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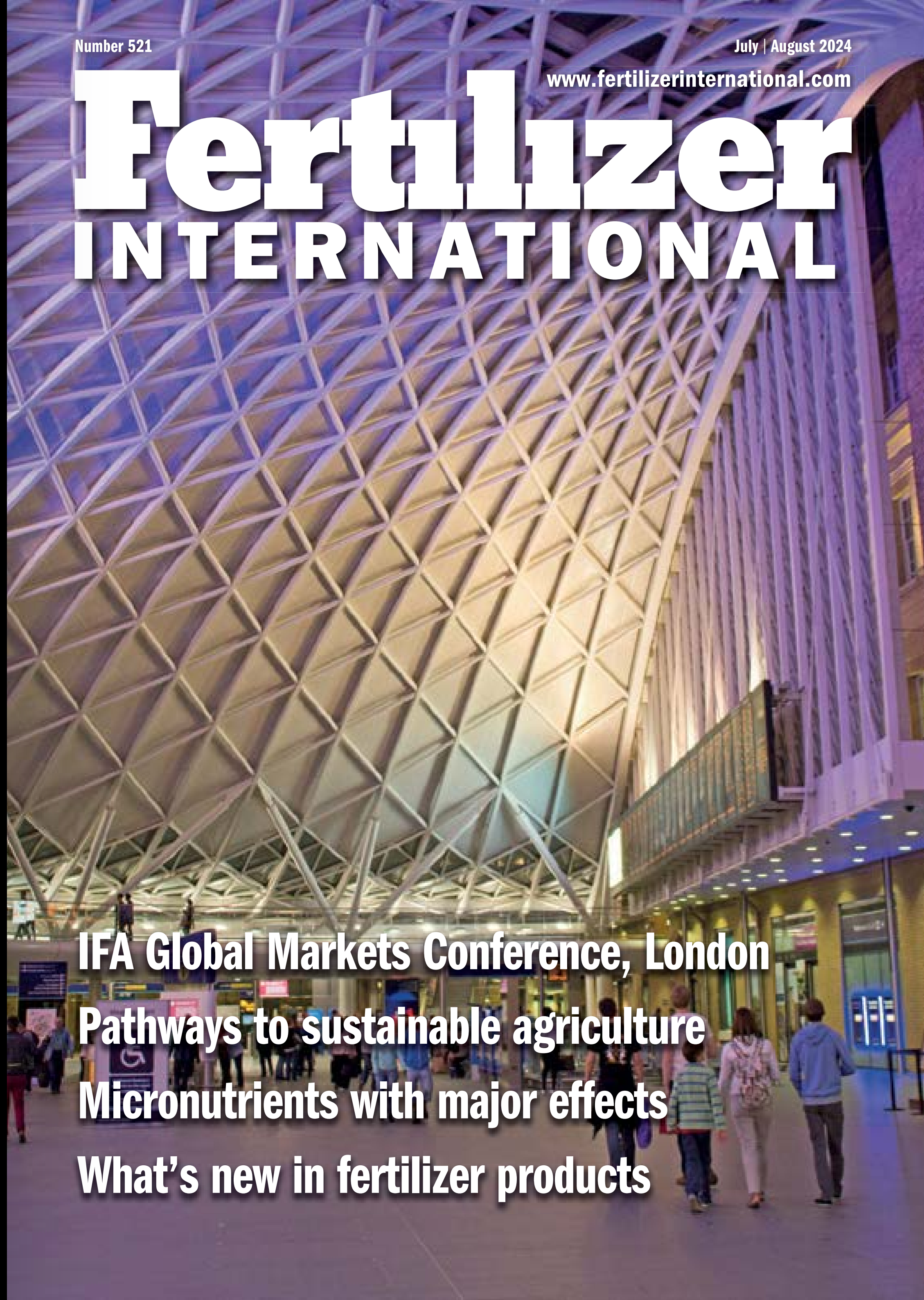

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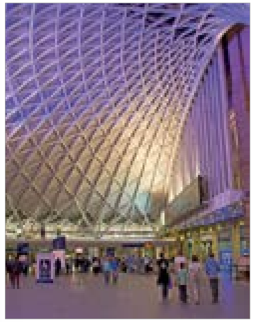

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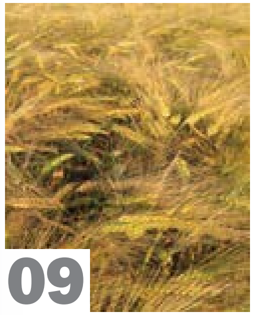

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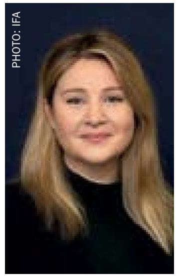


Laura Cross, Director, Market Intelligence, International Fertilizer Association (IFA).

A meeting of curious minds

Laura Cross, Director, Market Intelligence, International Fertilizer Association (IFA)

The fertilizer market is full of contradictions and caveats. What applies to some markets is irrelevant to others, seasonality trends can be thrown off track by a single tender or government decision, and we remain at the often shaky intersection of food, energy and mining market fundamentals.

For the most part, the major fertilizer markets have returned to being driven by typical supply-demand factors in 2024. This can make it easy to gloss over just how much the events of the last four years have changed the structure of the fertilizer market, with many countries still bearing the scars of geopolitical tensions, sanctions, trade defence and high production costs, among other issues.

To be a fertilizer analyst is to always be on your toes, ready for the next potential disruption or unexpected market driver that may crop up (agriculture pun intended). The need to be prepared for changing market trends is what underpins **IFA's Global Markets Conference**, an in-depth event catering to anyone tracking the fertilizer market and wanting to stay up to date on key developments, areas to watch, and new tools to help improve analysis.

> "IFA's Global Markets Conference – an in-depth event for anyone tracking the fertilizer market."

This year's event will be held on July 9-10 in London and offers a one-stop shop for everything you need to know about the fertilizer market. The programme features almost 30 expert speakers who will delve into global issues and drivers across the agriculture, energy and fertilizer markets.

The conference will open with a keynote session titled **Making Sense of the World Around Us**. This will set the scene for the conference with a summary of farmer insights prepared by McKinsey, highlighting the challenges and innovations in modern agriculture. The session will then move to examining the global economic landscape and a look at top global risks in 2024, ranging from conflicts and geopolitics, to polarisation of major economies, the fight for critical minerals and beyond.

The second session will focus on **The Growing Challenge of Shipping Fertilizers**, reviewing recent disruptions in global freight and their impact on the fertilizer industry. Experts will explore how these shipping issues are affecting availability and delivery times, and how fertilizers have been impacted compared to other commodities. The session will also include a long-term forecast of maritime trends to 2050, outlining future challenges and opportunities for the industry.

We have dedicated two further sessions to **Agriculture and Energy Markets**, with presentations on land-use change, crop supply and demand projections, and an IFA project working towards a global monitoring system for fertilizer use by crop and country. The energy session will feature the role of energy markets in global economic stability and a natural gas outlook, followed by a presentation on decarbonisation and the energy transition.

