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MARCH/APRIL 2015

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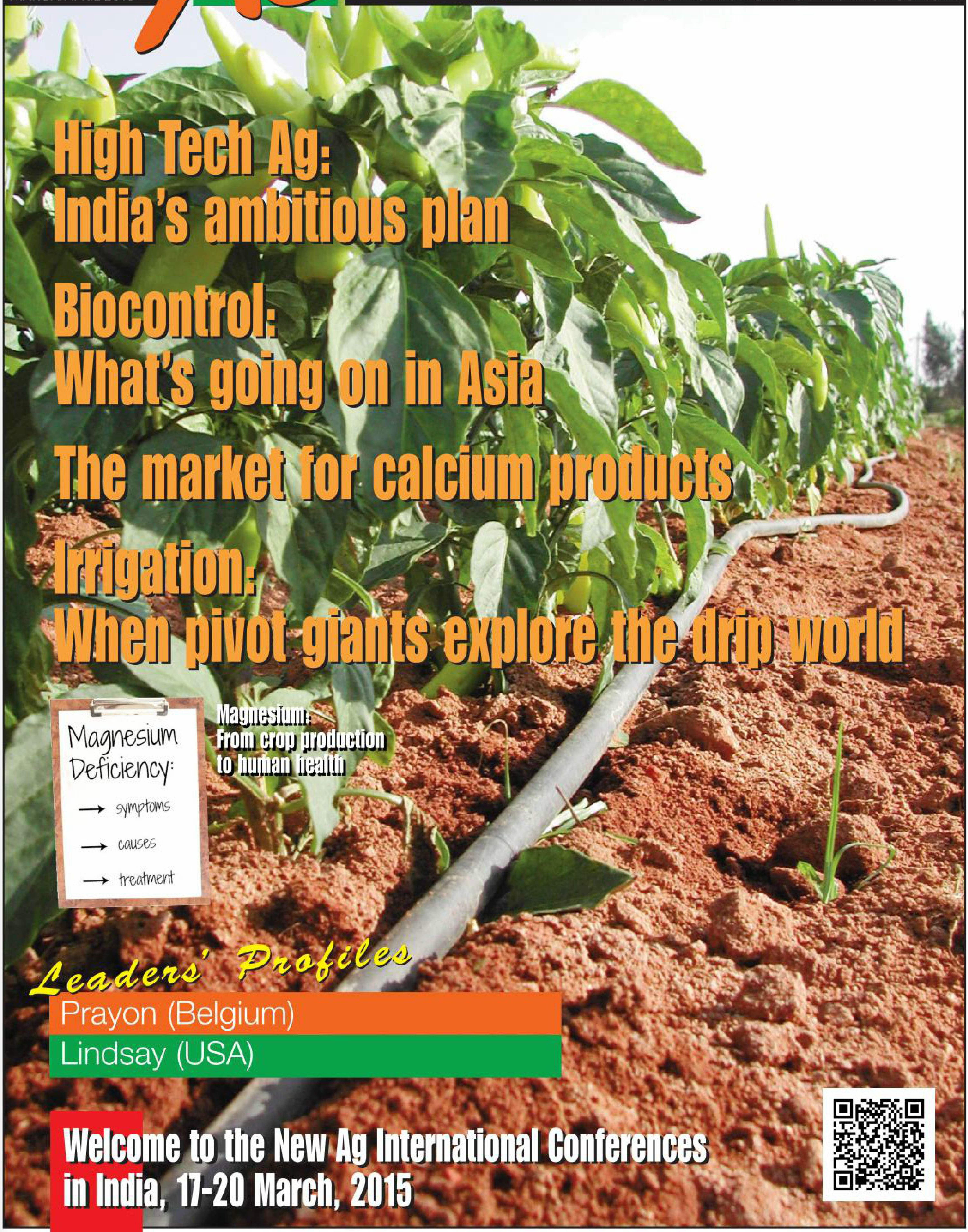

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Welcome to the New Ag International Conferences in India, 17-20 March, 2015

The Asian Biocontrol Market:

Current Situation and Perspectives on Implementation of Sustainable Agriculture

On the occasion of the first Asian conference fully dedicated to Biological control, jointly organized by New Ag International, 2B Monthly and IBMA, we asked the very best expert in the region to give us the highlights of the market for biocontrol in Asia. In this outstanding review, Dr. Thomas Jäkel, GIZ-CIM Plant Protection and Pest Control Expert, Chief Technical Adviser, ASEAN Sustainable Agrifood Systems (Biocontrol), Department of Agriculture, Thailand and his colleague Sulaiman Ginting, Deputy Project Director, ASEAN Sustainable Agrifood Systems (Biocontrol) based in Indonesia. present an overview on the Asian biocontrol market and reflects on the experiences and perspectives that evolved since 2002 during the course of two projects supported by German Development Cooperation and ASEAN Member States: The former 'Commercialization of Biopesticides in Southeast Asia' and the still ongoing 'ASEAN Sustainable Agrifood Systems (SAS)'. In 2012, SAS started developing the ASEAN Biocontrol Database, which contains annotated information on registered biocontrol agents (BCA) in that region. Large parts of this analysis rest on this. Information on other Asian countries was gathered through publicly available sources, business reports, and communication with business representatives.

