plantations after decades of planting. By enhancing and restoring soil microbrial activities, nutrient availability to the plant should be improved, hopefully ultimately benefitting harvest yield and quality. Certainly, the results produced from trials at a number of plantations have been promising, Peter suggested, with commercial trials using mature palms showing yield enhancements in 2007 over 2003 of 20% and 37% depending on location and application method.

Due to the increase in Agrofert's own NPK production capacity and the rise of other NPK plants in both Malaysia and Indonesia, the fertilizer landscape for oil palm cultivation has changed dramatically over the past 17 years.

NEW TYPES OF FERTILIZER IN CHINA

Proceedings were opened on the second day of papers at the 2011 FMB Asia meeting by **Mr. Zeng Feng, President and Chief Editor of China Agri-Production News**. Mr. Zeng Feng discussed ***"The Development of New Types of Fertilizer in China".*** The choice of paper, he contended, was particularly apposite as China Agri-Production News is proud of its role as an observer of new trends within the industry.

Mr. Zeng Feng noted three stages within the field of fertilizer product development in China, the budding phase, the lag phase and the rising phase. Three periods – the 1950s, late 1960s to early 1970s and the 1980s to late 1990s – exhibited budding phase characteristics; these periods marked the development and eventually production of bio-fertilizers, bacteria fertilizers and plant stimulators. However, these budding phases were handicapped by a lack of market support, the poor quality and low efficiency of the end products and a lack of regulation standards applying to the industry and its products.

The period late 1990s to 2006 Mr. Zeng Feng suggested was the lag phase. During this period, N, P and K fertilizers were the focus of investment activity and considerable profits were available from the production and use of chemical fertilizers. In-field yield increases showed the benefits to farmers of using these products which, in turn, stimulated fertilizer demand further.

The years from 2007 represented the rising phase, Mr. Zeng Feng contended. Overcapacity in chemical fertilizer production, as shown by rising exports of these products, brought with it an incentive to develop new types of fertilizer, according to Mr. Zeng Feng. During the rising phase, private enterprises play more dominant roles, products are more specialized and enterprises cater more for specific market requirements.

Mr. Zeng Feng then turned his attention to factors that can promote the rapid development of new fertilizer products in China. Government policy has a role to play, he contended. In common with governments elsewhere in the world, the Chinese government favours the production of highly efficient fertilizer products, produced with minimal energy use and with a low carbon footprint. The Ministry of Agriculture, through its promotional efforts, had a role to play, as did the National Grade Research Centre, through its research efforts and its quality assurance strictures. The government's policy of providing subsidies to the fertilizer sector also helped to foster new product development.

Market forces are also important. Rising agricultural products prices will provide incentives for increasing fertilizer uptake, raising living standards and aiding rapid economic development within China.


Mr. Zeng Feng.

An expanding knowledge of modern agricultural production techniques helps to create an environment encouraging the development of new fertilizer products. Low performance, low nutrient content fertilizers are now less acceptable to the Chinese farmers, who have seen the benefits in terms of better yields and higher profitability brought about by using high analysis fertilizer products.

Changes within the fertilizer sector could have a part to play. Currently, the inorganic fertilizer sector is highly competitive due to overcapacity; research into the production of new products can help to differentiate a particular producers' output from that of competitors, providing a marketing edge. Such fierce competition is also likely to lead to a rationalisation of production, a reduction in the number of producers and an increase in average size of the remaining producers, meaning that each market player in the future will have more resources to fund fertilizer product development activities.

In conclusion, Mr. Zeng Feng acknowledged that some obstacles remained to new product development within the Chinese fertilizer sector. However, these problems are being addressed, he contended; research and production standards are being improved, supervision by external bodies increased, promotional activities enhanced and backward agricultural techniques updated.

EGAN

In a departure from the norm at an FMB meeting, **Mr. Steve Dawson, President, Dyno Nobel Asia Pacific**, discussed ***"Explosive Grade Ammonium Nitrate (EGAN)".***

Steve began by outlining the activities of parent company Incitec Pivot Limited. A leading Australian listed company with a market capitalisation of A$6 billion employing over 4,400 people, Incitec Pivot is a leading global company in the manufacture, marketing and distribution of a range of industrial explosives, fertilizers, related products and services to global markets. Incitec Pivot is the No.1 supplier of fertilizers in Australia and the No. 1 supplier of industrial explosives, related products and services in North America.

Steve turned his attention to two Incitec Pivot Group enterprises. Quantum Fertilizers, established as a joint-venture with Incitec Pivot on 1 December 2009, is a business that will manage all exports from Incitec Pivot, currently around 500,000 tpa. To date, Quantum has traded nearly 3 million tonnes of fertilizers, ammonium nitrate and other raw materials. Quantum has offices in five countries and representation in 10 countries.

Dyno Nobel, the industrial explosives division of Incitec Pivot, is a global leader in the commercial explosives industry, providing blasting solutions and quality explosives products and services. Its geographical reach encompasses the USA, Canada, Australia, Mexico and South America while joint-venture operations are located in South Africa, Malaysia and China. More than 30 manufacturing plants including state-of-the-art initiating system facilities are located in the United States, Australia, Chile, Turkey and Mexico. The division can provide bulk explosives solutions, encompassing a variety of products and services; a range of explosion initiation systems; and technical services, such as blast modelling, high speed filming of explosions, studies of initiation systems etc.