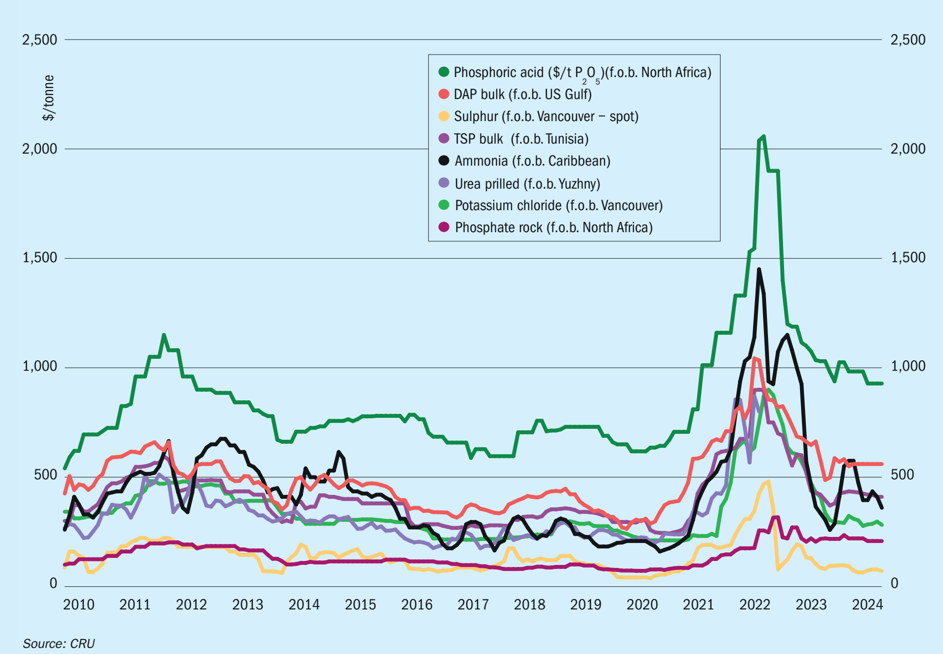
The fifth and sixth sessions will address the major commodity **Fertilizer Markets**, starting with nitrogen. Expert speakers will share perspectives on the ammonia, urea and nitrates markets, with the latter including an assessment of the role of nitrates in Europe in light of the recently introduced Carbon Border Adjustment Mechanism (CBAM). Kicking off the second day of the conference, the sixth session will begin with a country spotlight presentation on the Chinese fertilizer market, from recent supply and demand trends to policy developments and export restrictions. This will be followed by phosphate and potash market outlooks.

The conference will conclude with two sessions on **Emerging Trends** in the industry. The seventh session will discuss developments and opportunities in the specialty fertilizer market, trends in specialty phosphates and methodologies for estimating carbon emissions from shipping fertilizers in order to meet new reporting requirements.

The last session will explore **The Role of AI and Data Automation in Market Analysis**, featuring an overview of how AI is rapidly changing business decision making, and a panel discussion on use of artificial intelligence and data automation in market analysis. This session will cover how new tools are providing real-time insights and aiding long-term strategic decision-making, showcasing the transformative potential of these technologies in the industry.

Phew, a lot to be covered, but we're excited to bring this conference back for another year and facilitate the meeting of curious minds in London! ■

Historical price trends $/tonne



Source: CRU

Market as of 20th June 2024

PRICE TRENDS

Urea: Prices remain stable while the market awaits clear price direction on whether to hold current f.o.b. levels or to push higher. There is a definite sense of market softness – mostly triggered by Egypt's return to production (see page 12) – with buyers generally sitting on the sidelines. With about 200,000 tonnes of exports to be fulfilled from earlier sales, Egyptian producers may not re-enter the export market until July.

Prices fell in Brazil with further declines anticipated. Some suppliers reported a slide in the market to $360/t cfr amid very limited liquidity. There are fears of further price falls ahead as considerable volumes are arriving in Brazil and many tonnes are said to be unsold.

In Argentina, granular prices escalated with the latest sales agreed at $390-395/t cfr – as importers looked to secure tonnes for July arrival.

Ammonia: The ammonia market looks mixed, with prices in Europe and Asia rising while those in the Middle East have declined. In northwest Europe, both CF and Grupa Azoty are said to be looking for July tonnes. These enquiries should test how tight (or not) this market is going forward. Algeria has traded in the $400-405/t f.o.b. range suggesting slightly higher cfr values in Europe of $450-460/t.

The Middle East still awaits the return of one of Ma'aden's ammonia units from turnaround. But a price reduction in the region suggests the supply position is easing from recent tightness: PIC sold a parcel to the Far East at $330/t f.o.b. following recent sales as high as $360/t f.o.b.

While some expect a rollover in the $400/t f.o.b. Tampa price for July, more bearish observers are pointing to the weaker US domestic market – and in particular the aggressive fill programme announced by Koch on 20th June.

Phosphates: DAP/MAP prices climbed in many key global markets as suppliers capitalised on bullish sentiment. Producers continue to report limited availability, although some could be holding back product intentionally in the hope of pushing prices even higher.

The standout price rises have been in Brazil, driven by low stocks and tight supply. MAP jumped an average of $25/t to $615/t cfr. Sales for August loading have even been reported as high as $620/t cfr – a price not been seen in Brazil since late March 2023. These high prices are likely to eat into Brazilian MAP demand soon.

Greater export discipline by Chinese producers has been one of the reasons limiting availability. China's January-May DAP/MAP exports were down 30 percent year-on-year at 1.64 million tonnes. Consequently, Chinese producers have achieved DAP sales to South-east Asia as high as around $550/t f.o.b., with the China DAP benchmark rebounding by around $40/t over the past three weeks.

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Market price summary $/tonne – mid-June 2024

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phos Acid
f.o.b. Caribbean	360	-	f.o.b. E. Europe 225	f.o.b. US Gulf	560	-	-
f.o.b. New Orleans	-	316	-	-	-	-	-
f.o.b. Yuzhny	Port closed	Port closed	-	f.o.b. N. Africa	543	410	928
f.o.b. Middle East	330	308	-	cfr India	528	-	948
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	282	-	cfr US Gulf	116	f.o.b. Vancouver	71	-
cfr India	319	-	-	-	f.o.b. Arab Gulf	78	-
f.o.b. Western Europe	-	633	-	-	cfr China	105	-
f.o.b. Baltic	225	-	-	-	cfr India	103	-

Prices are on a bulk, spot basis, unless otherwise stated. Phosphoric acid is in terms of $/t P_2O_5 for merchant-grade (54% P_2O_5) product. Sulphur prices are for dry material. n.a. = not available.

European DAP prices, already at historically high levels and without much downside in recent months, also increased this week.

Potash: Price falls have been seen in Southeast Asia and the US, but remain flat elsewhere. Overall, potash spot price benchmarks are mostly stable, although the US market saw significant price declines in anticipation of summer fill. Potash summer fill programmes have begun to roll out in the US with Nutrien announcing a reference price of $335/st f.o.b. (Midwest terminal). Standard Southeast Asia potash prices also fell $10/t in a week to $280-290/t cfr. India's potash import contract negotiations, meanwhile, continue to drag on.

In Brazil, some producers are reporting sales at $320/t cfr. Potash fundamentals are not supportive of significant price rises, in our view, despite other fertilizers such as MAP reaching higher price levels in Brazil.