TO START WITH, one has to clarify in advance what BCAs (Biocontrol Agents) are. Due to the variety of categorizations and definitions out there, it was agreed also for the purpose of this article to apply the nomenclature of the British Crop Protection Council (BCPC) that was published in the 3rd edition of 'The Manual of Biocontrol Agents': Micro-organisms (or microbials), macro-organisms (or macrobials), semiochemicals, and natural products. The latter include molecules, or mixes thereof that are derived from living organisms, such as micro-organisms, crustaceans, higher plants, alga, etc. So, besides botanicals natural products also cover agricultural antibiotics, plant growth regulators, and so on. For purpose of differentiation, this article sometimes considers selected subgroups of natural products separately (see graphs). Although GM crops resistant to insect pests are grown in Asian countries (e.g. India, China, Philippines), too, they are not included here for reasons of clarity and brevity.

Dr. Thomas Jäkel

ASIA: MOSTLY SUBSISTENCE FARMERS

Asia supports about 60% of the global population on only about 23% of the world's agricultural land. More than 2.2 billion people in the region rely on agriculture for their livelihoods. Rice is by far the most important crop throughout Asia, whereby 90% of the world's production and consumption occurs here. Farm holdings in most Asian countries are highly fragmented. This inhibits agricultural mechanization and land consolidation efforts have been slow. Most Asian farmers are subsistence farmers, cultivating crops for family consumption. Almost all farm operations are done manually or with the help of draft animals. Exceptions are found in Japan, (South) Korea, and Taiwan, where small-scale equipment is widely used. Japan's agriculture, in particular, is input and machinery-intensive, resulting in high productivity on limited land resources.

Sulaiman Ginting

Despite forecasts of famine and starvation, most Asian countries became food self-sufficient in the 1970s and 1980s, thanks to the 'Green Revolution'. However, food and feed crop demand will nearly double in the coming 50 years. With 25% of the world's population and only 7% of the world's arable land, the agrifood trade is a crucial sector of China's economy. Projected imports of agrifood commodities in the coming decades will have significant implications within Asia. Demand for fruits, vegetables, meat, fish, and eggs is likely to grow with increased urbanization and industrialization. Demand for cereal crops will be reduced. In Japan, Korea, and Taiwan consumption of rice has already begun to decline. Increased crop production is required to feed the growing populations of Asia.

THE ASIAN BIOCONTROL MARKET: VERY SMALL BUT RAPIDLY GROWING

The Green Revolution also came along with negative impacts. It resulted in over- and misuse of fertilizer and pesticides, which continue to pollute environments and pose health risks to farmers, growers, and consumers alike. High-yield seeds now allow for up to three crops or more a year, coming with the consequence of enhanced soil degradation. In view of these problems and a worldwide desire to improve the situation one could image that the advent of a 'greener' generation of pesticides such as BCA is highly welcomed.

Commercial BCA (there are also unregistered products on home-grown markets or produced by farmers themselves) still represent

