 4) impacts on vertebrates; 5) impact on ecosystems and their services; 6) alternatives: case studies; and 7) conclusions. The same task force has updated these meta-analyses which are being published in a new set of peer-reviewed papers during 2018 (See www.tfsp.info/worldwide-integrated-assessment/.)

In addition, the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) Thematic Assessment on Pollinators, Pollination and Food Production, released in late 2016, covered changes in animal pollination as an ecosystem service that underpins food production and its contribution to gene flows and restoration of ecosystems. One of the six chapters of the assessment is dedicated to status and trends of pollinators, pollination and pollination networks at global scale. The IPBES work also discusses drivers of change (including pesticides such as neonicotinoids) as well as the effectiveness of responses to pollination declines and deficits in pollination. The IPBES assessment does not consider other ecosystem services, such as natural pest control, nutrient recycling or other biodiversity issues.

In the light of this intense scientific review and the regulatory actions taken in Europe, the InterAcademy Partnership (IAP) has decided to expand work on the impact of neonicotinoids on ecosystem services and biodiversity beyond Europe. To facilitate this, IAP will support additional regional assessments through its regional members, starting in Africa with the Network of African Science Academies (NASAC). This initiative was funded by the German government through the *Bundesministerium für Bildung und Forschung* (BMBF) ministry and is jointly managed by the Academy of Science of South Africa (ASSAf) and the German National Academy of Sciences Leopoldina.

The scientific evidence to date provides a substantial body of evidence on the widespread risks to non-target organisms and broader ecosystem services of the neonicotinoids in a range of applications and environments. Although much of the scientific literature has emerged from Europe, the United States of America (USA) and Canada, the findings can be applied to other countries' agricultural systems. Given the great dependence of African economies and societies on agriculture, there is an urgent need to identify and collate data which would allow the potential risks in Africa to be better evaluated. This is the purpose of the workshop.

In terms of next steps after the workshop, a working group of approx. 10 – 12 members will be created from participants, which will continue to collaborate with the project's scientific director to draft a report that summarises this workshop and outlines the state of knowledge on neonicotinoids and their impact on ecosystem services for agriculture and biodiversity in Africa. An African project assistant will support this project, mostly by identifying and collating relevant literature and creating a literature database.

A follow-up meeting of the working group will take place in May/June 2019 in Nairobi to review progress, draft key recommendations from science to policymakers, and discuss communication of the results to the relevant political and scientific authorities.

The final report will be published in July 2019 and subsequently promoted through a variety of means, amongst them a 'virtual launch' in September/October 2019.

DAY 1: 15 NOVEMBER 2018

1. Welcome and Introductory Remarks

Roseanne Diab welcomed participants and recounted the origins of this project, which trace back to a meeting between EASAC and the ASSAf representatives in Jordan several years ago. She particularly thanked Volker ter Meulen for being the engine behind this meeting, the funders, and the ASSAf and Leopoldina collaborators in making this meeting happen.

Mike Norton welcomed participants and thanked Roseanne Diab and ASSAf staff for the gala dinner on the evening of 14 November. He expressed the support of EASAC's President, Thierry Courvoisier, for this project. EASAC focuses on the interaction between emerging science and policy in the EU. In 2015, EASAC produced a report on neonicotinoid pesticides and their effects on ecosystem services, whose relevance goes beyond the European context, thus this project on neonicotinoids in Africa. Norton thanked ASSAf and the academies who nominated the present experts for their involvement in this project.

Peter McGrath welcomed participants and thanked ASSAf, the Leopoldina, and EASAC for organising this meeting. The EASAC report on neonicotinoids was very impactful. McGrath explained the structure of IAP, which includes the regional networks EASAC, NASAC, InterAmerican Network of Academies of Sciences (IANAS), and Association of Academies and Societies of Sciences in Asia (AASSA). All regional networks, and IAP as an overarching organisation, aim to produce science-based advisory reports for policy makers. An example is IAP's recent work on food and nutrition security and agriculture, which also contains some chapters on pesticides. IAP is excited to have funding for an African project on neonicotinoids, thanks to ASSAf and the International Centre of Insect Physiology and Ecology (ICIPE) (Kenya), and expects an excellent and impactful report to result from this collaboration between ASSAf, NASAC, EASAC, and IAP. IAP can guarantee widespread visibility of this report through its two bureaux in Trieste and the USA.

Session 1: Background and Overview of the Science Reviewed by EASAC and IUCN's WIA

1.1 The EASAC Study and Findings

Mike Norton (Environment Programme Director, EASAC) explained EASAC's organisational structure and explained why EASAC conducted its neonicotinoids study, namely the emerging concern throughout Europe about the effects of neonicotinoids, which had become the dominant pesticides in Europe within 15 years of their introduction to the EU market, on the environment. Neonicotinoids are systemic pesticides that are absorbed into all plant tissues from seed coatings with the pesticide. The presence of neonicotinoids in honey, pollen, and guttation water means that pollinators are also exposed to neonicotinoids. Widespread bee fatalities in the EU lead to restrictions on pesticide use in the EU in 2013, but industry and farmers opposed this EU decision. EASAC decided to provide scientific input to this discussion. The perspective of the EASAC report went beyond the widespread focus on honeybees and focused more broadly on ecosystem services, which can be divided into supporting, provisioning, regulating, and cultural services. Agriculture relies to some extent on ecosystem services, such as pollination, pest control, and soil health, each of which can be valued at many billion Euros per annum.

The key political dimension was a focus on honeybees, which were experiencing significant abnormal losses in many areas of Europe, but the prevalence of honeybees is subject to numerous socio-economic confounding factors. EASAC therefore compared honeybees (eusocial, large colonies, overwintering) with bumblebees (smaller colonies, only future queens hibernate), and solitary bees and other pollinators (where each individual counts for reproduction). Because of the different bees' social structure, the different pollinators have different buffering capacity for the effects of neonicotinoids and other adverse effects, so a focus entirely on honeybees does not adequately portray the consequences of neonicotinoids on the greater pollinator fauna. EU evidence points to losses of managed honeybee colonies, but even more importantly all wild ecosystem-service providers show major declines.

The key drivers of biodiversity decline are habitat loss, nutrient and pesticide inputs in agricultural areas, pests, and pathogens affecting ecosystem service providers and their genetic diversity. Neonicotinoids exercise their toxic effects on insects via blocking their neural system. About 1% of neonic seed dressing is blown away as dust, about 94% go into soil and water, and only about 5% are taken up by the crop plants themselves. Correspondingly, the entire agricultural ecosystem is exposed to neonicotinoids and with risks of associated negative effects on the entire fauna. Comparing laboratory, field, and semi-field studies, EASAC found that single research approaches cannot answer the complex questions about the effects of neonicotinoids. Laboratory studies have the advantage of controlled environments, but their conclusions are difficult to apply to field situations. Field studies take place in non-controlled environments, which has the advantage of representing reality, but the disadvantage of numerous confounding factors. Semi-field studies provide more realistic conditions than the laboratory and restrict many of the variables that affect field data, but by doing so; semi-field studies can only approximate field conditions. However, considering the totality of the evidence, EASAC concluded that there is an increasing body of evidence that the widespread prophylactic use of neonicotinoids has severe effects on non-target organisms that provide ecosystem services, including pollination and natural pest control. Despite this, use of neonicotinoids had been increasing and farmers could even struggle to find non-dressed seeds for planting.

Another conclusion of the EASAC study was that the effects of neonicotinoids work in synergy with pathogens and other stressors. There was clear evidence for sub-lethal effects of neonicotinoids, which are cumulative over time. Even low-level exposures accumulate over weeks, and long-term exposure to very low levels can have severe effects, e.g. through activating latent viruses. Given that only 5% of the active ingredient in the seed coating is taken up by the plant, the balance between risks and benefits of neonicotinoids clearly required reassessment. In addition, the EASAC study found that prophylactic use of neonicotinoids is inconsistent with basic principles of integrated pest management. Instead of focusing on prevention, cultural approaches/sanitation, and physical and/or mechanical action, and using chemical pesticides as a last resort, this has been reversed so that chemical pesticides are now often the first means of combating pests in agriculture.

EASAC's report received a substantial international media response, and in 2018 following a review of the scientific evidence by the European Food Safety Authority, the EU banned outdoor use of clothianidin, imidacloprid, and thiamethoxam. EASAC would now like to spread awareness of the problems associated with the use of neonicotinoid pesticides in Africa and kick off a collaborative programme involving representatives from throughout Africa.