Steve then turned his attention to EGAN supply and demand in South-east Asia. Based on in-house forecasts covering the period 2010 to 2017 incorporating year-on-year average demand growth over that period of 6.5% to 7.5%, the region is likely to remain a net importer to 2017, despite considerable additions to regional EGAN production capacity in Australia and Indonesia. Regional production in 2010 stood at around 1.8 million tonnes and

Mr. Steve Dawson.

demand at about 2.1 million tonnes; by 2017, regional output is likely to marginally exceed 3 million tonnes while demand is projected at around 3.5 million tonnes.

In 2010, the supply deficit was filled mainly by imports from China and Russia. Trade within the region was also substantial, with excess production in south-west Australia offsetting the shortfall in north-west Australia and the substantial supply shortfall in Indonesia being offset largely by imports from Thailand, the Philippines and the east coast of Australia.

Going forward, EGAN production capacity additions are forecast to enter service at Bontang in Indonesia and Moranbah in Australia in 2012, in Western Australia (Kwinana) in 2014 and in south-east Australia in 2015. While raising overall production levels, on current mine forecasts the region is likely to remain a net importer in 2017; Indonesia will remain a net importer and, due to increased coal mining activity, Queensland, Australia will move from a net surplus to a net deficit position post-2014 despite the opening of the Moranbah plant. South-east Australia and West Australia are likely to switch from net exporter to importer over the periods 2010 to 2014 and 2010 to 2013 respectively and then will revert to net exporter positions as new capacity enters service.

Mr. Dawson summarized his presentation in his conclusions. EGAN demand is likely to increase at a fast rate in South-east Asia, responding to the rapid industrialisation of the region. Historically, imports have balanced supply in the region as demand has run ahead of regionally-produced supplies. In the future, new capacity will be built close to the customer and just ahead of the likely build-up of product shortages. Low cost brownfield developments e.g. debottlenecking projects will supplement new plants in order to meet demand.

DEVELOPING NEW FERTILIZER PROJECTS

High fertilizer demand and strong agricultural product prices result in increased interest in adding to the production capacity for materials used in the manufacture of fertilizers. Consequently, the presentation ***"Developing New Fertilizer Projects – the Relevance of Asia"*** was particularly well attended, much to the satisfaction of its author, **Mr. Allan Pickett, General Manager, Forbes & Manhattan Agriculture Group.**

The potash sector from 1987 to 2004 was characterized by stability, Allan noted. No greenfield potash mines were established during this period, while MOP prices were low and unattractive, falling in the range $70 to $100 pt and averaging around $90 pt. Producers' profits were constrained as a result and there was little incentive for new producers to enter the market.

A similar story characterized the phosphates sector between 1987 and 2006, he suggested. DAP margins during this period were low, at around $11 pt; major profits in the sector could only be made by the judicious selling of phosphates-producing companies. Funding for junior companies wishing to promote new phosphate projects was lacking.

Changing potash and phosphate market conditions in the late 2000s brought an about-turn in these sectors. Potash Juniors now have a market capitalisation of over $2 billion and phosphate Juniors of over $1 billion, up from virtually zero in both instances in 2006. At the time of the 2011 FMB Asia meeting, funds raised by the potash and phosphate Juniors to finance their operations stood at approaching $500 million and $400 million respectively.

Currently, Asia produces just over 50% of its fertilizer requirements. Nutrient consumption totals around 109 million tonnes, with nitrogen accounting for two thirds of this figure, phosphate around 22% and potash around 12%. In terms of regional production, Asia produces around two-thirds of its nitrogen requirements, around 55% of its P_2O_5 needs and less than 20% of its K_2O supplies. China (over 50 million tonnes) and India (over 20 million tonnes) dominate fertilizer consumption in the region; Indonesia and Pakistan, the next most important fertilizer consumers in the region, are small by comparison at four million tonnes plus and three million tonnes plus respectively. Per capita usage is highest in Malaysia, at over 50 kg per head, followed by China (over 40 kg per head), Taiwan (over 30 kg per head), Pakistan and South Korea (each at over 20 kg per head). Overall, however, fertilizer use is low on agricultural land in Asia, averaging less than 100 kgs per hectare throughout the Continent, with application levels in only South Korea and Japan exceeding 200 kgs per

Mr. Allan Pickett.

hectare; also, fertilizer consumption is highly skewed towards nitrogen. This suggests that, if sufficient reserves are available, the region has considerable potential to increase regional production of potash and phosphate raw materials.

Outside China, apart from Israel and Jordan and the processing of imported MOP to produce other potash products in several other countries, Asia currently produces very little potash. Plans are in place to change this, through long-standing projects in Thailand (the ASEAN Potash Mining and Asia Pacific Potash projects), in Laos (often with Chinese backing, such as the projects of Sino-Agri Potash Co., Sinohydro Mining, Viet Lao Salt and Chemicals, and ZhongLiao Mining), in Mongolia (the General Mining Corp. project) and in India (where Tata Chemicals and Archean Chemical Industries plan to produce SOP based on imported MOP).

In terms of phosphate rock developments within Asia, all significant projects are located in China and are either expansions of existing mines or relate to greenfield opportunities for current producers. Projects totalling 7 million tpa of phosphate rock are projected for Hubei Province, already the largest producer of phosphates in China, with projects totalling a further 3 million tpa in each of Sichuan and Guizhou Provinces and projects of 2 million tpa capacity in total in Yunnan Province. These projects will swell China's already dominant position within Asia in phosphate rock production; current capacity in China totals 75 million tpa , with India, Vietnam and Indonesia relatively minor players by comparison, with capacities of two million tpa, two million tpa and one million tpa respectively.