Table 1 - Key Characteristics of Biocontrol Markets in Asia

	ASEAN	China	India	Japan	Korea
Estimated Value of BCA Market	>$200 Mio (2012); Indonesia, Vietnam, Thailand, and Malaysia biggest markets; considerable homegrown markets (e.g. botanicals)	About 5% of total pesticide use; $173 Mio imports & exports and 85 a.i. of BCA used on 26.7 Mio ha (2011)	Approx. $34 Mio (2014), mainly Gov. programs; Neem, *Trichoderma* spp., other microbials; private markets developing	$16 Mio microbials (2010); 0.4% of pesticide market ($4.1 Bio)	$35 Mio or 2.6% of pesticide market; $7 Mio microbials (2010)
Key Products and Markets	Rice, vegetables, fruits , industrial crops; insecticides & fungicides	Rice and cotton; **fungicides & insecticides** dominant	Major consumer of insecticides; cotton	Major consumer of **fungicides &** bactericides	Rice, horticulture; Fungicides & bactericides dominant
No. Companies	Vietnam (>200), Indonesia (119), Malaysia (41), Thailand (18), Laos (13), Singapore (8), Philippines (7), Cambodia (3)	>200 manufacturers; about 1700 antibiotics producers	About 32-69	About 26	About 14
Area of Arable Crops	62 Mio ha; about 15 Mio ha irrigated; Indonesia and Thailand largest agricultural land holders; ASEAN about 50% under rice	168 Mio ha; 29.4 Mio ha rice; GM crops 3.7 Mio ha (2009); wheat also important	190 Mio ha; 0.6% organic (2007); besides rice wheat and other cereals, cotton	3.2 Mio ha (>50% rice); 3.5 Mio farms (av. 3.5 ha);input and machinery intensive; organic only 0.2% of area	1.7 Mio ha (>50% rice); av. 1.5 ha farms; about 55,000 ha protected horticulture
IPM Policies	ASEAN Knowledge Network (ASEAN IPM) active from 1997 to 2011 linking Gov. institutions	Model IPM on 4,000 ha rice (1975) and 37 ha in Jinhua (2011); since 2010 promotion of microbials; agricultural sustainable development program (2013)	Federal and regional Gov. encourage IPM; 32 IPM Centres; promotion of BCA by Department of Biotechnology (DBT)	Gov. policies to cut down pesticide use (Basic Law on Food, Agriculture, and Rural Areas)	Gov. IPM in the 1990s
Pesticide Issues	Over- and misuse of pesticides and fertilizer	Over- and misuse of pesticides and fertilizer; $50 Mio Gov. program to counter residue issues	Resistance to GM cotton (2010); rice and cotton highest pesticide input	High agrochemical input	High agrochemical input
Growth Projects	Good for microbials and natural products; semiochemicals promising once better regulation	Continued growth; about 30 research institutes drive R&D	Despite governmental promotion not enough thrust behind BCA	Pesticide market mature; substitution potential; forest pests; fungicides	Good