1.2 The Scientific Findings of the IUCN Literature Reviews of the Effects of Systemic Pesticides

Jean-Marc Bonmartin (Centre National de la Recherche Scientifique (CNRS), France) introduced the scientific findings of the IUCN literature reviews of the effects of systemic pesticides. The IUCN WIA had comprehensively analysed all data. They noted that the IPBES estimates that 16.5% of vertebrate pollinators, and 40% of invertebrate pollinator species, are threatened by extinction. Amongst the threats are those from pesticides including neonicotinoids. Dr Bonmatin pointed out that neonicotinoids are a group of approximately12 molecules that act on the neuronal system of insects, resulting in lethal muscle spasms. The current use of 20 000 tons of neonicotinoids per year has the potential to kill 5×10^{18} honeybees.

Neonicotinoids became the most popular pesticides in the USA and Europe from around 2003; the most common active ingredient is imidacloprid. Traditional translaminar application of pesticides requires about 1 kg of pesticide per hectare. Seed dressings only require 0.1 kg/ha but their toxicity is approximately 7 000 times higher than that of Dichlorodiphenyltrichloroethane (DDT). Apparent reduction in pesticide usage is politically appealing but lethal and sublethal effects can be observed from 0.1ng/g in food resources, particularly if exposure is chronic. The WIA on systematic pesticides resulted in eight peer-reviewed scientific publications in 2014, followed by three new papers in 2017–- 18, containing updated meta-analyses on neonicotinoids and fipronil.

The objective of the WIA project was to assess the risks and impacts on non-target species. This was done by measuring real exposures (plants, soils, water, air), the measurement of real effects (acute, chronic, lab, semi-field, real field trials), and to estimate risk as the ratio of real exposure concentration to the lowest concentration having toxic effects. The publication *Environmental Fate and Exposure: Neonicotinoids and fipronil* reports mean values of contamination of soils, ground water, surface water, dusts, crops, fruits and vegetables, pollen, and honey with imidacloprid worldwide. The publication *An Update of the WIA on Systemic Insecticides. Part 1: New molecules, mentalism, fate, and transport* shows that 80 – 98% of neonicotinoids go into the soil and stay there for years, so accumulation is very problematic. In addition, some decomposition products are toxic and long-lived: Thiamethoxam persistence in soil is approximately one year, but it breaks down into clothianidin with a soil persistence of up to 30 years.

Honeybees, as well as wild bees and other pollinators, face cocktails of pesticides, outside and inside the hive. In the presence of neonicotinoids, bees suffer more from pathogens and pests, and this susceptibility is increased by limited and/or monotonous floral resources. In addition, the interaction of other agrochemicals, such as pyrethroids and fungicides, increases chemical toxicity. The publication *An Update of the WIA on Systemic Insecticides. Part2: Impacts on organisms and ecosystems* compares exposure pathways of different taxonomic groups and ecotoxicological effects on individual, population, and community level. Insect pollinators are most impacted, but similarly so are terrestrial invertebrates and aquatic invertebrates. There are also cascade effects to birds (in Europe the number of farmland birds has declined by 30% since 1990), and fishes, and likely to mammals. The data on mammals are very limited, but when looking at human exposure to neonicotinoids, exposure is ubiquitous in vegetables, fruits, juices, and wine, and there are known effects of neonicotinoids on human health, including tetralogy, anencephaly, Autism spectrum diseases, cancer, oxidative stress, endocrine disruption, neurodevelopment, cardiac/hepatic/thyroid diseases, immunity, finger tremor, learning and memory, etc.

Questions also are raised whether neonicotinoids are even the best way of protection crops. A study by the US Environmental Protection Agency (EPA) showed that there is no difference in the health of soybean plants treated with neonicotinoids and those not treated by any insect control treatment (*Benefits of Neonicotinoid Seed Treatments to Soybean Production* on EPA website). There is thus much interest in what are the alternatives to neonicotinoids. An interesting example from Italy is a study on Corn Crops: Integrated Pest Management (IPM) and Mutual Funds. A 30-year comparative study by Dr L Furlan (Veneto Agricultura, Italy; http://www.reterurale.it/apenet; http://www.pure-ipm.eu/project) compared the costs of neonicotinoid usage with those of IPM and/or coverage of harvest losses due to pests by mutual funds, and found that neonicotinoid usage is by far the most expensive solution to pest control (EUR 40/ha). A combination of IPM and damage cover through mutual funds was cheapest (EUR 14/ha). The publication *WIA of the Impact of Systemic Pesticides on Biodiversity and Ecosystems* also shows alternatives to prophylactic use of neonicotinoids, such as landscape design (patchy landscapes, edge shrubs and crops, wet zones), farming methods (insurance cover through mutual funds, crop rotation, use of resistant varieties, mixing varieties, intercropping, soil cover), use of organisms (parasitoids, predators, fungi, and bacteria), and others means (traps, repellents, basic substances, sex confusion, natural-derived insecticides, etc.).

In France, a commission was set up to identify alternatives to neonicotinoids for registered uses for the 130 crops grown in Frances. In 78% of cases, at least one feasible and efficient alternative exists. Consequently, the use of pesticides containing one or several active ingredients of the neonicotinoid class, and the use of treated seeds with these ingredients, was banned in France from 1 September 2018. In addition, to avoid companies introducing similar pesticides to the French market, another law bans the use of pesticides containing one or several active ingredients having modes of action similar to that of the neonicotinoid class, and of treated seeds with these products.

The publication *Conclusions from the WIA on the Risks of Neonicotinoids and Fipronil to Biodiversity and Ecosystem Functioning* summarises that neonicotinoids and fipronil are used mostly preventively and in massive amounts, have extreme toxicity to vertebrates, and are characterised by very high persistence in soils and solubility in water. This results in high contamination of air, soils, plants, and water, and their new mechanism of toxicity causes extended collapse of pollinator populations, soil organisms, and aquatic invertebrates. This causes large impacts on ecosystems and threaten ecosystem service provision globally, and thus food production, food security, and human health. These negative consequences are juxtaposed by limited usefulness of neonicotinoids and fipronil in the vast majority of causes and the development of pest resistance under preventative usage. There is a variety of effective alternative practices available to farmers that are also more cost efficient than use of neonicotinoids. Consequently, the present use of neonicotinoids is not sustainable. There was a strong argument that their use should be restricted and agriculture should shift to integrated pest management services, organic farming, etc.

1.3 Immunity, Stress and Sub-lethal Effects of Neonicotinoids

Francesco Pennacchio (University of Napoli Federico II, Italy) spoke on immunity, stress, and sub-lethal effects of neonicotinoids. Colony collapse disorder (CCD) was a multifactorial syndrome, and results from numerous interacting influences. Colony and bee health are functions of the bees' immunocompetency, i.e. their ability to withstand adverse effects. Immunity is determined by multiple factors, including parasite populations, gut microbial communities, diet, abiotic stressors, and nervous system.

CCD is strongly associated with high-pathogen load. Colonies affected by CCD show an increased susceptibility to a diverse set of pathogens, and co-infections can act synergistically. An experiment that intentionally induced colony collapse compared hives treated with acaricides with untreated colonies and showed that bees from colonies strongly infested with mites had downregulated immune systems, making them susceptible to other infections, e.g. by deformed-wing virus (DWV). DWV covertly infects most bee colonies but remains asymptomatic in healthy colonies. However, infection with *Varroa* mites triggers an immune reaction associated with severe metabolic stress, which promotes viral replication. In addition, the resultant immuno-suppression by DWV makes bees more attractive to *Varroa* mites and increases fitness of male *Varroa* mites, thus promoting *Varroa* infestation. Insecticides have a similar effect on DWV replication: both imidacloprid and clothianidin promoted DWV replication in honeybees. In conclusion, neonicotinoids contribute to reductions in immuno-competence in bees, making them more susceptible to infections by viruses, fungi, etc. Many infections are latent/covert and only break out once immune system sufficiently suppressed by *Varroa* mites and/or neonicotinoid pesticides.

Pathogens/pathobionts additionally affect bee immuno-competence via effects on the bees' gut microbiota. Gut microbiota are an essential component of insect physiology. Not only are gut microbiota important for nutrition, they also modulate immune response. Reduction or alteration of gut microbiota reduces bee immune response to pathogens. Neonicotinoids and glyphosate have such effects on *Drosophila melanogaster*, and other pesticides likely have the same effect. Wild and managed bees are also exposed to fungicides, which can greatly increase the toxicity of insecticides. Gut microbial communities are also strongly affected by diet, and dietary stresses from limited and/or monotonous floral resources likely contribute to reducing the ability of bees to cope with toxins and pathogens. Thus, nutrition cross-modulates honeybee immune pathways.

In addition, there is some evidence that immunity is also under some neural control: Neonicotinoids adversely affect immune signalling in a human cell lines and cause specific immune responses in mice. Given the effects of neonicotinoids on insect neural pathways, it can be expected that bee immunity is affected by neonicotinoids also via a neural pathway.