Northwest European potash prices are unchanged, while China's domestic potash prices remain flat currently at RMB2,400-2620/t fca ($317-361/t), having previously shown a steady price increase of 20 percent since hitting a floor of RMB2,050/t fca in late March 2024.

Sulphur: Prices are stable-to-lower currently as the market awaits direction.

In China, buyers resisted higher offers leaving the cfr range for domestic port spot prices unchanged for the fourth week at $100-105/t cfr – with the midpoint ($102.50/t cfr) at its lowest level since February. The current price is now 80 percent lower than in mid-June 2022, but still up 21 percent from mid-July 2023.

Latest sulphur business to Indonesia was at a lower price than previous business, with the published range down to $100-105/t cfr from $103-108/t. Elsewhere, a US Gulf sale of mid-$60s/t f.o.b. was reported due to the long market in that locale, although this has yet to be confirmed.

OUTLOOK

Urea: In the Middle East, urea is forecast at $340/t f.o.b. for July, before slipping lower to $320/t f.o.b. in August, and then rallying in September with good demand anticipated in the northern hemisphere.

China is not expected to return to the export market in July. Higher exports are expected from August onwards as producers look to clear inventory build-up. July is forecast at $340/t f.o.b., sliding to $320/t as volumes build, before recovering in September when global demand improves.

Baltic and Black Sea prices are expected to follow the path led by China and the Middle East in pursuit of exports to India.

Ammonia: Price support in the East is set to be sustained in the immediate term with supply constraints in both the Middle East and Southeast Asia unlikely to ease this side of July. A recent sale at $360/t f.o.b from the former is seen as indicative of the more bullish sentiment shaping this regional market.

In the west, ammonia is forecast to trend downwards, although not as much as previously anticipated. The $400/t cfr June Tampa agreement, $50/t down on May, is seen as indicative of a more bearish regional market. The Tampa settlement is, however, still set to decline further through the third-quarter before recovering as the year ends.

Phosphates: Global DAP/MAP prices could continue to increase in coming weeks, though high prices could soon start to impact demand in markets such as Brazil. As always, much will depend on Chinese export volumes.

Demand is expected to increase in both Brazil and India, absorbing some Chinese DAP/MAP exports. Consequently, DAP/MAP price increases in Brazil, India, and the US are expected over much of the next six months, with MAP prices touching a monthly average of $600/t cfr in Brazil in September-October.

Potash: Prices are expected to stay stable to slightly soft as the market awaits the Indian potash contract. In Brazil, producers continue to push for higher levels, although the upside remains limited.

Prices are therefore forecast to decline slightly in most global markets over the next six months, as ample supply pushes prices lower. Standard prices are expected to fall below $285/t cfr, while granular potash prices should hold just above $300/t cfr. The highly anticipated potash contracts are expected to be settled at $285/t cfr and below.

Sulphur: Global spot prices are likely to undergo little change over the coming weeks. Sulphur affordability remains good, with current downstream price increases improving this further. Overall, global demand remains lacklustre, while sulphur availability from most origins is ample. Looking further ahead, sulphur prices are likely to climb in the fourth-quarter, recovering from recent declines and rising further, although good availability will limit the upside. ■

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Fertilizer Industry News

NORWAY

Yara opens Herøya renewable hydrogen plant

Norwegian Prime Minister Jonas Gahr Støre (left) and Yara CEO Svein Tore Holsether (right) at the opening of Yara's renewable hydrogen plant at Herøya Industrial Park, Porsgrunn, Norway.

In a major milestone, Yara International has officially opened its renewable hydrogen plant at Herøya Industrial Park, Porsgrunn, Norway.

The company has already delivered the first tonnes of fertilizers made from the renewable hydrogen and ammonia produced at the site. These have been supplied to Swedish agricultural cooperative Lantmännen.

"This is a major milestone for Yara and for the decarbonization of the food value chain, shipping fuel and other energy intensive industries," said Svein Tore Holsether, Yara's president and CEO of Yara.

The 24MW renewable hydrogen plant at Herøya, the largest currently operating in Europe, was officially inaugurated on 10th June by the Norwegian Prime Minister Jonas Gahr Støre. The hydrogen generated by the plant – via water electrolysis using renewable energy – replaces natural gas feedstocks and will cut annual CO_2 emissions at the Porsgrunn site by 41,000 tonnes.

The electrolysis plant is manufactured by ITM Power and uses proton exchange membrane (PEM) technology. It has a nameplate capacity of around 10,000 kg/d for green hydrogen. This is enough to produce 20,500 t/a of green ammonia, which can be then converted to 60,000-80,000 t/a of low-carbon fertilizer.

Yara agreed a contract with Linde Engineering for the construction and delivery of the 24MW green hydrogen plant in January 2022. This project was partly financed by a NOK283 million ($26.5 million) grant from Enova, part of Norway's climate and environment ministry.

"This is a ground-breaking project and a testament to our mission to responsibly feed the world and protect the planet. I want to thank our dedicated employees who have worked tirelessly to get this cutting-edge production up and running, Enova for supporting the project, our partners and our brave customers who are first movers towards a more sustainable future.

"We are very pleased to have delivered the first tonnes of low-carbon footprint fertilizers to Lantmännen, a partnership which serves as a concrete example of how collaboration across the entire food value chain is required to decarbonize. Together, we have made this important step towards decarbonizing hard to abate sectors," said Holsether.

The low-carbon fertilizers produced using green hydrogen and ammonia will form part of a new portfolio called Yara Climate Choice. These products will benefit crops, says Yara, while at the same time contributing to the decarbonisation of the food system and reducing its climate impacts.

Low-carbon fertilizers produced from 'blue ammonia' – using carbon capture and storage (CCS) – will also form part of Yara's portfolio in future, the company confirmed

"Renewable ammonia is an important part of the decarbonization puzzle – however, developing it at scale takes time. As the world is rapidly approaching 2030, we are also working to produce low-carbon ammonia with CCS to enable the hydrogen economy and develop the emerging markets for low-emission ammonia," says Hans Olav Raen, CEO of Yara Clean Ammonia.

In 2023, Yara signed a binding carbon dioxide transport and storage agreement with the Norwegian Northern Lights project as part of efforts to reduce the CO_2 emissions from its Sluiskil ammonia production plant in the Netherlands by 800,000 tonnes. Yara says it is also evaluating world-scale CCS projects for blue ammonia in the US.

"The world needs to act urgently on multiple fronts to reach the goals of the Paris Agreement, and CCS is a critical stepping-stone to decarbonize rapidly and profitably. The green transition will require investments, predictable framework conditions, massive build-out of renewable energy and grid, continuously advancing technology, and a maturing market where demand and supply are developed simultaneously.

"The companies who take this seriously will have a competitive advantage. At Yara, we have already reduced our emissions by 45 percent since 2005, and with our strategy to profitably deliver decarbonized solutions quickly and at scale, produced with both renewable energy and CCS, we are uniquely positioned to deliver, both to shareholders, customers, employees and society at large," said Holsether.