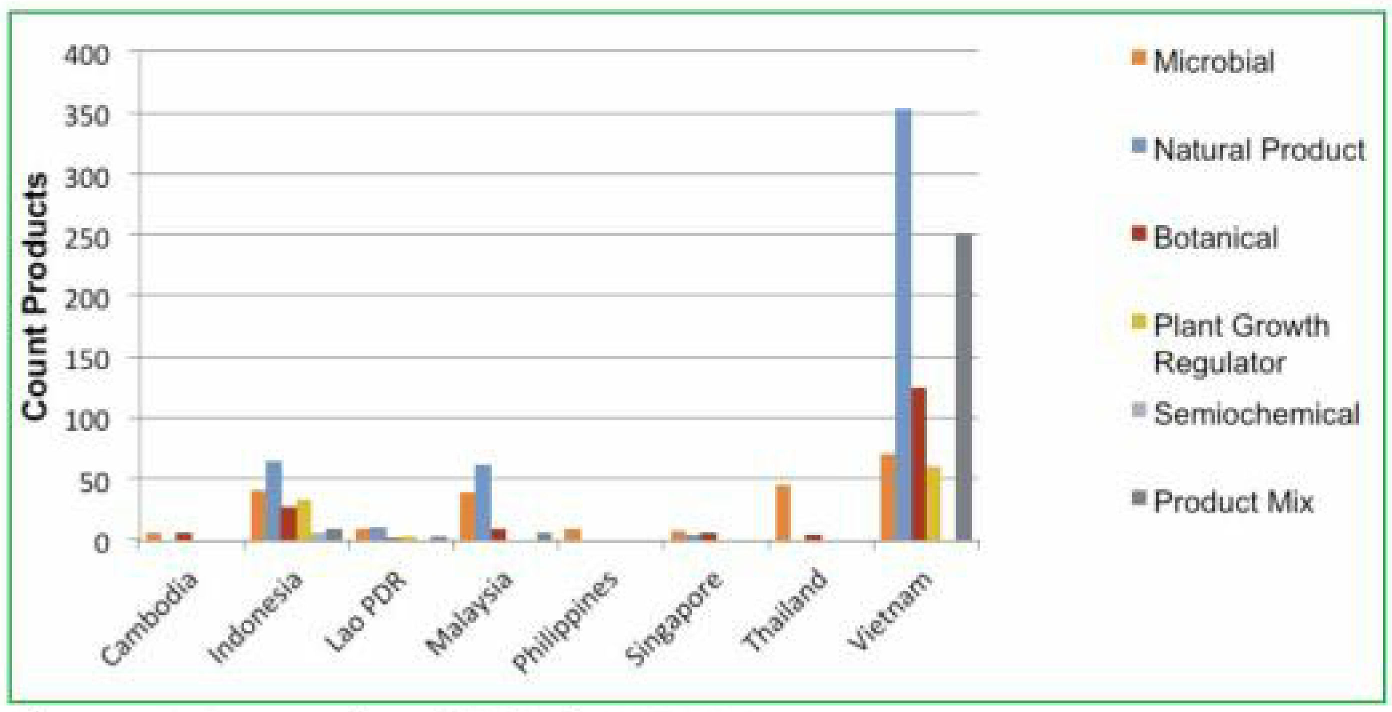

Figure 1: Categories of BCA in ASEAN

a small fraction of the total pesticide market in Asia (about 0.4% - 5%). However, annual growth rates of around 15% as predicted by several business reports appear impressive (compare also Fig. 2). Table 1 summarizes some key characteristics of biocontrol markets in ASEAN member states (Southeast Asia), China, India, Japan, and Korea.

It should be outlined that Japan and Korea can be characterized as high input – high productivity agricultural economies, whereas other countries have not yet attained this level of intensification. For instance, usage of active ingredients of pesticides was cited for 0.6 kg/ha/yr in India (2013) and approaching 4 kg/ha/yr in Thailand in 2009, whereas for Korea 13 kg/ha/yr were reported in 2007 and reached 19 kg/ha/yr in Japan at times. Interestingly, the latter two countries are now comparatively stronger consumers of fungicides and bactericides while insecticides dominate in the rest. Although high usage of insecticides is often said to be caused by high insect pressure in tropical agriculture,the further analysis below provides alternative explanations. China shows strong insecticide and fungicide/bactericide sectors, also due to the fact that she is the major producer and exporter of BCA in the region. Reports indicate that about 14% of the total Chinese industrial pesticide outputs are BCA. Although Asian governments have been promoting IPM (Integrated Pest Management) to varying extents in the past (Table 1), the proportion of use of BCA among pesticides is still comparatively low.

Major active ingredients of microbials and natural products registered in Asia are listed in Table 2. It confirms that besides insecticides China and Korea have quite diverse portfolios of fungicides and bactericides. The bulk of agricultural antibiotics in ASEAN are mainly registered in Vietnam. India shows a high diversity of BCA in all four categories of BCA (macrobials and semiochemicals are not shown), which is probably due to her comparatively long history of research and development in this sector. India is the only country that dedicated a governmental biotechnology department to the promotion of BCA since 1989. As indicated by the numbers of registrations (Table 2) insecticides like Abamectin (and related compounds) and Bt are major 'blockbuster' products in Asia. Of major importance are also agricultural antibiotics such as Kasugamycin, Validamycin, etc.

The use and (commercial) distribution of macrobials is difficult to assess. This is because they are often not registered and produced and distributed under government control (e.g. in pest management centers). For India it was reported that about 34 institutions were producing macrobials, including private companies. A major species used against lepidopteran pests in rice, other cereals, and forests are the small wasps of the genus Trichogramma. For China the area under control was reported 600,000 ha to 2 million ha at times, for Southeast Asia 0.3 million ha. Good control of diamondback moth (DBM) in highland vegetable areas in Southeast Asia (e.g. Malaysia, Thailand) was achieved by establishing Diadegma semiclausum. However, 'classical' biological control probably exists only in small pockets of farmland today due to the extensive use of broad-spectrum pesticides. Self-sustaining biocontrol agents like parasitoid wasps that - once released – take full control of the pest are not an attractive business model for the private sector. Nematodes are frequently used for pest management in turf partly owing to the popularity of golf in Asia.

Worldwide, lures for monitoring and mass trapping are at least covering 10 million ha. The use of semiochemicals in Asia is increasing and probably underestimated, because various products are sold without registration, or may not require registration in the first place (e.g. in Malaysia). They are used as pest monitoring tools, for mass trapping, as attract-and-kill preparations, or in autoconfusion systems. In many Asian countries regulatory authorities are uncertain about risk assessment of semiochemicals. Furthermore, efficacy trials are difficult to implement because they usually require large-scale field testing. There are only five pheromones registered in ASEAN (Indonesia), yet, they are also applied in neighboring countries in industrial crops (oil palm, coconut, cocoa) and fruit orchards. The use of sex pheromones for mass trapping or autoconfusion of stem borers in rice has been implemented in India, and is under trial in China, Indonesia and other ASEAN member states. Common to all pheromone-based pest management systems is that they require area-wide applications in order to exploit their full potential and make them economically attractive to farmers and growers.