Allan concluded by outlining the activities of Forbes & Manhattan (F&M). A leading private merchant bank with a global focus on the resource-based sectors, F&M employ in excess of 25 engineers, over 25 geologists, over 30 financial professionals, five full-time corporate and securities lawyers plus over 15 accounting and administrative staff in its back office. The group, which has launched over 30 public companies, has raised funding totalling over $5 billion in the past four years. Currently, the group has over 40 resource projects, nine currently producing assets and has projects in 22 countries. Apart from Agriculture, F&M portfolio interests encompass a wide variety of resource sectors, including Base and Precious Metals, Ferrous Metals, Energy and Finance.

Projects promoted by F&M have attracted investment interest from a range of different types of investors, including traditional private equity groups, strategic investors, investors focused on the mining and fertilizer sectors, hedge funds and institutional investors. The group has an excellent record in delivering, via project flotations, positive returns to investors and providing value through its project development and financing activities, the manner in which it structures and presents share issues and its project management activities. The group is involved in and can assist in bringing projects to fruition and in securing growing capital requirements as potential is converted into product. Its experience encompasses proving the resource, environmental permitting and completion of construction and commissioning and start-up phase. In terms of project management, the group has considerable in-house industry knowledge, technical know-how and expertise and an in-depth grasp of the intricacies of public markets.

Currently, the Agriculture Group portfolio of Forbes & Manhattan is concentrated on a number of potash and phosphate projects in Brazil. Potàssio Brasil, based in Belo Horizonte in Brazil, is a private exploration company focusing on conventional potash exploration and development in Brazil through an active program of drilling. From a similar location, Aguia Resources is focussing primarily on the exploration and development of two potentially large scale phosphate projects in Brazil. Early in 2011, Aguia added Potàssio do Atlantico Ltda (PALTDA) to its portfolio; PALTDA aims to bring on-stream a solution-based potash mine in Brazil adjacent to Brazil's only existing potash mine.

In conclusion, Allan suggested that the current investment climate in fertilizers is excellent, particularly in Asia. Fertilizer demand growth in the region long-term is put at 3% pa; currently, this continent can only produce around 57% of its own fertilizer requirements, meeting only 55% and 17% of its phosphate and potash requirements respectively. South America is in a similar position. Both of these regions have substantial phosphate and potash raw material deposits available; the most promising are those located close to substantial existing markets as this is likely to give them a competitive advantage over established producers.

NUTRIENT EFFICIENCY IN ASIA

Dr. Terry Tindall, Senior Agronomist at J. R. Simplot, has featured of late on a number of FMB Conference programmes. These included the 2011 FMB Asia meeting where he chose to outline ways of ***"Improving Nutrient Efficiency in Asian Markets"***.

Food security in Asia depends on the availability of affordable fertilizer, Terry noted, yet the use of fertilizer injudiciously results in considerable economic and environmental penalties. Best management practices (BMPs) in fertilizer use, applying the principle of the 4R's of Right Source, Right Rate, Right Time and Right Place, is essential if growers are to maximize the efficiency of the applied fertilizers for improving crop yields while caring for their soils appropriately. Traditional fertilizer improvements in BMPs include band application of fertilizers, in-season split applications, spatial variability through precision nutrient application techniques, foliar or in-season applications and using combinations of NPKs and micronutrients.

Terry asked *"Why has fertilizer efficiency become such a current hot topic?"* A number of answers sprang to mind, including environmental considerations, crop values, higher fertilizer prices and increasingly limited nutrient resources. Enhanced efficiency products could address all of these issues, he suggested. Such products offer improved agronomic efficiency through enhanced nutrient availability and increased output per unit of nutrient applied, thus increasing the profitability of farming; produce environmental benefits through greater safety in use and reduced nutrient losses to the atmosphere and waterways, enabling farmers to meet regulatory requirements and to participate in conservation programs; and provide increased operational efficiency through greater operational flexibility and a reduction in the number of applications required.

Terry highlighted increasing phosphorus use efficiency. 99.9% of phosphorus in the soil is unavailable and studies have shown that only 5% to 30% of applied phosphorus is utilized by the crop during the year of application. Generally, 70% to 80% of applied phosphorus is added to the soil's phosphorus pool where the bulk remains in non-plant-available forms in compounds linked with other elements such as calcium, iron, aluminium and manganese. This issue is of particular and growing concern, given the long-term decline in P_20_5 values of mined phosphate rock.

Terry noted that phosphorus deficiency is a problem that affects China. For example, phosphorus deficiencies have been recorded in rapeseed, a crop that provides around one third of edible oil for human consumption, is an excellent protein feed for animals and has potential for use in energy production, as green feed and vegetable crops, as a green manure and as a landscape crop. Trials on rapeseed in China over different time periods have produced increased yields from applications of phosphorus, although incremental returns and P_2O_5 efficiency varied between different time periods. During 1992, wheat field trials were carried out at Yutian in Hebei Province, China. An optimum fertilizer application mix/quantity was applied to a control plot and nutrients withdrawn from neighbouring plots. Wheat yields were then compared in order to ascertain the crop limiting nutrient. The wheat yields on the plot from which applications of phosphate were withdrawn were the lowest on test.