UNITED STATES

USDA investing $83 million in fertilizer projects

The US Department of Agriculture (USDA) has announced an investment of $83 million in domestic fertilizer projects across 12 states. The government finance will help build new fertilizer production plants, modernise equipment and install new technologies

The investment is part of the USDA's Fertilizer Production Expansion Program (FPEP). This is designed to boost domestic fertilizer production, increase competition and reduce costs to farmers.

The new tranche of investment includes the following grants:

- A $25 million grant to 4420 Serrano Drive LLC for a food waste upcycling plant in Jurupa Valley, California. The new plant will supply around 90 local customers with a total of the 11,400 tons of organic fertilizers annually.
- A $4 million grant for Cog Marketers, which also operates as AgroLiquid, to build and equip a manufacturing plant in Lake City, Florida. This is expected to produce two million gallons of fertilizer components annually and supply around 200 retailers in Alabama, Florida, Louisiana, Mississippi, North Carolina and South Carolina.
- Return LLC will use a $4 million grant to expand its current production plant in Northwood, Iowa.

Other grants were awarded to projects in California, Florida, Hawaii, Iowa, Illinois, Kansas, Kentucky, Minnesota, North Carolina, North Dakota, Oregon and Washington.

To date, USDA has invested $251 million in 57 projects across 29 states through the FPEP. That leaves around $649 million still to be allocated from the $900 million of FPEP funding the Biden administration committed to domestic fertilizer production in 2022. The FPEP was originally started in response to the doubling in fertilizer prices in 2021-2022 triggered by the conflict in Ukraine and other factors.

"The Biden-Harris Administration and USDA are committed to bolstering the economy and increasing competition for our nation's farmers, ranchers and small business owners," said USDA Secretary Vilsack. "The investments announced todaywill increase domestic fertilizer production and strengthen our supply chain, all while creating good-paying jobs that will benefit everyone."

Iowa slow-release nitrogen plant enters production

Landus has invested $15 million in a 75,000 square foot fertilizer manufacturing and distribution plant in Boone, Iowa. The project was backed by a $5 million grant from the US Department of Agriculture's Fertilizer Production Expansion Program (FPEP).

This Boone manufacturing plant will produce over 100,000 gallons of foliar, slow-release nitrogen (SRN) liquid fertilizer in its first operational year and 250,000 gallons in subsequent years. It also features a freestanding building for chemical and seed storage.

The opening of the new site allows Landus to manufacture its entire AcreEdge Performance Portfolio in Iowa. This includes over a dozen adjuvants, seed treatments and foliar nutrients.

"This state-of-the-art facility is more than just a building; it's a testament to our

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commitment to supporting our farmers and rural communities. By bringing fertilizer production closer to home, we are eliminating costly links from the supply chain, and keeping the farmer at the center as we hit the ground running with this new fertilizer production and distribution center. We're looking forward to bringing US made, sustainable and fully customizable fertilizers to our farmers across the Midwest," said Matt Carstens, Landus president and CEO.

Landus also hopes to have talusOne, a modular green ammonia unit developed by TalusAg, up and running by late August. The unit generates green ammonia using water, sunlight and energy and should produce 30 tons of green ammonia annually, once operational.

Matt Carstens, Landus president and CEO, speaking during the June grand opening of the company's fertilizer production and distribution facility in Boone, Iowa.

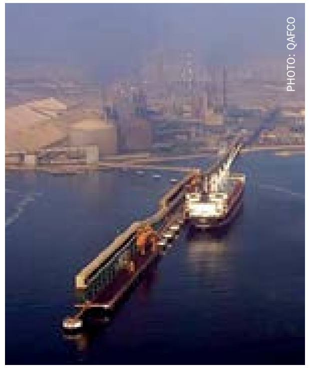
QATAR

QatarEnergy agrees 15-year urea supply deal with Koch

QatarEnergy signed a long-term urea supply agreement with leading US producer and supplier Koch Fertilizer at the end of May.

The 15-year supply agreement, which begins this July, covers the supply by QatarEnergy of up to 0.74 million t/a of urea to Koch Fertilizer. Under this agreement, Qatari-produced urea will be supplied to US agriculture and other international markets.

Saad Sherida Al-Kaabi, the Minister of State for Energy Affairs, and the president and CEO of QatarEnergy, said: "We are delighted to announce the signing of this long-term sales agreement with one of our valued partners, solidifying our longstanding relationship with Koch Fertilizer. This agreement marks a significant step in advancing synergy and cooperation and fostering mutual growth and value for both sides."



QatarEnergy affiliate company QAFCO is the world's largest single-site producer of urea and ammonia.

Mark Luetters, SVP of Koch Industries and the president of Koch Fertilizer, said: "QatarEnergy has been a cherished partner of Koch Fertilizer for more than a decade and we are thrilled to cement our mutually beneficial relationship for years to come. The agreement aligns with Koch Fertilizer's long-term vision and presents an exciting opportunity to better serve our customers."

Qatar is the world's second largest global exporter of urea – with Qatar Fertilizer Company (QAFCO), a QatarEnergy affiliate, being the world's largest integrated single-site producer of urea and ammonia.

BRAZIL

EuroChem starts MAP production in Brazil

EuroChem's new phosphate fertilizer complex at Serra do Salitre, Minas Gerais, has produced its first batch of monoammonium phosphate (MAP) fertilizer.

Brazil's president Lula da Silva officially inaugurated Serra do Salitre in March this year. The site will produce one million tonnes of phosphate fertilizers annually once it is fully operational – around 15 percent of Brazil's domestic demand, according to EuroChem.

Bernardo Silva, Executive Director of the Brazilian National Union of Feedstock Industry, emphasised the project's strategic importance to the country. "Expansion of local fertilizer production will not only strengthen the drivers of the Brazilian economy and agricultural industry but will also shield our country from market volatility and current geopolitical risk," he said.

Brazil is around 70 percent reliant on imports for its fertilizer supply currently.

"The new complex is the Group's largest international production project, built upon the engineering experience and expertise we have developed when delivering other large-scale projects," said Oleg Shiryaev, EuroChem Group president. "Over the last few years, we have launched several greenfield potash and ammonia operations and continue to invest actively in enhancing them and in the social infrastructure."

SPAIN

thyssenkrupp Uhde to decarbonise Fertiberia ammonia plant

Grupo Fertiberia has asked thyssenkrupp Uhde to modify and reduce the carbon footprint of its 'grey ammonia' plant at Puertollano, Spain.

A revamp project will partially convert production at the existing Puertollano plant from grey to green ammonia by injecting green hydrogen to partly replace the natural gas currently consumed. The revamp is designed to maintain nameplate capacity while minimising hardware modifications.

The green hydrogen required will come from a 50MW water electrolysis unit running on renewable energy. It's injection to replace natural gas should reduce the ammonia plant's CO_2 emissions by up to 40 percent.

The original plant, which used naphtha as its feedstock, was licensed and built by thyssenkrupp Uhde in 1969 with a nameplate capacity of 600 t/d. It has been in operation ever since. Fertiberia and thyssenkrupp Uhde have subsequently reduced the plant's greenhouse gas (GHG) emissions through several revamps since the 1980s. This included projects to switch over from Naptha to natural gas and implement energy efficiency improvements.

In a first-of-its-kind project, Fertiberia started green ammonia production at Puertollano in 2022 using green hydrogen generated by a 20MW water electrolysis unit. Its installation formed part of the company's 'Net Zero By 2035' strategy.