VIETNAM IN THE LEAD IN SOUTH EAST ASIA

If we specifically look at the situation in Southeast Asia (Fig. 1, Table 2), Vietnam shows the highest diversity and numbers of registered BCA, whereby many products are imported from neighboring China. Almost half of the BCA registered in ASEAN contain the active abamectin. However, there are also countries that treat abamectin as a conventional pesticide (e.g. Thailand). Again, with Vietnam in the lead there is a considerable variety of product mixes, BCA that contain more than one active or are combined with synthetic pesticides. Among the botanicals, which are shown separately here from the rest of the natural products, azadirachtin constitutes a major active ingredient, saponin is widely used as a molluscicide against the rice pest, golden apple snail. Many of the registrations in Vietnam did not become established in the market. A study conducted by SAS in 2013 revealed that only about 10 companies in Vietnam sell BCA in larger volumes. In Indonesia, the regulatory framework has been improved significantly and the government is subsidizing BCA under its current agricultural policy. After regulatory reform since 2009 the BCA market in Thailand

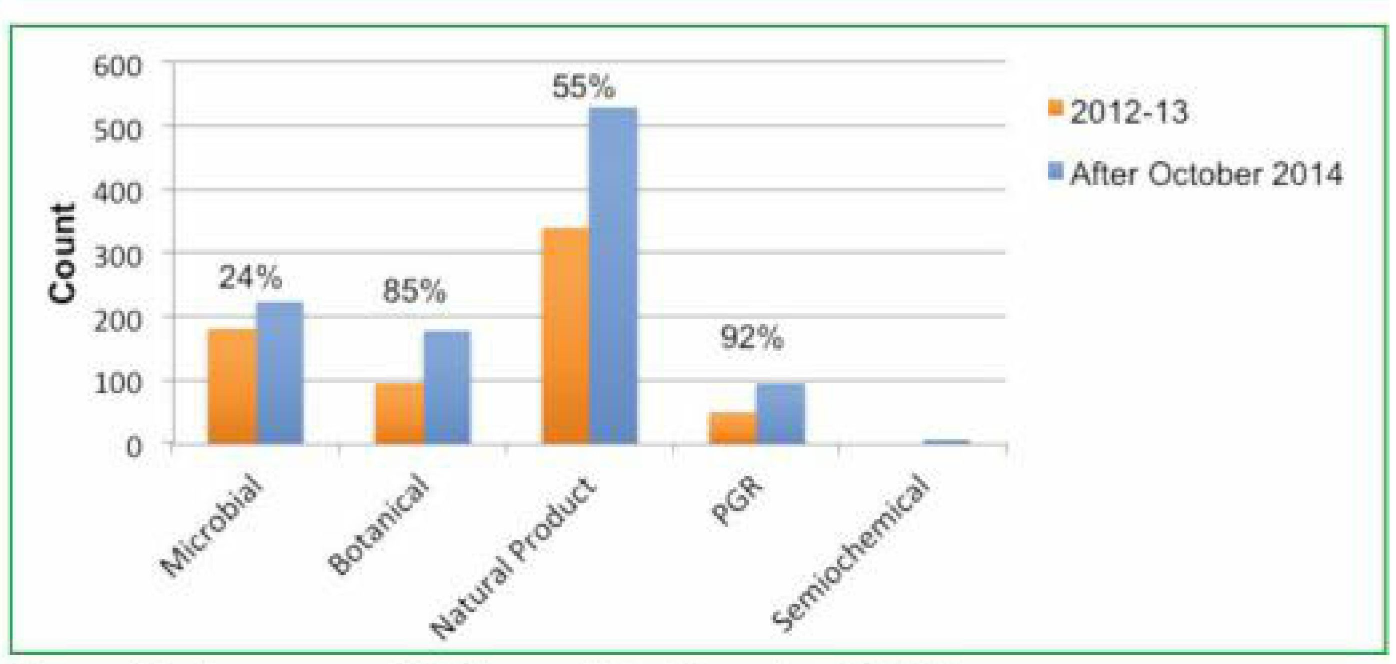

Figure 2: Increase of BCA registrations in ASEAN

is now picking up again: There was a surge in microbial registrations in 2014. The increase in registrations of BCA in ASEAN is remarkable, if we compare the situation in 2012-13 with the year 2014 (Fig. 2). A major driver behind this appears to be the quest of various governments in SE Asia to make crop and food production 'greener'. SAS has been supporting this process by helping improve regulatory frameworks for BCA, facilitating commercialization of biocontrol in collaboration with local companies and international industry, and developing and field testing IPM concepts that integrate BCA as a major pillar. A currently published guidance document, the 'ASEAN Guidelines on Regulation, Use, and Trade of Biological Control Agents (BCA)', the first of its kind in Asia, is available now for download (www.asean-agrifood.org). It should be acknowledged that the International Biocontrol Manufacturers' Association (IBMA) has been closely collaborating with SAS in fostering regulatory discussion within ASEAN member states in the OECD context.