Synergistic interactions between different factors thus create a complicated web of causality for CCD. A single factor may not be sufficient to trigger colony losses, but a combination of stressors appears to impact hive health. *Varroa* infestation and DWV replication contribute to 70% of colony losses. Field experiments exploring the causes of CCD must therefore be set up extremely carefully to ensure adequate replication of identical/similar conditions, and risk assessment must account for interactions and modifying pathways of CCD.

Discussion

Question: Will the effects of neonicotinoids become even more devastating because of accumulation? Are there any studies assessing the effects of this accumulation?

Answer: Accumulation is a function of geological, physical, and other factors, but field studies show increasing accumulation over time in fields. The effects of accumulation are already evident: Insect (both terrestrial and aquatic) and bird die offs have been quantified. Accumulation of neonicotinoids in soils was documented very early. Even after a single application, subsequent untreated crops contain sufficient neonicotinoids to harm pollinators. Companies propose mixtures of neonicotinoids to combat resistance development, but this only leads to accumulation of several neonicotinoids at the same time.

Question about alternative farming methods to neonicotinoid usage.

Answer: It is best to combine several strategies for maximum efficiency of pest control. Pest control using pesticides should be a last and highly targeted intervention, considering the type of pest, the economy of applying pesticide, and the efficiency of the pesticide of choice. Seed dressings, and any prophylactic treatments in general, are particularly inefficient.

Question: Are there decontamination protocols for neonicotinoid-containing soils?

Answer: No. Decontamination essentially relies on leaching, which transfers neonicotinoids to groundwater.

Comment: Presence of tiny amounts of neonicotinoids in water reduces immuno-competency to combat fungal infections affecting insects: Paper from Brazil.

Question about foliar applications of pesticides.

Answer: This is also very problematic. Foliar application is used in Japan and has caused public health problems. After foliar sprays in an adjoining forest, people reported to hospitals with symptoms of intoxication, so there are now plans to ban foliar applications, too.

Question: Are there thresholds for insects, and are those considered in application of pesticides? What about drift of neonicotinoids in dust?

Answer: Toxicological effects of neonicotinoids are the result of accumulation of irreversible neurological damage, so it is hard to establish thresholds. The question is whether thresholds are relevant, given that duration of exposure is more important than the total amount. Dust drift is very problematic and has in the past killed thousands of bees in Germany.

Lunchtime conversations: Prophylactic pesticide usage harms food security by contaminating the environment. Human health effects will likely become more relevant given the long lifespan of neonicotinoids and their toxic metabolites in soil, and their eventual leaching into groundwater.

1.4 Regulatory Responses across the World

Maarten Biljeveld van Lexmond (IUCN) presented the developments that lead to the establishment of the TFSP. The dramatic decline in insect populations worldwide over the last few decades alarmed scientists all over the world, and it was decided to investigate possible causes. This resulted in the Appeal of Notre Dame de Londres and the constitution of the TFSP in 2009. In 2011, the TFSP collaborated with two commissions of the IUCN, resulting in a TFSP website (www.tfsp.info) and eight scientific publications between 2013 and 2015. The TFSA report, *WIA of the Impact of Systemic Pesticides on Biodiversity and Ecosystem'* was launched worldwide in 2014 and published as a special issue of the journal *Environmental Science and Pollution Research* in 2015. The publication, *systemic Insecticides (neonicotinoids and fipronil): Trends, uses, mode of action and metabolites* reports increasing markets worldwide for neonicotinoids, which by 2012, were registered in more than 120 countries and for more than 140 crops. The work of the TFSP had been to bring the large body of research on neonicotinoids into a form in which it could be accessed readily by the global community and support the reconsideration of the risks and benefits of the widespread use of these insecticides.

1.5 Actions in the Philippines and Asia and Regulatory Responses across the World

Elizabeth Lumawig Heitzmann (TFSP, Philippines) reported on actions on neonicotinoids in the Philippines and Asia, and on regulatory responses across the world. The Philippines are big importers of neonicotinoids, chief amongst them clothianidin, dinotefuran, imidacloprid, and thiamethoxam. Agrichemical companies have a strong marketing system in the Philippines, reaching even into the remote areas. Farmers often use pesticides without knowing why or how to use them, even though clear guidelines for the different products, crops, pests, and rates are available. The Fertiliser and Pesticide Authority of the Department of Agriculture of the Philippines has recently started collecting data on volumes and values of technical products and formulated products of neonicotinoids on the Philippines, which amounted to approximately 540 000 kg/L (worth US$ 3.5 Mio) of technical products and over 7 Mio kg/L (worth over US$ 55 Mio) of formulated products in the first half of 2018.

Since the first registrations of neonicotinoids (imidacloprid) in France in 1991, the market has grown steadily, but first concerns about honeybees emerged as early as 1995, resulting in the first studies in 1997 and bans of imidacloprid and fipronil in 1999 and 2004, respectively. Between 2008 and 2013, other neonicotinoids were banned or restricted in some European countries, finally resulting in an EU-wide ban of outdoor uses of imidacloprid, clothianidin, and thiamethoxam in May 2018. France adopted a new Biodiversity Law in 2016, which enabled the ban of five neonicotinoids in France, and an extension of the ban to other neonicotinoid-like molecules like sulfoxaflor and flupyradifurone, from September 2018.

The Philippines have followed the EU in banning neonicotinoids locally and on the island of Marinduque, neonicotinoids were banned to protect the butterfly diversity and the butterfly-breeding system. Elsewhere, a total ban of outdoor use of three neonicotinoids will come into action in the EU and Switzerland. In Canada, neonicotinoid bans were instituted in some provinces between 2014 and 2016, and severe restrictions in others and from 2018, three neonicotinoids will be banned for five years. In the USA, a local ban in Maryland in 2016 was followed by a moratorium on new neonicotinoid molecules and full re-assessment of registrations from 2018.

1.6 Overview of General Considerations Specific to Africa

Christian Pirk (University of Pretoria (UP), South Africa (SA)) provided an overview of general considerations specific to Africa. The population of Africa may triple by 2100, so nutrition security remains paramount. Agriculture will have to intensify, integrated pest management will increase in relevance, and the demand for pollination will rise. In SA, over 105 neonicotinoid pesticides and over 130 imidacloprid insecticides are in use. Insecticides are used on all major crops of South Africa, for example macadamia, sunflower, grapes, citrus, maize, etc. Neonicotinoids are also common in honey, which is produced for financial gain and/or for its nutritional value. Imidacloprid and thiamethoxam are used widely in SA, particularly in areas where corn and wheat are grown and livestock are kept. SA legislation on pesticides relies mostly on European examples, which are suboptimal given that conditions in SA are different.

Experiments with honeybees have shown that neonicotinoids decrease sucrose responsiveness of honeybees at first contact, thus reducing foraging efficiency, pollination services for treated crops, and nutrition and survival of the colonies. In addition, thiamethoxam impairs bee thermoregulation ability both of their own body and the colony, and thus brood survival and health.

Literature searches in Web of Science on 'bee and neonicotinoid' revealed only 21 publications from Africa, compared to 137 from Europe. Similarly, searches for 'pollinator and neonicotinoid' reveal very few studies in Africa.

Biodiversity in SA is the highest in the Cape floristic kingdom. There, very specific pollination mutualisms with non-bees are put at risk from neonicotinoids. Similarly, baboon spiders could be very exposed because they spend most of their time in the ground. SA also has the highest endemicity in dung beetles and countless locally adapted populations of honeybees (*Apis mellifera scutellata*), which, when lost, could not be simply replaced. The genetic diversity of African honey bees is almost double of that in other regions of the world, which represents a rich and valuable resource. South Africa is estimated to have over ten million bee colonies, and Africa 310 million colonies, compared to Europe's 11.5 million colonies. A big difference between Europe and Africa is that European bees mostly have owners and are moved around, which can protect them, e.g. from spraying events. However, in Africa 95% of bees are wild, so it is harder or impossible to protect them. The same applies to other bee species in SA, as well as other pollinators such as bats, birds, and rodents.

Africa has healthy, sustainable wild populations of wild bees. In Europe, this is only the case in few areas. Wild honeybees are often harvested by luring wild colonies into boxes. Beekeepers thus exert considerable selection on wild honeybees when refilling boxes, and it would be helpful to create a comprehensive dataset on colony numbers and location.

Climate change is making agriculture more challenging while pressure is also on agriculture in Africa to become more intensive. Thus pesticide/neonicotinoid usage is likely to increase but so will demand for pollination services. The economic realities and possibilities for agriculture differ strongly among different parts of Africa and the effects of neonicotinoids must be viewed considering the floral and faunal diversity, climatic diversity and gradients, biodiversity with high levels of endemism, a growing human population, a predominance of wild honeybee colonies, and a high proportion of insect diversity in overall diversity. Little is currently known about pollinator populations, particularly honeybees, and their sustainable use.