David Herrero, Fertiberia's industrial director, said: "We are the first company in the agri-food sector that is committed to being carbon neutral within the next decade. This project is another step forward towards our goal to become one of the world leaders in the manufacture of low-carbon ammonia."

Nadja Håkansson, CEO thyssenkrupp Uhde, said: "We are very proud to have been selected once again by our longstanding customer Fertiberia to further decarbonize its production. By gradually replacing fossil-based ammonia production with green ammonia production, we have a huge lever for the green transformation of agriculture and entire industry sectors."

CANADA

Phosphorus added to critical minerals list

Natural Resources Canada added phosphorus to the country's Critical Minerals List in June.

The Canadian government uses the list to safeguard and promote sustainable mineral exploration and extraction, advanced manufacturing, clean technology, as well as ICT and semiconductors. The listed minerals are often in short supply, integral to a variety of products, and critical to the energy transition and future economic prosperity.

"Critical minerals are the building blocks for the green and digital economy and demand for them will only grow throughout the global energy transition," Natural Resources Canada said in a statement.

Canada first released its Critical Minerals List in March 2021 with a commitment to review and update this every three years. The updated 2024 list retains all 31 minerals from the 2021 list and adds three new minerals – high-purity iron, phosphorous and silicon metal – raising the total to 34.

These three additions follow public consultations with provincial and territorial governments, government departments, industry, indigenous groups and other interested parties. They were included for the following reasons:

- Silicon metal is essential to the manufacture of chips and semiconductors, being used in almost any and everything electronic.
- High-purity iron ore is essential to green steel and integral to decarbonisation.
- Phosphorus, combined with potash, is essential for food security through the production of fertilizers. It can also be used in lithium iron phosphate (LFP) batteries and is therefore part of the strategic opportunity for Canada in the electric vehicle (EV) value chain.

"By updating Canada's Critical Minerals List, we are taking a proactive step to ensure that Canada's efforts to seize the generational economic opportunity presented by our critical minerals wealth is well informed by the most accurate market trends, geopolitical factors and science," said Jonathan Wilkinson, Canada's Minister of Energy and Natural Resources. "Investments in critical minerals projects create good jobs for workers, more avenues for Canadian innovation and lower emissions across the country — all of which form an important part of our plan to build a cleaner Canada and a prosperous, sustainable economy."

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EGYPT

Urea production outages due to natural gas curtailments

Reporting by Pranshi Goyal, Ben Farey & Christine Gregory

PHOTO: MOPCO

Loading a bulk urea shipment, Egypt.

A series of intermittent halts to natural gas supply have affected Egyptian fertilizer production since early June.

CRU estimates that Egyptian urea production could drop by around 150,000 tonne in June, assuming a 50 percent output curtailment during the month over a two week period. Even lower production remains a possibility, should the current gas supply issues extend beyond a fortnight.

The supply cuts began on 4th June. This forced at least four urea producers to halt production, including Abu Qir, Helwan, Alexfert and Kima. Mopco, meanwhile, said it had been forced to close two lines, the third having already closed for a week's maintenance.

While gas flows to producers were expected to gradually return to normal from 6th June, according to a joint statement from Egypt's oil and electricity ministries, supply curbs again returned on 10th June, with some plants down completely once more, while others reduced output significantly.

All urea plants were understood to be still down on 13th June, albeit with suggestions that gas supply was returning. By 18th June, nearly all producers reported that gas supply had resumed, with plants restarting and operating at around 80 percent of capacity by 20th June. Kima in Aswan was the exception. It was not expecting its gas feedstock to return until 24th June.

No Egyptian producers were offering urea product at the time of writing. Abu Qir was the only producer to report output of prilled and granular urea at normal levels.

Export urea prices from Egypt have surged in the last few weeks. Egyptian f.o.b. prices have rallied $50-60/t since early April. Prices increased by as much as $70/t by 12th June, from a low of $285/t f.o.b. on 9th May, when NCIC reported a 5,000 tonne granular sale at $355/t f.o.b. Urea production at NCIC is understood to be offline with the most recent sale made from stock.

Multiple sales that could be affected by the closures – thought to amount to more than 300,000 tonnes – have been made for June shipment in recent weeks. There have, however, been no reported cancellations to date. On 20th June, around 200,000 tonnes was still waiting to ship to clear these sales, with fresh exports not anticipated now before the second half of July.

Egypt has seven main urea exporters and some of the country's large-scale production assets are among the lowest cost globally, according to CRU's Cost Analysis Tool (CAT). They include:

- Misr Fertilizers Production Co (Mopco): 1.9 million t/a capacity
- Fertiglobe at Ain Sokhna: 1.65 million t/a capacity
- Abu Qir: 1.45 million t/a capacity
- Alexfert: 635,000 t/a capacity
- Helwan Fertilizer Co (HFC): 635,000 t/a capacity
- Kima in Aswan: 528,000 t/a capacity
- El Nasr Co. for Intermediate Chemicals (NCIC): 380,000 t/a.

This capacity is almost exclusively for granular urea except for the limited prilled urea capacity offered by Abu Qir.

Temporary gas reductions to Egypt's urea plants are not uncommon in very hot weather. The country has a rapidly expanding population of around 115 million – and consequently huge demand for natural gas to power cooling systems.

Last year, Egypt's total gas production fell to its lowest since 2017, figures from the Joint Organisations Data Initiative (JODI) show. Gas production in 2023 was around 59.29 billion cubic meters (bcm), its the lowest production level since 2017 (50.72 bcm) and a fall of 11.5 percent year-on-year. Imports from Israel last year totalled 8.6 bcm approximately.

Egypt has traditionally been an exporter of liquified natural gas (LNG) from Damietta. But the country halted LNG exports in May, for the first time since 2018, and has resorted to LNG imports to meet its domestic demand for gas-fired power generation. Kima is expecting the import of 17 LNG cargoes from July to September to cover the current gas shortage.

The Egyptian government increased the gas price for fertilizer producers from $4.5/MMBtu to $5.75/MMBtu in the fourth-quarter of 2021. It subsequently introduced a new formula in September 2022 linking the gas price paid by fertilizer producers to urea pricing. This is based on the sales price of urea to the state (Ministry of Agriculture) and the urea export price (f.o.b. Egypt).

Egyptian nitrogen producers are required to sell 55 percent of their urea output to the Ministry of Agriculture at what CRU assumes is a domestic sales price of $255/t, although this may have changed in 2024.

An Egyptian urea trader has told CRU the recent gas outages seem to be more serious than expected and commented on the lack of official information about the problems. The offshore Tamar field in Israel underwent planned maintenance in May but is understood to have since returned to production While Operator Chevron has said deliveries of gas to customers in Israel, Jordan and Egypt are ongoing, it is not clear whether the field is operating at capacity. This has led some in Egypt to question whether the field is producing as it should be. ■

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People

Marc Hechler is EuroChem Group's new CEO, replacing Samir Brikho who held the position since August 2022. Mr Hechler brings with him more than 20 years of global fertilizer industry experience. He has led EuroChem's European business operations for the past five years. His leadership experience includes the successful execution of restructuring projects.