Terry turned his attention to products that increase the efficiency of phosphate fertilizers. When conventional sources of phosphate are applied, phosphorus is only absorbed by the plant when the root system is in contact with the phosphorus. Calcium, iron, magnesium and aluminium ions can fix phosphorus in the soil, making it unavailable to the plant. Various products can help to counter these effects, to the benefit of plant nutrient uptake and ultimately crop yields. Organic acid extracted from Leonardite, a mineraloid oxidation product of lignite that is a rich source of humic acid, is available in liquid and dry product forms; additions of humic acids in fertilizer bands is possible and positive yield and quality responses have been documented from using humic acid with P fertilizers, usually in soils with a low organic matter content. Thermal Polyaspartic Acid (TPA), a biodegradable biopolymer, is used as a phosphate fertilizer enhancer, producing limited yield responses on crops.

An alternative product, marketed as *AVAIL*[R], employs a highly charged Dicarboxylic Acid Co-polymer; this sequesters antagonistic cations in the soil solution around the P fertilizer granule or in the fluid band. As a result, the P remains unfixed and available for plant uptake; highly concentrated zones of available P are ensured for plants. As the process is soil chemistry related, all plant species can benefit from this technology, Terry noted. Trials undertaken in 2001/2003 on corn in Kansas show a rise in crop yield (of 8.8% to 11.1%) and in P agronomic efficiency (of 56% to 124%) when MAP treated with *AVAIL*[R] is used rather than untreated MAP, the increases varying with quantity of P_2O_5 applied. Trials in Minnesota in 2002/2004 involving the same crop/fertilizer products produced yield increases of 3.7% to 6.4% and improvements in agronomic efficiency of 71% to 124% for *AVAIL*^{R}-treated MAP over untreated MAP, with the actual percentages again varying with quantity of P_2O_5 applied. The potential impact of using *AVAIL*^{R} on a farmer's bottom line was illustrated in trials on corn carried out in Oregon in 2009. A cash return of 15:1 resulted from the additional yield when 10-32-10 plus *AVAIL*^{R} was applied compared to straight GSP and of 5.5:1 when 11-20-10 plus *AVAIL*^{R} was used compared to straight 10-32-10. The benefits of using *AVAIL*^{R} are not limited to corn; trials on rice over the period 2004 to 2006 in Missouri produced increased yields of 4.9% and an improvement of agronomic efficiency of 78% when 28 kgs P_2O_5 per hectare of TSP plus *AVAIL*^{R} were applied compared to TSP alone, although these figures fell to 1.3% and 13% respectively when the P dosage was raised to 56 kg P_2O_5 per hectare. Rice trails in the Philippines using 16-20-0 showed enhanced returns for 16-20-0 plus *AVAIL*^{R} over untreated 16-20-0. Turning to wheat, trials in Kansas undertaken in 2009 comparing the effects of applying untreated DAP with *AVAIL*^{R} coated DAP found that using the latter product produced yield increases of 3.7% to 5.2% and increased the agronomic efficiency of P by 57% to 72%. In China, the DAP/ *AVAIL*^{R} combination was also scrutinized this time as an input in the production of Chinese cabbage. Both yield and plant uptake of P_2O_5 improved when *AVAIL*^{R} treated DAP was applied compared to straight DAP.

Turning to nitrogen, Terry noted that conventional N fertilizers lost N to the environment, through volatilization, denitrification and leaching. The extent of these losses varied, depending on form of nitrogen applied, soils and climatic conditions. The losses can be addressed and reduced by using enhanced efficiency nitrogen products, he suggested. These products work in a variety of ways. Inhibitors or stabilizers work by slowing or inhibiting biological or environmental processes; they can provide a specific benefit for a specified length of time e.g. a few days to several weeks. *Agrotain, Super U, N-Serve* and *NutriSphere-N* are among the brands within this category. Uncoated, slowly available fertilizers protect N by delaying availability; the release rate of N is determined by the resistance of the material to chemical degradation (weeks to months). However, once the chemical compounds are degraded, N is released at an uncontrolled rate, so that the N is then susceptible to biological and environmental processes. Urea formaldehyde, methylene urea, isobutylidene diurea, triazones, organic N, *Nfusion* and *CoRoN* are products within this category. Coated water soluble fertilizers, such as sulphur coated urea, depend on the biological oxidation of the coating to control N release. For polymer coated fertilizers, the release rate is determined by chemistry, thickness of coating and temperature; brand names to look out for in this category include *Osmocote, ESN, Polyon, Duration, Trikote* and *Flori Kote*.

Studies have proved that enhanced efficiency products can reduce ammonia losses to the atmosphere. This is certainly the case with *NutriSphere N (N-N)* Polymer, a water-soluble and slowly biodegradable (temperature dependant) large branched polymer that can be applied to a dry granule or added to liquid solutions. A study undertaken at the University of Missouri in 2010 assessing cumulative ammonia loss from a moist loam soil following a surface application of urea showed that *N-N* reduced ammonia volatilization of urea by 48% over an eight day study period. In tests conducted in 2008 by the University of Arizona to assess the effect of *N-N* on soil ammonium concentration in 10 soils showed an increase in soil ammonium concentration of 31% for *N-N* over urea for sand/sandy loam soils and of 20% for *N-N* over urea for loam soils. Trials by Sanchez indicated that using *N-N* on loamy soils resulted in the production of more fertilizer-derived soil organic N than comparable quantities of urea. The organic fraction appears to be held within short-lived micro-organisms that are then mineralized, thereby releasing N during the initial growing season. This allows N to be enhanced and N use efficiency to be improved during the cropping season. Turning to crops, Terry provided a number of examples of field trials relating to corn. A University of Minnesota study suggested that the income generated by the additional yield returned by using *N-N* outweighed the cost of using *N-N* by 5.5 times. In trials undertaken by the University of Illinois on different N sources applied to corn crops, using *N-N* increased the corn crop by an average of 8.5 bushels per acre. Trials in California during 2010 on corn silage showed extra returns to the farmer of $53 per acre from using UAN plus *N-N* over straight UAN; in this