Discussion

Question: Are there any papers on differences of neonicotinoid degradation rate between Europe and Africa?

Answer: There may be some local papers.

Question: What are the perspectives?

Answer: We need to work with local governments and the agricultural sector to understand pollinators better and to work towards a more sustainable food supply. A bigger picture can emerge from collaborations.

Question: Beekeeping as a profession – there is a market for honey, but it would be important to get the next generations interested in beekeeping.

Answer: In SA there are commercial beekeepers, as well as subsistence farmers, so no one method of beekeeping fits all. Local situations must be considered and acceptable to beekeepers, as must be the use of the bees' services (pollination, honey production, medicinal products).

Session 2: Current Situation in Africa and Current Activities

2.1 Armand Paraiso, University of Parakou, Benin

Neonicotinoid insecticides in Benin was reported on. Imidacloprid, acetamiprid, thiacloprid, and sulfoxaflor are in use. Agriculture employs almost 80% of the labour force, contributing almost 70% of to export earnings and 40% to gross national product (GNP). Protection of agricultural crops, particularly cotton, is based essentially on the use of chemical pesticides. Producers often spray crops with a variety of pesticides at inappropriate doses. The mean dose applied to vegetables and cotton cultures are between 1.5 and five times higher than the recommended doses. Benin has very important apicultural potential and a high diversity of pollinating insects, but in the past years a drastic decrease in bee populations has been observed, and also severe reductions in bee activity and sudden disappearances or massive bee mortalities. Reasons for these declines are the destruction of bee food plants, parasites, predators, diseases, and the exposure of bees to various insecticides used in crop protection, especially neonicotinoids.

A study on the effects of different pesticides on *Apis mellifera adansonii* was carried out at the Laboratory of Bees Pathology, Parasitology and Plant Protection (LAPPAB) at the University of Parakou. Bees were taken from hives to the laboratory and were exposed to different pesticides, amongst them 'Thunder' (containing imidacloprid) and 'Pacha 25 EC' (containing acetamiprid), which are the most widely used neonicotinoids used in cotton, market gardening and arboriculture protection (dependent to 90% on insect pollination for crop yield) in Benin. Pesticides were applied topically in doses between 50 and 5 000 ppm, and LD50 and mortality over time were determined. Mortality from the pesticides containing neonicotinoids was comparable and dependent on dosage and time since application. In the lowest doses, mortality after ten hours exceeded 60% and by 48 hours mortality approached 100%. This study clearly illustrates the extreme toxicity of neonicotinoids and other commonly used pesticides to the most important crop pollinator, *Apis mellifera adansonii*, and the results from the present study tally with those by Suchail *et al* (2000) on *Apis mellifera mellifera* and *A. m. caucasica*. Further studies are needed to assess the toxicity of pesticides to sub-Saharan bee species.

The widespread use of pesticides also has consequences for beekeepers. In Africa, beekeepers are giving up because they feel left alone by scientists and because of ubiquitous pesticide usage.

In conclusion, rational use of chemical pesticides is necessary to protect plants and biodiversity. Current practices negatively affect bees and result in bee products polluted with pesticides. All crop-protection strategies should specifically consider the protection of bees. Insecticides should be strictly regulated. Good agricultural practices in plant protection should be promoted to ensure sustainable agriculture that protects the environment, human health, and biodiversity.

2.2 Motshwari Obopile,Botswana University of Agriculture and Natural Resources (BUAN)

The status of neonicotinoid use and possible impact on ecosystem services in Botswana was reported. The economy of Botswana is historically based on agriculture. Since the discovery of diamonds, the contribution of the agricultural sector to gross domestic product (GDP) has declined to 2.4%. Botswana is a net importer of most agricultural products (including food grains and horticultural produce) except beef. At farm level, a great majority of rural dwellers depending on agriculture are net food buyers. Constraints to low arable productivity is due to pests and diseases, water shortage, poor soil fertility, weeds, lack of market, labour, irrigation facilities, and capital, wildlife damage, and poor transport and management. A survey of knowledge about neonicotinoids showed that the most important crops are maize, sorghum, cowpea, and tomatoes. The most important pests are aphids and stem borers. A broad range of pesticides is in use in Botswana, amongst them imidacloprid. Pest control through natural enemies or culture measures in Botswana are of greatest importance to combat stem borer and aphids. Insects also provide provisioning services as food sources – directly (Mopane worms) and indirectly. Another important ecosystem service is biological nitrogen fixation to enrich poor soils.

A survey of farmers on neonicotinoid use and impact showed that most of them use neonicotinoids of different brands, and 56% agreed that they cause ecosystem damage. The farmers' knowledge about possibly impact of the pesticide 'Neonys' on insect health was generally good but there is still plenty of scope for further education. Most farmers did not know that neonicotinoids will affect non-target organisms. In summary, more than 50% of survey respondents knew neonicotinoids and believed that they can negatively affect ecosystem services. Imidacloprid is the only registered neonicotinoid in Botswana, supplied in different brands, and used to control different aphid species. Neonicotinoids are also used to kill termites and destroy the mounds. In the past, neonicotinoids were used in seed treatments. In construction it is used for insect control or as insect proofing at the beginning of construction, and to kill existing underground nests and so to increase building stability.

The implications are that neonicotinoid usage will increase as crop production increases. As old chemicals are banned, the use of neonicotinoids will increase, so research on the impact of neonicotinoids on ecosystems in Africa will be critical. BUAN has recently proposed work on the role of beekeeping as a source of livelihood and bees as ecosystem providers, including sting-less bees, and studies on the impact of neonicotinoids and other pesticides will be initiated.

Discussion

Question: Only one neonicotinoid is registered in Botswana – are there others in the pipeline? How long does pesticide registration take?

Answer: Registration takes between six months to 12 months. Currently there are no applications for neonicotinoids in the pipeline.

Question: Are farmers using unregistered neonicotinoid pesticides?

Answer: No. Most subsistence farmers use cultural methods of pest control because they cannot afford the expensive neonicotinoids. However, the surveyed farmers could afford to buy registered pesticides.

2.3 Leonard Ngamo Tinkeu, University of Ngaoundéré, Cameroon

The current situation of registration and use of neonicotinoids in Cameroon was discussed. Main pest control used is through chemical pesticides, and it is poorly controlled. Farmers are untrained or trained by public servants who are unaware of hazards. Pesticides are registered on a yearly basis and a list of registered pesticides is available every year. This report lists the active ingredient, the constraints (target organisms), and the registered formulations of the active ingredient. For imidacloprid, 35 formulations are registered, for acetamiprid, 20 formulations, and a further three and eight formulations for thiacloprid and thiamethoxam, respectively. Some crops, such as cocoa and cotton, can be treated by several neonicotinoids. Many hazards are associated with the use of neonicotinoids without any particular control of their negative impact on the environment. Trials are ongoing for the registration of 'Fortenza Duo' (thiamethoxam and imidacloprid) to treat corn seeds. Treated seeds, promoted by Syngenta, will be used from 2019 onwards in all of Cameroon. In conclusion, there is need for Cameroon to raise awareness to prevent negative impacts on non-target animals.

Discussion

Suggestion: The present experts could consider writing a letter to the government of Cameroon, expressing their concern about the introduction of treated seeds.

Observation: Combination products containing two neonicotinoids (as opposed to one neonicotinoid and one other pesticide) seem to suggest that in Africa there are less issues with neonicotinoid resistance.

Comment: Africa is now in the process in harmonising pesticide laws. The harmonising committee found that many countries already have pesticide laws. Registration involves a form of pre-authorisation followed by two years of trials, and then reassessment.

Comment: Fast evolution of resistances is what necessitates mixing of two neonicotinoids.

Question: Who gives advice to farmers in Cameroon?

Answer: Normally, such advice is given by civil servants.

2.4 Alexandre Akpesse, Félix Houphouët-Boigny University, *Cote d'Ivoire*

Experiences with neonicotinoids in the Ivory Coast was discussed.. Agriculture contributes 20% of GDP and employs half of population in *Cote d'Ivoire*. About 40% of agricultural crops are exported. Main crops are cocoa, rubber, coffee, palm oil, cotton, and plantains. Chemical control of pests involves over 800 formulations approved by a pesticides committee. There is no formulation plant in Ivory Coast. Companies import pre-formulated products in bulk or packaged, as well as active ingredients used in the manufacture of pesticides. Companies are mostly subsidiaries of multinationals, national small and medium enterprises (SMEs), and free enterprises. Imports come from Europe (France, Switzerland), Asia, and the USA. Pesticides (mostly insecticides) are also exported, mostly to other countries in the sub-region.