HARDLY ANY IPM PRACTICED IN ASIA: A HINDRANCE TO BIOCONTROL DEVELOPMENT

So why do BCA still make up a small fraction of the pesticide market, although demand for 'green' products appears to be constantly rising? Why do governments and industry alike uphold the principles of Integrated Pest Management (IPM) and use of environmentally friendly technology, if reality in the field looks bleak? There are various reasons, of course. Let's start with one major problem: the current pest management paradigm is on the wrong track. There is hardly any IPM practiced by farmers and growers in Asia today; at least not as perceived by the founders of the concept, which emphasized elements of prevention rather than pure 'reaction' to pest problems and pesticide application based on (economic) thresholds. Today IPM is widely (mis)understood as the mixing and rotating of different active ingredients of pesticides. Synthetic pesticides are firmly locked into the system, the so-called 'pesticide treadmill', with routine (calendar) applications being the norm rather than the exception. Recent results of interviews with smallholder farmers in Asia all show that even long-term practitioners in rice or vegetable production have no or little knowledge of proper IPM practices.

As illustrated in Figure 3, we can distinguish different pest management systems. IPM in its true sense is a holistic approach that does permit the use of synthetic pesticides, but their use should be 'judicious' and selective. Overall, IPM aims at reducing use of pesticides. And this is, naturally, in direct conflict with the general business model of the pesticide industry.

That the way pesticides are used today is unsustainable can be nicely illustrated by the very spectrum of targets they are sold against. In preparation for this article, 72 products of BCA registered in China (about 2000) were randomly selected only including the actives abamectin, spinosad, and three microbials (Bt,

Table 2 - Major Active Ingredients in Asia (2011-15)

	ASEAN	China	India	Japan	Korea
Microbials	Bacillus thuringiensis (143) B.t. var. israelensis (9) Beauveria bassiana (15) M. anisopliae (14) Spodoptera litura NPV (1) Bacillus subtilis (8) B. coagulans (1) P. fluorescens (3) Streptomyces lydicus (2) Trichoderma spp. (19) T. harzianum (5) Sarcocystis singaporensis (3) (rodenticide)	Bacillus thuringiensis (202) B. sphaericus (3) Heliothis armigera NPV (19) Spodoptera exigua NPV (5) Autographa californica NPV (2) Pieris rapae GV (2) Plutella xylostella GV (1) S. litura NPV (3) Beauveria bassiana (13) Metarhizium anisopliae (8) B. subtilis (11) Paenibacillus polymyza (3) Pseudomonas fluorescens (2) Trichoderma spp. (10) Chlamydosporium (2) Paecilomyces lilacinus (6)	Bacillus thuringiensis (19) B.t. var. israelensis (7) B. sphaericus (2) Helicoverpa armigera NPV (11) Spodoptera litura NPV (9) Beauveria spp. (29) B. brongniartii (2) Metarhizium anisopliae (19) Nomuraea rileyi (2) Paecilomyces fumosoroseus (5) Verticillium lecanii (25) Ampelomyces quisqualis (4) B. subtilis (5) Pseudomonas fluorescens (28) Trichoderma spp. (44) P. lilacinus (19) Hirsutella thompsonii (2)	Bacillus thuringiensis (6) Beauveria spp. (5) S. litura NPV (2) Homona magnanima-Adoxophyes orana GV (2) Bacillus subtilis P. fluorescens (3) Pasteuria penetrans (1)	Bacillus thuringiensis (15) Beauveria bassiana (2) Paecilomyces fumosoroseus (1) Ampelomyces quisqualis (1) Bacillus amyloliquefaciens (2) Bacillus pumilus (1) Bacillus subtilis (16) Streptomyces colombiensis (1) Streptomyces goshikiensis (1) Trichoderma harzianum (1) Monacrosporium thaumasium (1) Paenibacillus polymyxa (N fixation)
Natural Products	Abamectin & similar (472) Azadirachtin (57) Citonella oil (6) Eucalyptol (1) Garlic extract (4) Ginseng extract (15) Matrine (20) Pyrethrin (10) Rotenone (14) Kasugamycin (65) Ningnanmycin (33) Polyoxin (5) Validamycin (54) Chitosan (22) Gibberellic acid (86) Oligo-alginate (2) Methyl Eugenol (23) Saponin (44) (molluscicide)	Abamectin (1503) Emamectin benzoate (223) Pyrethrins (22) Rotenone (14) Matrine (60) Spinosad (43) Azadirachtin (20) Jinggangmycin (160) Kasugamycin (83) Polyoxin (65) Ethylicin (19) Ethephon (91) Gibberellic acid (99) Hexaflumuron (87) (IGR)	Azadirachtin Emamectin Benzoate Pyrethrum Spinosad Kasugamycin Streptomycin Validamycin Milbemectin Gibberellic Acid	Spinosad (12) Emamectin benzoate (5) Abamectin (2) Pyrethrin (3) Milbemectin (6)	Emamectin benzoate Spinosad Kasugamycin Polyoxin Streptomycin Validamycin Milbemectin Oxytetracyclin (bactericide) Pelargonic acid (herbicide) Gibberellic acid
Use type	Insecticide/Repellent Fungicide & Bactericide	Nematicide Acaricide	Plant Growth Regulator Attractant	(No. of products in parenthesis where available)	