Dr. Terry Tindall (second from left) discusses local soil quality in Mongolia.

instance, the cost of the *N-N* used was $10 per acre. Trials on winter wheat in Kansas in 2008/2009 brought additional returns to the farmer of $38.36 per acre when urea (40 kg N per acre) with *N-N* was applied rather than untreated urea while the return at applications of 60 kg N per acre totalled $43.84 per acre; the cost of *N-N* used was $4 per acre and $6 per acre respectively.

In conclusion, Terry suggested that increasing the efficiency of all fertilizer sources and applications benefits everybody. It has been shown that enhanced efficiency products have agronomic advantages. By using natural resources more effectively, their lives are extended, aiding whole communities.

ZINC DEFICIENCY IN CROPS AND SOILS

The importance of a specific micronutrient was highlighted by **Dr. Ming Xian Fan, Director, China Program, International Zinc Association (IZA)**, in his presentation ***"Zinc Deficiency in Crops and Soils and Zn Fertilizers".***

Ming placed China in the spotlight. China has a population of 1.3 billion, around 20% of the global total, yet possesses just 9% of the global arable land, at 122 million hectares. With the help of substantial and judicious use of fertilizers (54 million tonnes or 35% of world fertilizer consumption), China accounts for around a quarter of global grain production, at 528 million tonnes.

However, average use efficiency of conventional fertilizers in China is poor, at below 20% for applied phosphorus, around a third for nitrogen and closer to 40% for potash. Such leakages from the soil-crop system year-on-year represent substantial economic losses to farmers and pose significant potential risks to the environment. Moreover, as fertilizer use has increased, returns to fertilizer applications have declined; in the 1950s, one kilogram of fertilizer applied in China increased grain yields by 15 kgs but the returns to 1 kg of fertilizer use fell to 8 to 10 kgs of grain in the 1970s and to 6 to 8 kgs of grain in the 1990s. These figures suggest that the agricultural and fertilizer sectors face significant challenges, namely improving fertilizer use efficiency for current fertilizers and developing specific new fertilizers with improved agronomic efficiencies.

Fertilizer improves crop quality and human health, Ming suggested. By providing plants with a properly balanced diet, fertilizer ensures high yielding, good quality crops, which benefits human health. In a similar way, through the use of zinc fertilizer, widespread zinc deficiencies, in soils and in humans, can also be addressed, he contended. 50% of world soils are deficient in zinc, which causes severe losses in crop yield and nutritional quality; a third of the world's population are deficient in zinc.

According to the results of China's Second National Soil Survey conducted during the 1980s, phosphorus and zinc were the two most deficient nutrients in China; soil samples taken in China over the period 1995 to 2005 suggest that zinc deficiency levels have become more critical and more widespread as time has elapsed with the intensification of agricultural production, coupled with the use of large amounts of macronutrient fertilizers, such as nitrogen (N), phosphorus (P) and potassium (K). Nearly 60% of arable soils are low in plant available Zn, limiting further sustainable increases in agricultural production and improvements in human health. With this in mind, is it not surprising that over 50% of Chinese children are at risk of zinc deficiency; this level varies from 55% to 90% among children in the 1 to 8 age category.

Plants deficient in zinc display visible symptoms of physiological stress, have reduced levels of dry matter production and lower yields of grain, fruits and roots; they also suffer from impaired crop quality, have an increased susceptibility to stress by high light intensity and low temperature and soil moisture and are also more susceptible to fungal diseases and heavy metal toxicity. A range of soil conditions can adversely affect zinc bioavailability to plants and thus limit zinc uptake; these include high lime content, high soil pH, clay soils, low organic matter content, low temperature and soil moisture levels, and high availabilities of phosphorus, silicone, iron oxide and aluminium oxide.

As crop yields have increased and potential nutrient drawdown from soil stocks has risen, applications of zinc have not increased proportionally and remain below replacement levels, resulting in zinc deficiency becoming a major limiting factor for crop yields and quality. This, in turn, has created a major market opportunity for the fertilizer industry. By providing zinc-containing product and encouraging the use of applied zinc, the fertilizer industry can help to ensure that zinc will no longer be *"the limiting nutrient"*, improving fertilizer efficiency and returns to other nutrients, perhaps substantially, while enhancing human health.