The pesticides committee consists of representatives of several ministries (research, health, environment, trade, industry, interior, economy, finance), of public and para-public structures (Directorate of Plant Protection, Control and Quality, Permanent Secretariat of the Pesticides Committee, National Centre for Agronomic Research, Laboratory for Analysis and Support to Agricultural Development, Ivorian Anti-Pollution Centre), and of professional organisations (CROPLIFE, *L'Association des entreprises nationales phytosanitaires de Côte d'Ivoire* (AMEPH-CI) (national phytosanitary SMEs)). The pesticide committee issues exercise approvals for pesticide applicators, distributors, and retailers, and for phytosanitary products.

Numerous international companies are involved in the Ivory Coast pesticides markets and hold important market shares, but there is no investment in stewardship or regulation. The main neonicotinoids used are imidacloprid, thiamethoxam, acetamiprid, and thiacloprid, which were introduced to control pests on cocoa, cotton, and plantain. Foliar application is conducted with manual pressure sprayers on growing, young, and established plantations, and treatment schedules are based on knowledge of pest population dynamics.

Research evaluating the efficiency of neonicotinoids for pest control is conducted by the group of Prof Akpesse and others. Research is also conducted at the National Centre for Agronomic Research (CNRA) and the Laboratory for Analysis and Support to Agricultural Development (LANADA). Doctoral research is underway to evaluate neonicotinoid effects on animal populations colonising rivers neighbouring cocoa fields, as well as on pollinators of this crop. Research on the effects of neonicotinoids on human health is lacking.

Chemical control of Miridae has been shown to be of limited advantage on several occasions. First, the toxicity of insecticides can cause serious health problems for both producers and consumers, e.g. of cocoa beans. Second, the use of active ingredients with a broad spectrum of action has led in some cases to the breakdown of biological balances in plantations. Thus, some pests considered initially as secondary have proliferated because of the destruction of their natural enemies by chemical control aimed at mirids. Third, given that e.g. cocoa is pollinated by insects, the application of insecticides at the time of flowering can lead to a decrease in the pollination rate.

Key problems associated with pesticides in *Cote d'Ivoire e* are the proliferation of fraudulent pesticides on the local market (around 40% according to the actors), non-compliance with labelling standards and product packaging materials for products by illegal companies, and the risk of pollution and destruction of the environment due to the improper or uncontrolled use of pesticides. To address these problems, an anti-fraud commission should be established, the regulatory framework should be strengthened, and the informed and reasonable use of pesticides should be promoted.

Discussion

Question: Are neonicotinoids banned in other countries used in *Cote d'Ivoire*?

Answer: No neonicotinoids are banned in *Cote d'Ivoire*. However, recently a conference to make an inventory was held, and the recent legal changes in France might bring change since *Cote d'Ivoire* generally follows France. However, the conditions in I *d'Ivoire* are very different from Europe. In fact, conditions in Africa can make pesticides more toxic than they are in Europe. Some reasons for that are uneducated farmers, the absence of advisory systems, a lack of independent assessment of pesticides, and lack of monitoring of wild bee populations.

2.5 Youssef Dewer, Central Agricultural Pesticide Laboratory, Egypt

Neonicotinoids and Their Impact on Ecosystem Services for Agriculture and Biodiversity in Africa were discussed. The Central Agricultural Pesticide Laboratory (CAPL) is the only authority that can register pesticides for Egypt, and CAPL follows USA and Japan's standards and decisions. Because of continued world population growth, more agricultural production is necessary, but this creates more waste and pollution. Natural resources are already depleted, and humans compete with pest insects for food. Farm mechanisation reduces biodiversity and damages agroecosystems. Neurotoxic insecticides affect not only pest insects, but also beneficial insects and humans. Pathogens and pesticides contribute to CCD. Bees are exposed directly (spray application) and indirectly (residues) to pesticides. Bees do not only produce honey, but also enable production of 75% of agricultural crops through pollination. Recent research suggests that the insect olfactory system could provide a new avenue for pest control. Chemical signals enable finding of food sources and mates and can induce distinct behaviour. The insect's antenna is the main olfactory organ. Volatile chemicals bind to receptors and stimulate specific responses. Receptors can be blocked by antagonists and thus prevent stimulation of behaviour. Could this principle be used in pest control? Could chemicals that block the perception of chemosensory signals prevent behaviours like food finding – if insects cannot smell their food/host plants, could they be kept away?

Discussion

Question: Could this method of pest control be used in the field?

Answer: Field trials using pheromones are ongoing. Capture of males with pheromone traps will reduce population sizes of pest insects. However, research focuses on specific chemicals that will not affect humans.

Question: Could sexual confusion be useful?

Answer: We did some research on this and there is data on Lepidoptera, aphids, and others.

2.6 Saliou Niassy,ICIPE, Kenya

Prospects in the use of neonicotinoids and ecosystem services preservation. ICIPE is an international Centre of Excellence in Africa, with a focus on capacity building in general and applied entomology and a staff of >500 from 39 nationalities. ICIPE works on human, environmental, and plant and animal health, whose resultant overlaps enable work on the One Health agenda, and on cross-cutting capacity building and institutional development. ICIPE works in almost all African countries in the context of several African and international agreements, such as the African Union's (AU) Agenda 2063, Feeding Africa, and the United Nations COP21 and Sustainable Development Goals (SDGs).

Neonicotinoids are particularly harmful given the African context of vulnerable smallholder farmers, low literacy, lack of concern, lack of investment, poor regulatory systems, weak extension services, and limited access to markets and loans. Africa missed the Green Revolution because technologies are not being adopted.

A survey published as Farmers' Knowledge and Perception of Grain Legume Pest and Their Management in the Eastern Province of Kenya showed that farmers strongly prefer the most toxic chemicals for pest control. Use of agrochemicals is the main control method practiced. Practises such as increased concentration, chemical alternation, frequent application, and a combination of chemicals are used to maintain pesticide effectiveness. Some 89% of farmers generally did not receive any extension services on pest management, and farmers encounter considerable labour costs in the application of pesticides.

Neonicotinoids (imidacloprid, acetamiprid, and thiamethoxam) are amongst the pesticides used in Kenya.

The African Reference Laboratory for Bee Health was established recently as the first African innovation centre for research, development, advocacy, capacity building, and strategic networking for honeybee diseases and pests. It consists of four satellite bee-health stations and a diagnostic laboratory. The reference lab is accredited by the World Organisation for Animal Health (OIE) as a collaborating centre for bee health in Africa, with a mandate of detecting emerging pests and diseases, and to respond before they threaten food security.

The diversity of bees is declining due to a variety of stressors, but also non-bee insects are declining due to pesticide use. A recent paper entitled Relationship between New Farming Practices and Chemical Use and the Consumption of the Giant Cricket showed significant rarefaction of this insect, which is eaten by humans, due to pesticides, identifies a need for training and surveillance concerning the trade of pesticides in the region, and proposes further investigations into pesticides residues or traces in giant crickets collected for human consumption.

Africa needs more efforts to protect the environment, to advise all stakeholders involved in pesticide use, production, trade, and regulation, to regulate pesticides better, and to evaluate the efficiency and effects of pesticides on the environment. Africa is also struggling with constant introduction of new pests, for whose control even more chemicals are used. The economic consequences of pests and pest control are wide-ranging: Complete restriction on trade (e.g. USA bans on some horticultural produce from Africa due to their infestation with *Bactrocera* fruit flies), rejection of exports at port of entry, or restriction/rejection due to stringent maximum residue levels (e.g. in the EU) result in losses of export markets, incomes, jobs, and poor nutrition in African producer countries.

In terms of worldwide pesticide use, African countries consume relatively little: 2015 data show that Africa used 58.6 mio kg of the worldwide consumption of 3.5 billion kilograms of active ingredient. Within Africa, South Africa, Ghana, and Cameroon are the biggest consumers of pesticides. In emergency situations such as outbreaks of fall armyworms (e.g. early 2017 in Rwanda), huge investments are made to combat outbreaks with pesticides to avoid famines. However, studies have shown that under normal conditions bio-based IPM schemes that are less reliant on external inputs can significantly increase yields while reducing pesticide input and are thus the best option for Africa.

In terms of prospects, Africa should equip itself to detect, measure, and assess pest outbreaks; collect data to quantify the damage, losses, and gains; engage policymakers and create awareness; develop a platform for debate, lobbying, and advocacy; integrate pest-control mechanisms that are mindful of environmental health; and focus on innovation using new alternatives and technical backstopping. Non-chemical management options, e.g. for fruit flies, thrips, *Tuta absoluta*, and fall armyworm, include habitat management/sanitation, use of healthy seeds/seedlings and resistant cultivars, quarantine, parasitoids and other natural enemies, monitoring, biopesticides, male annihilation, bait spray, auto-dissemination of insect diseases (lure and infect), and post-harvest assessment treatment. Adoption of such measures and dissemination of the associated technology results in improved yields and incomes, employment, improved health, low-production costs, access to inputs, and healthier and safer foods.