"Marc's new role will focus on managing risks and maintaining efficiency of our European business, an important task in these challenging times," EuroChem said in a statement.

Samir Brikho will continue in his role as the chairman of EuroChem's board.

Marc Hechler, the new CEO of EuroChem Group.

Gregory D Cameron became executive vice president (EVP) and chief financial officer (CFO) of CF Industries in June, following his election by the board. Mr Cameron will report to Tony Will, the company's president and CEO, and will serve as a member of the senior leadership team. He succeeds Christopher D Bohn, who was recently promoted to EVP and chief operating officer (COO).

"We are pleased to welcome Greg to CF Industries," said Tony Will. "He brings proven leadership, financial and clean energy expertise, and a strong track record of developing high-performing teams that will serve our Company, employees and shareholders well."

Mr Cameron was previously president and CFO of Bloom Energy, a global leader in solid oxide fuel cell technology having joined Bloom Energy in 2020 as EVP and CFO. Prior to this, Greg held a series of senior roles at General Electric for more than 26 years. These included stints as president and CEO, global operations, GE Company, and president and CEO, global legacy solutions, GE Capital.

Jeffrey Cathey, the newly appointed CFO of Compass Minerals.

Jeffrey Cathey is the new CFO of Compass Minerals. Mr Cathey joined Compass Minerals in December 2023 as chief accounting officer. In his new role, he will be responsible for all aspects of financial management – including accounting, reporting, tax, internal audit, treasury, financial planning and analysis, and investor relations.

"A key driver in our efforts to get back to the basics by creating value through our core Salt and Plant Nutrition businesses is rigorous balance sheet management. Jeff is a proven leader who has built and improved financial organizations and systems over his career. His skillset aligns extremely well with where the company is today, and more importantly, where we want to go," said Edward C Dowling Jr, the president and CEO of Compass Minerals. "I'm confident his leadership as CFO will help further our efforts to manage costs, reduce debt, and improve our overall financial performance."

Jeffrey brings to Compass Minerals more than 15 years of financial leadership experience in public and private companies. Before joining Compass Minerals, he spent 10 years in positions of increasing responsibility at Crestwood Equity Partners LP, most recently as principal accounting officer. Previously, he held roles at Shamrock Trading Corporation and Ernst & Young LLP.

Mr Cathey holds Bachelor of Science degree in both finance and accounting, and a Master of Science degree in accounting from Kansas State University. He is also a certified public accountant.

He succeeds Lorin Crenshaw, who has departed Compass Minerals with immediate effect, having served as the company's CFO since December 2021.

"I appreciate Lorin's service and contributions during his tenure at our company and wish him continued success in his next pursuit," added Dowling.

Calendar 2024

JULY

9-10
IFA Global Markets Conference, LONDON, UK
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

14-18
98th Annual Southwestern Fertilizer Conference, NASHVILLE, Tennessee, USA
Contact: Pat Miller
Tel: (512) 259-2118
Email: SWFC@SWFertilizer.org

OCTOBER

2-3
TFI World Fertilizer Conference, WASHINGTON DC, USA
Contact: Valerie Sutton
Tel: +1 202 962 0490
Email: vsutton@tfi.org

8-10
IFA Crossroads Asia Pacific, HONG KONG, China
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

NOVEMBER

4-6
CRU Sulphur & Sulphuric Acid Conference 2024, BARCELONA, Spain
Contact: CRU Events
Tel: +44 (0)20 7903 2444
Email: conferences@crugroup.com

12-15
Biostimulants World Congress, MIAMI, Florida, USA
Contact: New Ag International
Tel: +44 (0)20 8052 2011
Email: info@newaginternational.com

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Pathways to sustainable agriculture

Wheat field, England, summer 2024. Regional cropping systems, such as those in Europe, offer major opportunities for greenhouse gas (GHG) emissions savings, according to a 2022 report commissioned by the International Fertilizer Association (IFA).

PHOTO: SIMON INGLETHORPE/CRU

The production and use of nitrogen fertilizers are responsible for around five percent of global greenhouse gas (GHG) emissions. The fertilizer industry will need to drastically cut these emissions by 2050 as part of its contribution to the 1.5°C global warming target. Yet around 48 percent of the global population rely on crops grown with nitrogen fertilizers. Guaranteeing food security, by continuing to supply affordable crop nutrients at scale, while transitioning to a low-carbon future, is therefore *the* collective challenge for the global fertilizer industry and world agriculture.

A decarbonisation trilemma

Mineral fertilizers are vital for world food production and security. By raising crop yields – and so boosting the amount of food produced from a fixed area of agricultural land – they are responsible for feeding around half the global population[1]. Yet nitrogen fertilizer use is associated with annual greenhouse gas (GHG) emissions of around 717 million tonnes (Mt) carbon dioxide equivalent (CO_2e) a year[2]. This is broadly equivalent to the total emissions of Germany. Furthermore, use emissions from farm land are primarily in the form of nitrous oxide (N_2O) – an ozone-depleting gas with a global warming potential almost 300 times greater than carbon dioxide.

Emissions from nitrogen fertilizer use, when combined with those generated by its production, collectively account for around six percent of total food sector GHG emissions, a sector which itself is responsible for around one-third of total global GHG emissions.

In recent years, fertilizer producers, primarily through the International Fertilizer Association (IFA), have been working collaboratively on plans to reduce their GHG emissions by 2050 and ensure the global fertilizer industry plays its role in meeting the Paris Agreement's 1.5°C limit on global warming. The challenge for the industry and policymakers is threefold:

- How to place the agricultural sector on a sustainable low emissions trajectory
- While continuing to supply framers with the fertilizers they need to feed an ever growing population.
- Yet do so without imposing a crippling cost burden on fertilizer producers, farmers, the food industry and ultimately food consumers.

Driving down production emissions

The Ammonia Technology Roadmap – a collaboration between the International Energy Agency (IEA), the European Bank for Reconstruction and Development (EBRD) and IFA – was published in October 2021 just ahead of the COP26 climate conference in Glasgow[3]. Described by IFA at the time as its number one priority (*Fertilizer International* 505, p36), the roadmap set out a plan to decarbonise ammonia production globally by 2050. This report and its findings have been covered in depth previously (*Fertilizer International* 508, p38).

Producing ammonia requires a lot of energy. On average, around 2.4 tonnes of carbon dioxide are emitted per tonne of ammonia produced, although this varies according to the hydrocarbon feedstock used. To put this in context, ammonia's per tonne emissions intensity is twice as high as steel, for example, and four times higher than cement.

Direct emissions from global ammonia production currently total 450 Mt CO_2e per annually. This is comparable to the total emissions of South Africa.

The IEA/IFA roadmap sets out three future scenarios for ammonia production out to 2050 each with a different set of actions and outcomes (see box). Two scenarios – SDS and NZE – achieve 70-95 percent emissions reductions by 2050. These deep emissions cuts will be hugely costly. Indeed, meeting or going beyond Paris Agreement climate goals will require the global ammonia industry to invest $14-15 billion in production decarbonisation annually, according to IEA estimates.