Data from China relating to the 1990s and 2000s suggests that applying Zn fertilizer raises crop yields substantially. In sixty-six experiments involving rice undertaken in Hubei and Sichuan Provinces, using Zn fertilizer increased crop yield by 6.4% to 17.8%. In Shandong Province, 118 experiments were carried out on wheat; Zn fertilizer produced yield rises of 8.2% to 15.6%. 104 experiments involving maize, also in Shandong Province, resulted in yield increases of 7.7% to 24.1%. In Shaanxi Province, apple crops came under scrutiny; here, a total of 52 experiments indicated that apple production increased by 14.5% to 41.3% following the application of Zn fertilizer. However, results can vary considerably, depending on application method used and type of Zn fertilizer applied. In the 1990s, Zhou applied zinc sulphate to wheat crops in various concentrations using a variety of delivery methods; all plots receiving zinc treatments returned increased yields, with foliar spraying (at the lowest Zn concentration application – 0.1% water solution) producing the smallest yield increase (4.4%) and soil application at 16.5 kg per hectare (the largest quantity applied) producing the largest yield increment (18.5%).

Zinc fertilizers come in many forms, from straight zinc (including chelated Zn-EDTA at 12% or 9% Zn, zinc chloride at 48% to 50% Zn, zinc carbonate at 52% to 56% Zn, and zinc oxide at 60% to 80% Zn) through products supplying zinc and secondary nutrients (notably zinc sulphate heptahydrate at Zn 21% and S 15% and zinc sulphate monohydrate at Zn 33% and S 15%) to zinc/primary nutrient combinations, such as zincated urea (2% Zn and 43% N) and zincated phosphate in suspension (19.4% Zn and 12.9% P_2O_5). The characteristics and cost of these products vary greatly. Zinc sulphate-based products and chelated Zn-EDTA are generally soluble; zinc oxide and zinc carbonate are insoluble, for example. In terms of cost, powdered oxides are usually the least expensive with granular oxides usually available at a 20% premium to powdered oxides. Granular sulphates are generally over twice the cost of powdered oxides. Chelates top the league in terms of cost, with organic chelates about 10 times and EDTA and other chelates up to 20 or 40 times the cost of powdered oxides. Zn bioavailability depends on water solubility; Zn chelates are preferable in soils with a potential for Zn immobilisation while zinc sulphate-based products may be the preferred choice in sandy soils, for foliar application and in nurseries using soilless cultivation methods.

A variety of application methods are available for Zn fertilizer. 20 to 50 kgs per hectare of zinc sulphate monohydrate can be applied to the soil before planting. Soil application during the planting process is an option; here, banding 5 to 10 kgs per hectare of zinc sulphate monohydrate is an efficient means of delivering zinc to the plant roots. Seed dressing – using 2.2 to 4.4 kg of zinc per tonne of seeds – is an option while root dipping in a suspension of 2 to 4% ZnO before transplanting may provide sufficient Zn to meet crop requirement. Foliar spraying, taking place three to five weeks after emergence, is a popular option. In this instance, the tank mix should consist of a single kg. of zinc sulphate heptahydrate per hectare plus 1 kg of urea per hectare in 100 litres of water plus a surfactant at the rate of 100 millilitres per 1,000 grams of liquid product per 100 litres of the spray mixture. For transplanting crops, seed or seedling enrichment is a possibility; this involves applying 20 to 30 kgs of zinc per hectare to the nursery bed and mixing it with the top soil at seeding. Zinc can also be added to a NPK formulation, either by full incorporation into the mix at the product granulation stage or as a coating to NPK/NP granules. Another option is to include zinc in plant nutrient applications by fertigation. Adding Zn fertilizers and NPK to irrigation waters can improve uniform distribution and homogenous mixing, enhance plant nutrient availability and reduce the risk of damage to plants, especially in semi-arid or arid areas.

Crop trials around the world have shown that applying Zn fertilizer can have a beneficial impact on crop yields and on the farmer's bottom line. For example, in India, Ming noted that trials have been carried out on the effects of using Zn enriched urea on rice and wheat crops. Yields, Zn content and protein content of aromatic rice all improved with the use of zinc-enriched urea compared to urea alone; economic returns to zinc use were also substantial. Similar trials involving wheat and Zn enriched urea produced enhanced grain yields and improved Zn concentrations in the harvested grain.

Recently, the International Zinc Association (IZA) has stepped up its global effort to encourage increased use of Zn fertilizers by initiating a four year program focussing largely on China and India. This zinc nutrient initiative aims to increase zinc fertilizer use (where needed), in so doing raising crop production and the nutritional status of the crops produced. The IZA approach to these tasks included establishing demonstration crop trials, promoting the Zn fertilizer use message through enhanced communication activities, including workshops and seminars, and undertaking country-based Zn fertilizer marketing drives. Within China, this project aimed to develop best Zn fertilization practices/recommendations for higher yields, improve economic returns, better quality and enhanced nutritional values in crops. Thirty two field trials involving three grain crops were implemented in six provinces. Rice trials were undertaken in Jiangsu, Anhui and Sichuan Provinces, maize trials in Jilin, Hebei and Shaanxi Provinces and wheat trials in Hebei, Shaanxi, Anhui and Jiangsu Provinces. In addition, efficient use of Zn fertilizer in China was addressed through education and promotional programs.

The results of these IZA efforts were encouraging. Results from the IZA sponsored field trials have supported the hypothesis that Zn fertilizer can improve crop growth and N fertilizer efficiency. Applying Zn fertilizer at an average rate of 10 kg per hectare significantly increased crop yield for rice, corn and wheat, by 6% to 18%. Zn fertilization also improved crop quality, especially the Zn and protein contents of crop products and economic returns for farmers.


Dr. Ming Xian Fan.