To spread information, ICIPE produces leaflets, reports, policy briefs, and apps in collaboration with its tech transfer unit. ICIPE research includes alternative pollinators, databasing plant-pollinator interactions, studying pollinator diversity and ecological networks in natural and agricultural habitats, and applied bioprospecting, which can yield alternative applications to reduce pest insects. With regards to bees, the African Reference Laboratory for Bee Health will develop a world class bee research portfolio with the purpose of improving honey bee health in Africa and beyond, focusing on bee health, endosymbionts, nutrition, and pollination. A project focusing on sting-less bees as potential crop pollinators has developed rearing techniques and species identification tools, and has studied the diversity, foraging communication and pollination efficiency of sting-less bees. A study on IPPM (integrated pest and pollinator management) in avocado and cucurbit cropping systems was launched in 2018.

Discussion

Question: What are the prospects for farmers?

Answer: Dissemination, outreach, policy briefings, advisory services, etc. are necessary to educate farmers.

2.7 Mkabwa Katambo, Department of Crop Sciences and Beekeeping Technology, University of Dar es Salaam, Tanzania

Neonicotinoids and their impact on ecosystem services in Tanzania were discussed. Studies have shown that micronutrient availability depends on pollination, e.g. vitamin A, iron and folate. In Tanzania, pesticide usage is regulated by the Plant Protection Acts of 1997 and its regulation of 1998, which states that "Every person importing pesticides shall obtain a permit for importing that pesticide from the Registrar. All pesticides manufactured, formulated or compounded for disposal in any way for use in Tanzania, shall be registered in accordance with the Act and Regulations", and "Every application for pesticide registration or renewal of registration shall be accompanied by detailed information".

The information required to register a pesticide includes "A dossier containing additional information to determine the suitability of the pesticide as to its use and including a technical data sheet and directions on how to detect and quantify the active ingredient" and "A written declaration that the pesticide has or has not been banned or restricted in the country of origin". This means that pesticides restricted or banned in the country of origin cannot be registered in Tanzania. In addition, registration applicants must "Present a representative sample and a certificate of analysis if available", and "Every pesticide submitted for registration shall be submitted for analysis to Tropical Pesticide Research

Institute (TPRI) that carries out field tests within three cropping seasons and laboratory analysis as are necessary to determine its suitability".

However, impacts on non-target organisms have not been adequately studied in Tanzania. Beekeepers observe that colony sizes are decreasing, empty hives become more common, and that the production of honey and beeswax is decreasing. A pesticide is disqualified from registration if it is subject to a Prior Informed Consent procedure; if it is highly toxic, persistent, and biologically cumulative; or if it causes poisoning effects to human and animals for which no effective antidote is available. Seven neonicotinoids are registered in Tanzania in 133 formulations, most are formulations of imidacloprid. Dust, 'wettable' powder, and flowable and microencapsulated formulations can cause severe losses of both foraging bees and hive bees as toxic effects may remain in a hive for months, thus preventing recovery.

The choice of which pesticide to use is determined by the level of poverty, with poor farmers using mostly pesticides classified as extremely hazardous and highly hazardous by the World Health Organisation (WHO); other farmers use mostly organophosphates and carbamates. Pollination makes a major contribution to a country's GDP, but data is missing for most African countries despite the dependence of most African economies on agriculture.

Discussion

Question: How should experts convince policymakers to make changes despite the lobbying by the seed/pesticide companies?

Answer: Europe has done it by following science-based advice.

2.8 Patrice Kasangaki, National Agricultural Research Organisation, Uganda

The current situation of neonicotinoids in Uganda was reported on. The Ugandan Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) has four directorates and six agencies, of which the National Agricultural Advisory Services (NAADS) provide advice on pesticide usage. Pesticide handling and management happen at several levels, namely the MAAIF's Directorates of Crop Protection and Animal Resources, the Vector Control Division of the Ministry of Health (responsible for vector control), the National Environment Management Authority (NEMA), the National Drug Authority (NDA)(regulation of human and veterinary drug use), the agriculture police unit (control of counterfeit pesticides and monitoring of correct use of pesticides), and the Uganda National Bureau of Standards (involved in registration). The National Agricultural Research Organisation issues advice to farmers on pesticides, particularly in emergency situations such as outbreaks of fall army worm, and conducts research, e.g. on reductions of bee-drone sperm counts following exposure to neonicotinoids.

Only limited information is available on neonicotinoid usage in Uganda, and it is difficult to access. Thiamethoxam, imidacloprid, and acetamiprid are used to combat various pests. In addition to uses on crops, neonicotinoids are used to control biting Diptera, ticks, mosquitoes, cockroaches, bedbugs, termites, etc. in livestock, human health, and forestry. The key challenges are quack suppliers selling unregistered and/or counterfeit products, limited knowledge about the pesticides' usage and effects, poor handling and usage of pesticides (tank-mixing, rotational application), resistance development, effects on non-target organism, wash-off/over to water bodies, and residues in plant and animal products. The frequencies of bee swarms have notably increased, beekeepers are struggling to stock their hives from wild swarms. Ways forward involve registration of dealers, commercial applicators, fumigators and premises; sensitisation/training and education of dealers and users; import control; compliance monitoring and inspection at various points; quality assurance at point of entry, distribution systems, etc.; surveillance and enforcement; research on available pesticides, their application, and their impact on the ecosystem and products.

3. Summary of the Day's Proceedings

Christiane Diehl reflected on the afternoon's talks. There is quite a lot of real evidence on what research has been done, which pesticides are available and used, results from studies, and difficulties encountered in Africa. There are possible alternatives for a future of pest control without neonicotinoids. The workshop participants' reflections on regulation, and on improvements of existing regulations were very interesting, as were reflections on use and sales of neonicotinoids and on compliance and monitoring of pesticide usage.

Mike Norton summarised the afternoon, which included talks from a diverse spectrum of African countries with some common and some different problems. In terms of field effects, the observed declines in bee and other insect populations should be quantified and classified. Some presentations spoke of national research efforts on neonicotinoid effects on bees and confirmed that there is no zero-effect dosage in neonicotinoids. A number of presenters commented on numbers of bees, but it would be desirable to add data on non-bee pollinator species and/or ecosystem services. It is very useful to know the regulation status in the different countries, also the penetration rate of the different neonicotinoids in the different countries (codify, inventory). What are the channels that bring the pesticides to the users – agencies, little shops, international pesticide companies?

There should be a discussion on how to communicate advice to the farming community and how to control the supply chain. It is worth noting the differences in importance and severity of insect attacks between Europe and Africa. In Europe, attacks are generally slow and not too severe, so with existing monitoring efforts crop losses can be limited quite easily. In Africa, pest attacks can threaten the food security of entire countries. There seems to be a consensus on the importance of IPM amongst workshop participants. Workshop participants should think about the way forward. This workshop is only a starting point; there will be a working group and a second meeting in May/June 2019. We should consider which countries are present but have not spoken today. Their issues are of great interest too, so the project team will prepare a questionnaire to assess the different countries' issues and perspectives (plus any additional input).

Volker ter Meulen commented on the minority representation of Africa in this workshop – which countries specifically should be included in this project? A working group of approximately 12 volunteers will be needed.

Discussion

- Morocco, Ghana, Tunisia are all big consumers of pesticides.
- Also add Nigeria, there are several people who work on honey in Nigeria.
- Ruanda, Zambia, Zimbabwe, Malawi, Ethiopia have also been overlooked. Countries that rely exclusively on maize are particularly vulnerable to pest attacks and presence of chemical companies. Ruanda is also interesting from a regulations' perspective.

- Will the presentations be made available somewhere, so they can serve to advertise for this project? Other countries/researchers might want to join the project once they see what has been done so far.
- **Answer:** Presentations will be put up on the IAP website: http://www.interacademies.org/48926/Assessing-the-Impact-of-Neonicotinoids-in-Africa-
- This report could also provide inspiration to African countries to build up their research agenda.
- There should also be social scientists in the working group.
- **Answer:** The report will be built on a natural-sciences base, a social-sciences dimension could be added later.

Day 2: 16 November 2018

4. Nabil Bashir, Department of Pesticide Toxicology, Medical Entomology, and Vector Control, University of Gezira, Sudan

The situation in the Sudan was reported on. In Sudan, the Pesticides Act was established in 1969. Today, over 350 ingredients under 1 100 tradenames are registered, though not all of them are in use. Neonicotinoids are used under approximately 20 registered trade names in the Sudan. Thiamethoxam is used for seed treatment, imidacloprid for foliar sprays.