The deployment of low-carbon technologies is expected to do most of the heavy lifting on emissions reductions out to 2050. In the SDS scenario, for example, ammonia production via electrolysis powered using renewable electricity would account for around one-fifth of global production by 2050 (versus less than 0.01% today), this share rising

Decarbonising production - three possible futures

The IEA's *Ammonia Technology Roadmap* sets out three future scenarios for ammonia production – each with different sets of actions and outcomes by 2050 (see Figure 1)

- **Stated Policies Scenario (STEPS)**. The industry follows current trends and, while making incremental improvements, falls well short of a sustainable trajectory.
- **Sustainable Development Scenario (SDS)**. The sector adopts the technologies and policies required to put it on a pathway to meet Paris Agreement goals.
- **Net Zero Emissions by 2050 Scenario (NZE)**. A trajectory for the ammonia industry that reaches net zero global emissions by 2050.

While the STEPS scenario is a modest improvement on business-as-usual that only delivers marginal emissions cuts, both the SDS and NZE scenarios deliver desirable outcomes, according to the IEA, by achieving 70-95 percent emissions reductions. These two scenarios would, however, require the ammonia industry to either meet or go beyond Paris Agreement goals.

Stated Policies Scenario (STEPS)

This assumes that progress over the next 30 years is driven by currently stated government policies. This projection is based on current trends in consumption and production and commitments made at the COP26 meeting in Glasgow. In this scenario:

- Ammonia production would increase by 37 percent by 2050, driven primarily by economic needs and population growth
- While emissions from production fall by about 10 percent
- Cumulative direct emissions from ammonia production between now and 2100 would amount to around 28 gigatonnes (Gt)
- This amount is equivalent to six percent of the emissions budget needed to limit global warming to 1.5°C.

The report assumes that actions under STEPS – because they do not improve enough on business-as-usual – are inadequate and would result in unsustainable outcomes.

Sustainable Development Scenario (SDS)

This assumes that governments and industry actions meet the goals of the Paris Agreement and limit the global temperature rise to well below 2°C. The two key elements in this scenario are:

- Cutting direct CO_2 emissions from ammonia production by more than 70 percent, relative to today
- Action on nitrogen use efficiency (NUE) to limit the growth in ammonia production and consumption to 23 percent by 2050.

Four main actions would make the following individual contributions to this 70 percent reduction in emissions:

- 45 percent achieved by deploying low-carbon technologies – including electrolytic hydrogen generation (30% of emissions reduction) and carbon capture and storage (CCS, 15%)
- Energy efficiency from the adoption of best available techniques (BATs) and operational improvements contributes 25 percent
- Fuel switching – from coal-based production to less energy intensive gas-based production – is responsible for 10 percent of the reduction

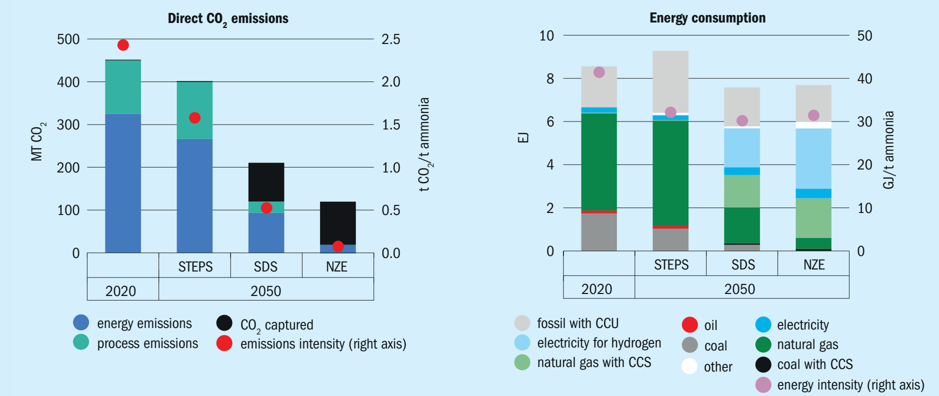
This ambitious scenario requires:

- $14 billion in annual capital investment for ammonia production to 2050
- The installation of more than 110 gigawatts (GW) of electrolyser capacity
- 90 million t/a of CCS CO_2 storage capacity.

Net Zero Emissions by 2050 Scenario (NZE)

This sets out a trajectory for a fall in ammonia industry emissions of 95 percent by 2050. The additional emission reductions in this scenario – compared to the ambitious SDS trajectory – are achieved by even more rapid deployment of electrolysis and CCS technologies. The main difference between NZE and the SDS scenarios is therefore one of degree. Indeed, the NZE Scenario requires only slightly higher annual investment: $15 billion per year to 2050.

Fig. 1: **Comparison of ammonia industry direct CO_2 emissions (left) and energy consumption (right) in 2050 vs 2020. Outcomes for three different future scenarios – STEPS, SDS and NZE. See text for details.**



Notes: CCU: carbon capture and utilisation; CCS: carbon capture and storage; STEPS: Stated Policies Scenario; SDS: Sustainable Development Scenario; NZE: Net Zero Emissions by 2050 Scenario.

Source: IEA, 2021

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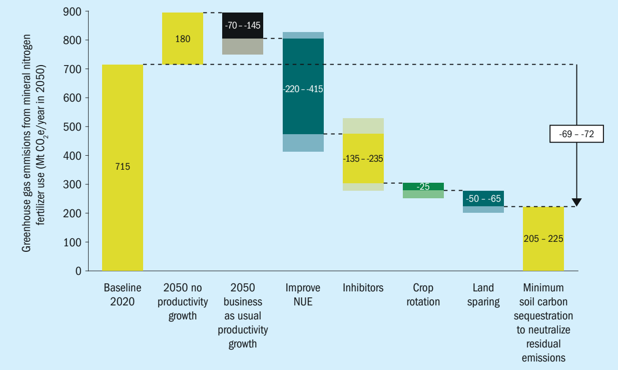
Fig 2: **Cumulative cuts to fertilizer use (Scope 3) emissions by 2050 via the adoption of five main measures.**



Source: Systemiq/IFA (Oppenheim, et al, 2022)

to above 40 percent in Europe, India and China. In the NZE scenario, meanwhile, the global production share for the electrolysis pathway doubles to more than 40 percent.

Carbon capture and storage (CCS) also looks set to play an increasing role, capturing 91 million tonnes and 101 million tonnes of ammonia industry CO_2 emissions annually by 2050 in the SDS and NZE scenarios, respectively.

These two low-carbon technologies would need to be "deployed at a rapid clip" according to the IEA[3]. This is, if anything, an understatement. Under the SDS scenario, for example, more than 110 GW of electrolyser capacity and 90 million t/a of CO_2 transport and storage infrastructure would be needed by 2050. That equates to the installation of ten 30MW electrolysers (the largest capacity currently in operation) per month on average, together with the completion of one large-scale CCS project (1 million t/a CO_2 capacity) every four months between now and 2050. Even more rapid deployment of these technologies would be necessary under the most ambitious NZE scenario.

> **"Emissions from the production and use of nitrogen fertilizers are responsible for approximately five percent of the global total - a share that is similar to that of the iron and steel industry, the largest global source of industrial emissions.**

Working with the World Business Council on Sustainable Development (WBCSD) and others, IFA is using the ammonia decarbonisation roadmap as a springboard to develop a Sectoral Decarbonization Approach (SDA) for the fertilizer industry to drive down Scope 1 and 2 emissions as part of the Science Based Targets initiative (SBTi)[2].