Beauveria bassiana, Metarhizium anisopliae). The four most frequently registered target pests were diamondback moth (DBM) in cabbage (19 registrations), leaf-folders in rice (10), stemborers in rice (8), and other lepidopteran pests in cabbage (6). A similar 'hit list' emerges, if we look at the target spectrum of all BCA currently registered in ASEAN member states: DBM (368 product registrations), fungal diseases (380), thrips (225), rice leaffolder (177), brown planthopper (BPH) (150), red spider mite (148), and aphids (81). The rest, 130 target pests and diseases, show much lower product hits. The examples show that the bulk of pesticides including BCA are registered against relatively few pests. In particular those insect or arthropod pests that are known to quickly develop resistance to synthetic pesticides: These are DBM, BPH, or red spider mites for instance. Frequent 'burn out' of new products (e.g. spinosad, abamectin) is observed in brassica production areas throughout Asia, where DBM is a major target. Another indicator for 'burn out' is the high number of product mixes in certain countries (e.g. Vietnam, Fig. 1). There is ample published evidence that insect pests like DBM or BPH are pesticide-made pests so to say – they would not have attained this status without mis- or overuse of pesticides. Hence, development and marketing of BCA largely follows the pesticide treadmill, too.

Because the current IPM model is largely following a reductionist approach (Fig. 3), it is difficult for many BCA to fit into the system. Abamectin or Bt can be regarded biological mimics of conventional pesticides. But, what about BCA with non-toxic modes of action? How often do we read that BCA are not as effective or fast acting like synthetics? In a holistic pest management system (one that considers the whole agro-ecosystem, not just a single growing period) speed of action is largely irrelevant, and efficacies between 70-98% (e.g. as exhibited by various microbials) are perfectly fine. Even a 50% efficacy is useful once this is targeted against low pest population levels at the right time.