The IZA has followed up this work this year with a project undertaken with the China Agricultural University (CAU), again promoting Zn fertilizer use through research, demonstration, promotion and education. 18 field trials have been established in six provinces; these will test two application methods (soil application and foliar spray) and four rates of Zn fertilizer use (0, 15, 30 and 60 kgs per hectare of zinc sulphate heptahydrate). A further 18 demonstration plots have been established in six provinces; each plot is from 0.5 to 1 hectare in size and will demonstrate the effectiveness of Zn fertilizer by comparing a crop treated with 30 kg per hectare of zinc sulphate heptahydrate with a control. Promotion and education provisions under this program include the publication of brochures, promotional materials and papers; field days, site workshops and training classes; national workshops and the creation of a dedicated web site.

Another IZA project, this time in conjunction with China's National Agro-Tech Extension Service Center (NATESC), aims to promote Zn fertilizer use in upland farming and fertigation through large-scale nationwide research and demonstration projects, in conjunction with a promotional and education program.

Ming expressed his belief that China has great potential for additional Zn fertilizer use, particularly in the fertigation/water soluble fertilizer sectors. Currently, fertigation production techniques are used on only 1% of Chinese agricultural land; Ming suggested that this should be increased to 20% by 2020. He acknowledged that this was an ambitious target but outlined the benefits of hitting this level. The area under fertigation would rise to 25 million hectares. As a result of the more judicious use of water in agriculture, 37.5 billion cubic metres of irrigation water would be saved on an annual basis. More accurate targeting of plant nutrients would reduce fertilizer waste by 7.5 million tpa. Demand for water soluble fertilizers would be increased to five million tpa (basis an average application rate of 200 kgs per hectare) and Zn fertilizer demand in fertigation to 50,000 tpa.

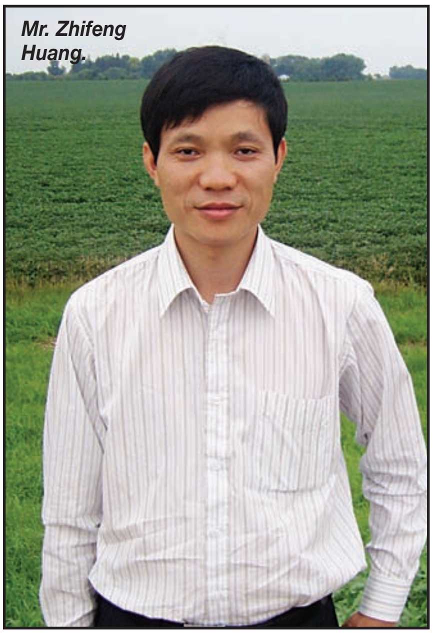
In conclusion, Ming noted that the increasing demand for Zn fertilizers and their use in agriculture provides significant benefits to the zinc industry, fertilizer manufacturers, farmers and agriculture, human nutrition and health and for the environment. He projected that the success of the project would lead to significant increases in Zn fertilizer use in China, contributing to the improvements of both crop production and human nutrition. In China, the estimated area of zinc deficient soils totals 50 million hectares; at an application rate of 10 kgs per hectare, thus equates to an annual zinc fertilizer requirement of 500,000 tonnes. The use of Zn fertilizer in these quantities could raise the Chinese harvest by 10% annually (around 30 million tonnes of grain), he concluded.

SEAWEED PLANT NUTRIENTS

The closing paper marked a first at an FMB meeting, namely a presentation dedicated to seaweed fertilizers. **Mr. Zhifeng Huang, Overseas Business Director, Beijing Leili Agrochemistry Co. Ltd. Company** presented a paper headed ***"Seaweed Plant Nutrients Leading Eco-friendly Fertilizers Development Trend and Research in Seaweed Active Substance Formulation Principle and Application on Crops".***

Mr. Huang commended his presentation by outlining the concept of seaweed fertilizers. Seaweed (marine algae) is harvested from the sea and processed via the use of biotechnology or special biochemical techniques to extract the active ingredients. The result is agricultural seaweed extracts, products defined in academic circles as bio-stimulators or as plant metabolic enhancers. In practice, in addition to being high value-added fertilizer products, these extracts can have crop protection properties, acting as a natural insecticide and pest control agent, depending on their composition. As a result, they are classified differently depending on product content and application; also, registration regulations vary greatly between different countries. In terms of crop nutrient products, seaweed-containing fertilizers can come in many forms, including seaweed extract liquid/powder, seaweed compound liquid/powder, soluble fertilizer containing seaweed active ingredients, organic granular fertilizer with seaweed active ingredients and organic/inorganic granular fertilizers with seaweed active ingredients.

Mr. Huang then reviewed the varieties of seaweed currently used in the production of seaweed plant nutrients. Currently, around



Mr. Zhifeng Huang.