Pesticide registration is based on data, which comes from internal research centres. New chemicals are first tested on a small scale for two years, then on a larger scale, before a registration application is submitted to the pesticides committee. The pesticides committee assesses the data underpinning the registration application. Each active ingredient's technical file contains, amongst others, published data on the ingredient. If the Registrar approves the pesticide, it can be manufactured or imported. Bans are based on data, either from Sudanese labs or from the WHO. Sudanese standards are being put into place for each ingredient and formulation. On arrival in the ports of Sudan, imported chemicals are analysed in Sudanese labs and if they conform to Sudanese standards, they are allowed into the country. The Sudan imports about 100 million US dollars worth of pesticides per year.

Neonicotinoids are used mainly on cotton and wheat. Sorghum and millet are organic and grown mainly in rain-fed areas, which is where most bee colonies live. Correspondingly, Sudan's wild bees are not affected by pesticides. Most pesticides are used in the irrigated areas, with up to 13 sprays per season at peak times. However, now pesticide applications are limited by thresholds, resulting in only 2 –3 sprays per season. Spraying also depends on seed treatments, which reduces the number of sprays. Seed treatments thus enable natural enemies to develop. Problems with bees or natural enemies are not apparent. Residue analyses of soil and field verges showed acceptable levels according to the Joint Meeting on Pesticide Residues (JMPR) and Joint Meeting on Pesticide Specifications (JMPS) standards.

Discussion

Question: Is Sudan self-sufficient in terms food production, or do you produce so little food that you do not notice problems yet?

Answer: Sudan is one of the biggest African countries. 40 million acres are cultivated over summer, plus winter crops. Sudan exports a lot of its food and has managed to reduce foliar applications through IPM and targeted application. Extension services are highly qualified, with 12 faculties of agricultural research institutes and the Agricultural Research Institute of Sudan is 100 years old this year. There are enough scientists in all areas and particularly crop protection. There were also no problems with resistance development noted.

5. Breakaway Discussions and Feedback

Mike Norton introduced a questionnaire (Appendix B) to collate data systematically and identify further relevant issues. The workshop participants split into four groups to discuss the questions posed in the questionnaire, and one rapporteur per group presented the groups' feedback. Rapporteur presentations were followed by discussion with the workshop participants. The feedback from the questionnaires and the group discussions was collected systematically and will feed into the report.

Group A

- Other issues: work on standardization across Africa and finding ways of sharing the load, e.g. by working in regional groupings such as Southern African Development Community (SADC).
- Might there be data in the health sector on human effects of neonicotinoid usage?
- Neonicotinoids are widely used, information available from government, company reps, independent consultants.
- Educating farmers: Farmers want to see fast results and tend to overdose to ensure pest control.
- In SA, seed dressing is likely more common than foliar application. Usages include 3000 different applications (Christian Pirk referred to a South African website here)
- Neonicotinoids are also used on introduced/invasive pest species
- Most SA users unaware of how problematic neonicotinoids are, available in every garden shop

Group B

- For Africa, the EU model for determining colony losses cannot be used. Most African bee populations are wild, resistant/resilient to Varroa mites, and different countries have different bee-keeping practices. Colony losses are more likely due to swarming than to death.
- Regulatory status: There are regulations in almost all countries, but no enforcement. The diversity of the continent suggests that regulations should remain country-specific, but continent-wide authorisation.
- Most farming is subsistence so development of usage should perhaps be per household/capita rather than by volume or value.
- Farmers use different ways of planting seeds – keeping seeds from previous harvest *versus* buying new seed stock. Companies push for annual purchases of new seed stock, which is a concern.
- Information is provided to farmers through extension services and non-governmental organisations (NGOs), but training of extension service staff is mainly in correct application of pesticides rather than IPM.

- Various IPM strategies are available for different purposes on the continent, but they need to be transferred to the farmers, particularly in terms of technology transfer. International input for technology transfers would be welcomed.
- It was suggested that the project should include Portuguese-speaking countries.
- Africa is sitting on a time bomb, there is no time to first do research and then advise policymakers (bottom-up approach). Could we find a way of taking shortcuts and advise African policymakers faster (top-down approach)? Perhaps by creating direct links between the EU and African policymakers, making EU funding conditional on neonicotinoid exclusion, getting EU funding for projects working towards neonicotinoid bans.
- ASSAf: contact with New Partnership for Africa's Development (NEPAD) an agency of the AU and discuss how to fast-track this project to African policymakers.
- There is quite a lot of data on different bee subspecies, and on 'killer bees' in the Americas (which originated in SA) so data could be transferrable – use existing data to make a faster point about Africa rather than recommending lengthy research programmes.
- Focus on consumer health.
- In Benin, the honey hunters are complaining about reductions in bee populations, and farmers are complaining about the lack of crop pollination, beekeepers experience honey yield losses. Benin participant will send a reference quantifying this.
- Resistance to Varroa is very varied across Africa. Overall lower infestation of hives with Varroa than in Europe. Dr Yusuf would have information quantifying this. An African model is needed to quantify colonies and explain colony losses.
- On capacity building: In 2009, a group identified a gap in knowledge about bees. Honeybees are not the only pollinators, so it is important to educate farmers in the identification of honeybees and other bees and explain that they are not pests. More than 3 000 species of bees in Africa.
- Honeybees are responsible for only about 30% of pollination of crops, the remainder is due to other bee species, so ensure adequate focus on all bee species/pollinator species.
- Data collection to policy change in SA would take a minimum of seven years. Strengthen regulatory agencies, enforce existing bans, and implement bans applied in other countries. Africa does not have the luxury of time.
- Tread carefully when transferring data and information from other countries. Make sure it is supplemented and supported by any available local data.
- EU regulation is based on precautionary principle. In the USA the focus is on economic development, substances are only banned if things go seriously wrong.

Group C

- South Africa has reported bee declines, Uganda observed the decline of managed wild bees. Sudan and Egypt no decline in pollinators.
- Other issues: Do neonicotinoids have a future? Learn from glyphosate and Monsanto. What is the companies' role in this? Will they provide their own research to 'counteract' independent research? What is the role of other pollutants on the decline of bee/insect species? Identify synergistic or potentiating effects between neonicotinoids and other pollutants.
- How to improve on application, particularly regarding timing. Regardless of whether crops are flowering or not, the bees are threatened by residues year round

Group D

- Need to move to a regulation that includes foods. Compliance with international regulation, find out why neonicotinoids are not cited as highly hazardous pesticides.
- Regulation emphasis should be on human health, this might have greater impact than ecological/agricultural concerns.
- Food-safety perspective: People's concerns about food safety could exert pressure on policymakers.
- Use of neonicotinoids in vector control – is this done? Usual? Effective? There are two products registered in Cameroon for use in indoor treatments of mosquitoes?
- What about data on neonicotinoids in dairy products? Cattle might accumulate neonicotinoids from fodder. Any information on immune responses in cattle to neonicotinoids?
- Are there any studies on human health effects, particularly autism, from neonicotinoids? A global review of research on neonicotinoids mentioned some mental effects, including autism disorders. Research on this is in the early stages. Studies from Japan report that accidental exposures result in neurological effects that one would expect from neonicotinoids' mode of operation. Human health has not been on the research agenda with regard to neonicotinoids until the past few years. Current evidence is sufficient to continue doing research.
- Recent study in Taiwan on bats showed some effects.

6. Next steps

Mike Norton outlined the next steps of this project, including drafting of a report based on workshop discussions and inputs by March 2019, electronic consultation with workshop participants (and potentially additional experts nominated by NASAC member academies), a second meeting of the working group in Nairobi, and a completed report with policy recommendations in mid-2019

7. Discussion Formation of a Plan for Future Actions

- NASAC was consulted in the lead-up to this workshop but had not yet engaged in the project (there had been limited time available for workshop organisation). Workshop participants were thus present as individual experts and not representing their country's academy. Steps should be taken to engage NASAC and ask member academies to support/nominate their experts.
- Recommendations should not suggest that there should not be more research on neonicotinoids in Africa, only that it's not precluding the production of no-regret advice now.
- Identify some milestones that would enable tracking of progress.
- What is the goal of this effort? Sign-off by heads of state of the AU? A step-wise approach might work best, involving contact with politicians before/during/after the launch of the report, and then take it from there. Whatever works (best) for the different countries of Africa, working group members are welcome to provide advice.
- Comment on lack of input of academies/independent scientists into policy on harmonisation of pesticide registration.