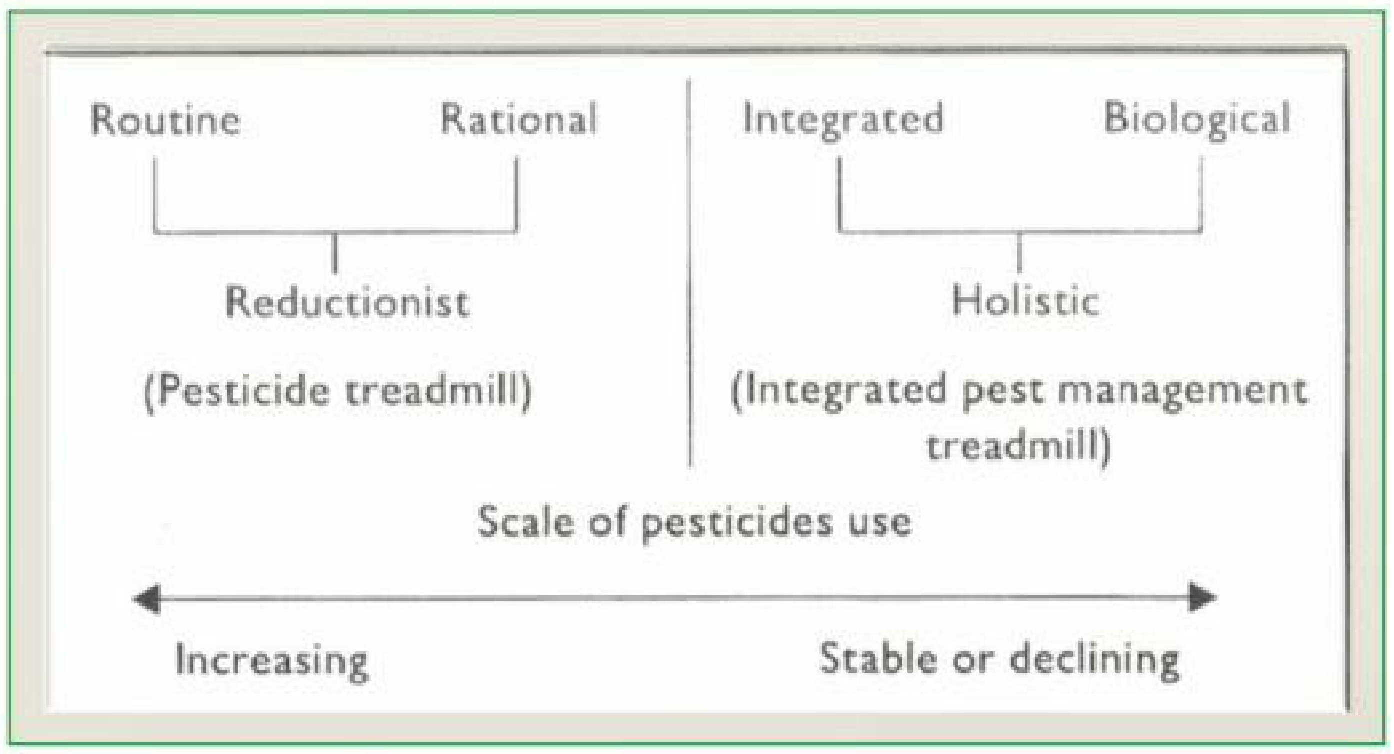

Figure 3: Classification of Pest Management (Vennila & Kairon 2000)

THE KEY TO FUTURE GROWTH: USER KNOWLEDGE RATHER THAN PRICES

This brings us to the role of the user and consumer of pesticides again. As outlined earlier, there is little knowledge about IPM among farmers and growers, let alone proper handling of pesticides. During my 20 years of experience in field implementation of pest management in Asia I have also observed that in particular smallholders often have a very limited understanding of the agronomic ramifications of their actions. Hence, it is difficult to advertise economic benefits of any product or technology and appeal to users' profits, if farmers are not fully aware of the economic consequences of their actions. Currently, a considerable portion of Asian farmers is in debt due to overuse of agrochemical inputs, a dependency that in my view constitutes another hurdle for adoption of BCA. It is often argued that BCA were more expensive compared to synthetic pesticides. This may be true, if one considers package or unit prices, but this is certainly not true, if one analyses application rates over one or more growing seasons. Benefit-to-cost ratios of certain macrobials are among the highest in pest management, the use of pheromones and other attractant technologies can outcompete conventional pesticides in industrial crops in Asia, and the property of self-replication of various microbials allows for reduced application rates. The latter is a valuable property that should be exploited better in the future. I predict that once knowledge of farmers and growers with regard to good agricultural practices improves, adoption of BCA will increase further. User knowledge rather than prices is the key to future marketing of BCA. Results of international studies indicate this already. This is also an area where biocontrol companies need to engage more actively in the future. It can start with improved after-sales services and continue with 'stewardship' programs to raise knowledge and satisfaction among users and customers.

THERE IS MORE TO AGRICULTURE THAN JUST PEST MANAGEMENT!

Firstly, pest management is not in the position to 'increase' yields of crops. It helps protecting yields, not more, not less. Yield is a function of crop variety, soil condition, and climate to name the major parameters. Recent large-scale international studies have revealed that in certain crops, in particular rice and vegetables, conventional use of pesticides even suppresses yields. Secondly, in consequence of the above a healthy soil function should be given more attention. Here, micro-organisms and other products could play a major role in the future (and increasingly do so, if we look at the increasing importance of fungicides and bactericides in some Asian countries). Some keywords may suffice: developing 'suppressive' soils to control fungal and bacterial diseases; enhancing N-fixation; improving nutrient availability and uptake by crops to save fertilizer; new modes of delivery in connection with water management, etc. Trichoderma fungi are a good example for the combination of disease-controlling functions with improved nutrient uptake by plants. Field trials by SAS in rice and vegetables in Cambodia have shown that application of T. harzianum together with compost can be a cost saving and yield increasing strategy for smallholders in Asia.

Finally, our approach to insect pest management needs an overhaul. In rice, for instance, the role of insect pests is generally overrated. Becoming serious about IPM by applying threshold levels for action would be a good start. Because application of broad-spectrum insecticides depletes populations of natural antagonistic organisms, the 'natural biocontrol function' becomes suppressed. There exists ample evidence now that BPH and other pests are not a problem in rice areas where natural biocontrol is intact. Entomopathogenic fungi, macrobials like Trichogramma spp., and insect lures are powerful BCA for controlling key rice pests, if that becomes necessary.

Last but not least, single-farmer operations are pointless in pest situations that require area-wide approaches. Addressing larger farming communities, municipalities, business associations, or plantation industries could be a way to organize pest management in highly fragmented smallholding landscapes and reach the critical mass that makes business profitable. ■