25,000 species of seaweed have been identified. In terms of agricultural applications, brown seaweed is of prime importance, with Ascophyllum and Fucus Vesiaulosus the most popular species in the Northern Hemisphere, Ecklonia Maxima of key importance in South Africa, with Sagassum, Laminaria and Undaria Pinnalifida of major commercial significance in China. The main components of these seaweeds varies considerably; consequently, they have spawned a vast array of products worldwide, varying from plant growth stimulants, biostimulants and biofertilizers to animal feed products and health products. In addition to Leili in China, the main producers of seaweed nutrition products internationally include Boost, Aqua-Maxx and Hortan (USA), Algaigert and SM3 (UK) and Nutrakelp (Australia). As the benefits of using seaweed extracts in fertilizer products have become more widely recognized, their popularity has grown and the number of companies offering fertilizer products containing seaweed extracts has expanded. Consequently, research into using other varieties of seaweed as a raw material has grown, with red varieties now the focus of attention. This expansion in popularity has resulted in a tighter regulation of seaweed fertilizer products worldwide; however, the regulations can be confusing as different countries have adopted different classification standards, some requiring registration for these products as organic fertilizers, others as crop protection agents and others as special functional fertilizers. At an organisation level, EU IMO, ECOCERT, American OMRI, Japanese JAS and Chinese Organic Food Standards all classify seaweed nutrients as organic agricultural inputs, soil fertility agents, crop nutrition agents and disease control agents.

The efficacy of seaweed extracts as plant nutrient providers and the manner in which they operate came under the spotlight. Various studies have been undertaken to identify the active ingredients for plant nutrition within seaweed extract and the manner of their operation and various theories have been tested with this in mind, including the hormone theory, polysaccharide theory and cocktail theory; currently, molecular biological mechanisms are the focus of experimentation. The plant genes of the major crops are being sequenced and the manner in which the substances regulating crop growth contained within the seaweed extract are being identified and studied at the molecular biology level.

In practice, products containing seaweed extracts are either applied directly to the crop (either via treating the seed or through foliar application) or to the soil (through incorporation, soil drenching or the addition of extracts to hydroponic solutions). Favourable effects reported to result from using such products include growth responses (improved shoot and root growth, greater flowering and fruit set, better yield), biotic stress resistance (resistance to fungal, bacterial and viral pathogens and to insect pests), abiotic stress resistance (enhanced tolerance to drought, salt, and very cold weather conditions and enhanced photosynthesis), improved nutritional quality of the resulting crop, a suppression of soil-borne diseases and nematodes, improved nodulation and the promotion of plant growth via the production of additional quantities of rhizobacteria and improved root stress resistance to lack of water and lower temperatures.

Turning to the future, Mr, Huang then looked at likely future developments in seaweed plant nutrients. Climate change could adversely affect crop yields and quality through increasing biotic and abiotic stress factors on plants; some research has indicated that the use of seaweed extract can enhance the ability of plants to combat such stresses, suggesting that the market for products including seaweed extracts could increase substantially going forward. They are low energy use, low carbon products. Moreover, Japanese research has indicated that they can enhance plant uptake of nitrogen and, due to their alginic acid content, can help to release phosphorus fixed in the soil and improve soil structure, soil aeration and capillary action within the soil. Seaweed is rich in potassium; it is also rich in non-nitrogen organic matter, which can help to activate microbes within the soil and ultimately enhance crop flavour and sugar content.

A large number of field trials have suggested that crop nutrition packages based on seaweed fertilizer offer fertilizer use savings of 20% to 30% and pesticide savings of 10% to 20% when compared to conventional fertilization practices, while improving crop quality. Specific trial results reviewed by Mr. Huang included a maize trial in Jilin, China, where, on a demonstration plot of 1,000 hectares, a yield of 15,000 kgs per hectare was achieved when using a soil-applied seaweed organic/inorganic fertilizer in conjunction with a foliar seaweed extract compound liquid and a seaweed root promoter; this compares with an average corn yield in China of 8,000 kgs per hectare. Another trial involved the sewing of a 100 hectares demonstration plot to peanuts; this plot received a soil dressing of *"Double Win"* (12.8.10 solid fertilizer) with the plants receiving a foliar application of seaweed extract compound liquid fertilizer and a seaweed root promoter. The peanut yield achieved was 7,500 kgs per hectare. By using this fertilization programme, input costs increased by $450 per hectare; however, due to improved yields, farmer income increased by about $3,150 per hectare, resulting in a sevenfold return on investment. Mr. Huang commented that trials involving wheat in China had produced yield increases averaging 26.5% while results in Africa, Europe and elsewhere in Asia had shown the benefits of using seaweed-based fertilizers on a wide range of crops, including rice, sorghum, potatoes, grapes, tomatoes, beans, peaches, apples and garlic. Considerable research efforts continues along a variety of avenues, all aimed at defining more specifically the mechanisms by which seaweed products can enhance crop production.

If seaweed-based fertilizers are to become mainstream products within crop nutrition, Mr. Huang argued that industry standards and specifications should be developed. He noted that, in China, one standard is currently in place i.e. for a soluble fertilizer containing seaweed extract. No standards have been established for other products, such as for seaweed organic fertilizers, biostimulators. Mr. Huang told delegates that Leili is currently working with the authorities to remedy this situation. He also suggested that the seaweed fertilizer sector needed to build a fully vertically-integrated chain, commencing with the research institutes and including producers distributors, marketers etc. in order to foster and promote the use of seaweed-based products internationally. Certainly, raw materials are available in vast quantities to support such a development, he concluded, and their availability is increasing due to climate change and fertilizer run-off. On the site of the sailing competition of the 2008 Olympics in Qingdao City, a particular type of seaweed was recorded as growing at a rate of 30 cms. per day. With terrestrial resources diminishing at a swift rate, using seaweed as a raw material is becoming more attractive, suggested Mr, Huang; the development of the seaweed plant nutrients industry is a method of returning plant nutrients lost to the sea to the land with the help of modern biological technologies, he concluded.■