- Mike Norton outlined the EASAC process of the work of the working group and subsequent endorsement, a similar structure with NASAC is envisioned for this project.
- There is no equivalent of EASAC's relationship with the European Commission (EC) in Africa – NASAC has no close relationship with the AU Commission. However, perhaps there are people in this workshop who have experience with working with the AU (amongst them Roseanne Diab) who could enable NASAC to build closer ties with the AU.
- Workshop attendants agreed that the outcome of this project should involve science advice for policy and help to build bridges between the African science academies and policymakers. He clarified that EASAC has no specific relationship with the EC, EASAC's relationship with the EC is similar to that of NASAC with the AU.
- In Tanzania, scientific advice goes to the corresponding ministry where it gets examined and possibly adopted.
- SADC process or at Regional Economic Communities (REC) level? Any issue needs to be raised by at least three states. Proposals are taken to the Council of Ministers at SADC, from where it can go to heads of state or AU. A functioning SADC secretariat is instrumental to raise issues from national to SADC to AU level. SADC meetings are very important and efficient platforms to make proposals at national and/or regional levels.
- Invite SADC representative to the next meeting?
- National pesticides institutes/authorities – could they be invited to the Nairobi meeting? And/or heads of councils, Registrars?
- Harmonisation is not unification, and harmonisation efforts were collaborative, involving all Registrars from all African countries.
- Involving RECs is important to ensure that proposals/documents can be discussed at all appropriate levels so nobody feels left out. Economic Community of West African States (ECOWAS), SADC, Northwest Africa (MAGREB), Central region, Eastern African REC each have their own meeting.

8. Closing and Vote of Thanks

Roseanne Diab gave the closing Vote of Thanks on behalf of ASSAf and thanked all participants for their consistent engagement during this workshop and their valuable contributions from a scientific, procedural perspective, and in terms of ways forwards. She thanked the European experts, and particularly Mike Norton, for contributing their expertise and driving the project forward, and the speakers for contributing a broad variety of inputs. Thanks goes to Volker ter Meulen, IAP, and EASAC for securing funding and making this meeting happen. Thanks goes to the ASSAf staff, particularly Khutso Phalane-Legoale, for making this workshop happen on very short notice, and for their interest in the science. Christiane Diehl joined her in thanking ASSAf for their outstanding support. Volker ter Meulen wrapped up the workshop and thanked all participants for their contributions.

9. Appendix A – Online Presentations

Presentations which are available as online resources are;

- Summary of the EASAC work on ecosystem services, agriculture and neonicotinoids (Prof Mike Norton) Presentation 1. (full report here)
- Scientific findings of the IUCN reviews of the effects of systemic pesticide (Dr Jean-Marc Bonmatin) Presentation 2.
- Immunity, stress and sub-lethal effects (Prof Francesco Pennacchio) Presentation 3

- Regulatory responses (Maarten Biljeveld van Lexmond) Presentation 4.
- Responses in Philippines (Beth Heitzmann) Presentation 5.

Information-sharing session on the status of neonicotinoid registration and use across Africa by some of the 30 expert representatives brought together from some 12 African countries. Presentations available online are:

Benin – by Abdou Paraiso, University of Parakou

Botswana – by Motshwari Obopile, Botswana University of Agriculture and Natural Resources

Cameroon – by Leonard Ngamo Tinkeu, University of Ngaoundéré

Cote d'Ivoire – by Akpa Akpesse, University Félix Houphouët-Boigny

Egypt – by Youssef Dewer, Central Agricultural Pesticide Laboratory

Kenya – by Saliou Niassey, International Centre for Insect Physiology and Ecology

South Africa – by Christian Pirk, University of Pretoria

Sudan – by Nabil Hamed Hassan Bashir, University of Gezira wad medani

Tanzania – by Mkabwa Katambo, University of Dar es Salaam

Uganda – by Patrice Kasangaki, National Agriculture Research Organization.

10. Appendix B: Questionnaire

Subject	Information	Priority data gaps	References
Are there currently effects noted in the field?	Decline in bees noted in several countries Reports of localized declines in other species (e.g. crickets) as food	Data on bee decline from other countries Any trends in other pollinators? Any trends in other insect species? Any trends in other ecosystem services?	
Testing on neonicotinoids in African countries	At least one country has done their own testing on toxicity to bees of neonicotinoids	What other countries have conducted their own toxicity tests? Any other testing, e.g. effectiveness, persistence, human health effects?	
What is the regulatory status?	Regulatory status appears to be country-specific	Status of neonicotinoid	

	Several examples of numerous products containing neonicotinoids available in some countries, other countries registration more limited	regulation in other countries What are the implications of regulatory harmonisation at continental or regional scale? Is any regulatory data available?	
Extent of neonicotinoid use	Honey contamination suggests widespread use Some quantitative data available on usage between different crops Overall use (sales?) for Africa suggests still lower usage than other parts of the world	Data on trends in use	
Manner of neonicotinoid use	It appears that foliar application is still dominant, but it is possible that systemic application will be increasing in future	Is this supported by data? Trends in individual countries	
Informing farmers	Surveys show that farmers lack information on the risks of neonicotinoids General lack of adhering to recommended dosages and instructions Lack of confidence in quality and safety of the	Are there good examples of extension services in Africa? Best practice on how to inform farmers, including effective communication on IPM	

	product (fraud, counterfeit)		
Specific pest challenges in Africa	Army worms mentioned in several countries	What is an effective strategy that avoids negative environmental effects of neonicotinoids?	

Other countries not represented at this workshop			Suggested contacts
Other issues?			

11. Appendix C: List of Participants

#	**Title**	**Name**	**Surname**	**Affiliation**
1.	DR	Ovokoroye	Abafe	Agricultural Research Council
2.	Prof	Akpa	Akpesse	*University Félix Houphouët-Boigny*
3.	Prof	Nabil	Bashir	Blue Nile National Institute for Communicable Diseases
4.	Ms	Cathy	Bester	University of Pretoria
5.	Dr	Maarten	Bijleveld van Lexmond	IUCN Task Force on Systemic Pesticides
6.	Dr	Jean-Marc	Bonmatin	*Centre National de la Recherche Scientifique*
7.	Dr	Lestrade Anne	Bonmatin	

8.	Dr	Siyavuya	Bulani	Academy of Science of South Africa
9.	Mr	Tony	Carnie	Freelance Environmental Journalist
10.	Ms	Farisai	Chibange	Ministry of Agriculture (Zimbabwe)
11.	Dr	Youssef	Dewer	Central Agricultural Pesticide Laboratory, Egypt
12.	Prof	Roseanne	Diab	Academy of Science of South Africa
13.	Dr	Christiane	Diehl	German National Academy of Sciences Leopoldina
14.	Dr	Ezette	du Rand	University of Pretoria
15.	Prof	Mary	Gikungu	National Museums of Kenya
16.	Dr	Elizabeth	Heitzmann	International Association of Butterfly Exhibitors and Suppliers
17.	Dr	Nina	Hobbhahn	German National Academy of Sciences Leopoldina
18.	Prof	Hannelie	Human	University of Pretoria
19.	Mr	Theodor	Kaambu	Ministry of Agriculture (Namibia)
20.	Dr	Robert	Kajobe	National Agriculture Research Organisation (NARO)
21.	Dr	Patrice	Kasangaki	National Agriculture Research Organisation (NARO)
22.	Dr	Mkabwa	Katambo	University of Dar es Salaam
23.	Dr	Peter	McGrath	InterAcademy Partnership

24.	Ms	Phakamile	Mngadi	Academy of Science of South Africa
25.	Dr	Misheck	Mulumba	Agricultural Research Council
26.	Dr	Fiona	Mumoki	University of Pretoria
27.	Prof	Leonard	Ngamo Tinkeu	University of Ngaoundré
28.	Dr	Saliou	Niassy	International Centre of Insect Physiology and Ecology
29.	Prof	Michael	Norton	European Academies Science Advisory Council
30.	Prof	Motshwari	Obopile	Botswana University of Agriculture and Natural Resources
31.	Dr	Olabimpe	Okosun	University of Pretoria
32.	Prof	Abdou	Paraiso	University De Parakou
33.	Prof	Francesco	Pennacchio	University of Napoli Federico II
34.	Dr	Khutso	Phalane-Legoale	Academy of Science of South Africa
35.	Dr	Motlalepula	Pholo	Ministry of Environment (Botswana)
36.	Prof	Christian	Pirk	University of Pretoria
37.	Ms	Kelebogile	Seotloe	Academy of Science of South Africa
38.	Mr	Ian	Shendelana	Academy of Science of South Africa
39.	Dr	Christian	Stutzer	University of Pretoria

40.	Prof	Volker	Ter Meulen	German National Academy of Sciences Leopoldina
41.	Ms	Henriette	Wagener	Academy of Science of South Africa
42.	Dr	Abdullahi	Yusuf	University of Pretoria