Action plan on fertilizer use emissions

For the fertilizer industry – and its agricultural and food industry partners and customers – meeting Paris Agreement climate goals is not just about delivering a 70-95 percent cut in the 450 Mt CO_2e of direct emissions currently generated by ammonia production globally. It also means tackling the even bigger 717 Mt CO_2e annual emissions associated with the global use of nitrogen fertilizers by farmers – so-called Scope 3 emissions.

IFA again has addressed this head on by commissioning a comprehensive report and action plan on Scope 3 emissions from UK-based change consultancy Systemiq. Published in September 2022, this report sets out a pathway for reducing global GHG emissions from nitrogen fertilizer use by 70 percent by 2050 – while feeding a global population of 10 billion[2].

This drastic reduction in fertilizer use emissions could be achieved by applying existing knowledge and technologies, according to Systemiq. The report's findings – and its pathway to a more sustainable agricultural system –are summarised in Figure 2.

Overall, there is potential to cut Scope 3 nitrogen fertilizer emissions from global farming by 69-72 percent (from a 2020 baseline), suggest Systemiq, by applying the following emissions reduction measures sequentially:

- **Improved nutrient use efficiency (NUE):** potential to reduce use emissions by between 220-415 Mt CO_2e. NUE is increased to 65–75 percent through adoption of best practices by farmers. These include the existing 4Rs framework on nutrient stewardship: applying the right nutrient source, at the right rate and time and in the right place.
- **Greater use of nitrification and urease inhibitors:** potential to reduce use emissions by 135-235 Mt CO_2e. Inhibitors are applied to half the crop area and half the area fertilized with urea, respectively. This reduces direct nitrous oxide emissions on those areas by 30–50 percent and the fraction of nitrogen from urea that is lost to volatilisation by 30–60 percent. The report also envisages greater adoption of controlled-release fertilizers (CRFs) and other types of enhanced efficiency fertilizers (EEFs) in future.
- **More legumes in crop rotation:** potential to reduce use emissions by 25 Mt CO_2e. The number of legumes in crop rotations is increased from around 14 percent to 20 percent of global cropland. Growing more legumes such as soybeans can reduce nitrogen fertilizer use – and therefore the associated agricultural emissions – as they can fix nitrogen directly from the atmosphere.
- **Land sparing:** potential to reduce use emissions by 50-65 Mt CO_2e.This is achieved by a dietary shift away from animal products that allows the release of agricultural land away from crop production.

Additionally, there is potential to neutralise the remaining 30 percent of use emissions (205-225 Mt CO_2e), according to Systemiq, by supporting soil carbon sequestration. This improves soil health while providing a source of income for farmers through carbon farming (*Fertilizer International* 509, p32).

Systemiq's report does make a number of underlying assumptions about ag productivity growth. With no productivity growth, use emissions from nitrogen fertilizers would be expected to increase by a further 180 Mt CO_2e by 2050. Systemiq scales this increase back to around 35-110 Mt CO_2e by creating a more realistic 'business-as-usual' scenario for 2050. This assumes the global population grows in line with UN projections, agricultural productivity growth of 0.8–1.1 percent per annum (p.a.) and nitrogen uptake growth of 0.4–0.6 percent p.a. Additionally, it is assumed that the gap in nitrogen application rates between Africa and the current global average closes by between one- and two-thirds.

Regional approach

The IFA/Systemiq report identifies measures that could deliver 84 Mt CO_2e of emissions savings globally across six regional cropping systems. Around one-quarter of the emissions reduction measures identified generated a cost saving for farmers – as more efficient fertilizer use should reduce crop inputs while maintaining or improving crop yields.

The savings opportunities primarily come from the adoption of best fertilization practices and changes to crop rotations. While many measures deliver cost savings, farmers still face barriers to change such as:

- Credit constraints and other financial market failures
- Perverse public policy incentives
- Lack of knowledge or access to appropriate skilled labour
- Lack of scale to enable technology adoption.

Major emissions savings opportunities were identified in two regional cropping systems in particular:

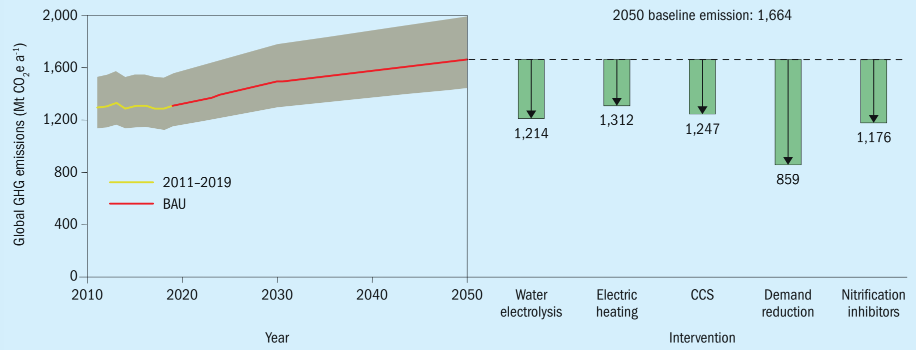
- **Maize-soybean in Brazil.** Raising NUE to 70 percent across Brazil: potential 21 Mt CO_2e emissions savings, although use of precision agriculture by farmers faces cost and staffing barriers. Adding inhibitors to sugarcane fertilized with nitrogen and vinasse: this is a low cost measure with potential emissions savings of 2.7-8.1 Mt CO_2e, although there are no strong incentives for farmers to change their behaviour. Insert soybeans into fallow period of the sugarcane crop cycle: highly profitable option for farmers, given high yield and low production costs, but delivers only limited emissions savings of around 0.2 Mt CO_2e.
- **Wheat-maize in North China Plain.** Adoption of precision agriculture at an annual investment of €2-5 billion: potential 11.2 Mt CO_2e emissions saving. Diversifying crop rotation with legumes: potential 8.7 Mt CO_2e emissions saving, although crop yields would need to rise above the 3 t/ha global average for growers to break even.

> **"Approximately two-thirds of fertilizer emissions take place after their deployment in croplands. Increasing nitrogen-use efficiency is therefore the single most effective strategy to reduce emissions.**

Total life cycle approach

The total life cycle GHG emissions from nitrogen fertilizers were mapped in a 2023 *Nature Food* paper by Yunhu Gao and André Cabrera Serrenho of Cambridge University's engineering department[4]. The two authors also determined the maximum mitigation potential of various interventions across the whole life cycle. They concluded that total global GHG emissions from the production and use of nitrogen fertilizers could be cut to just one-fifth of current levels by 2050.

Fig 3: **Driving down fertilizer emissions. Historical and future global life cycle GHG emissions of nitrogen fertilizers (left) and the maximum mitigation potential of individual interventions in 2050 (right).**



Source: Gao & Serrenho (2023)

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They estimated that GHG emissions from the production and use of nitrogen fertilizers (1.31 Gt CO_2e p.a.) are responsible for approximately five percent of the global total – a share that is similar to that of the iron and steel industry (7%), the largest global source of industrial emissions, and cement (6%) and plastics (4%) manufacturing.

They also note that fertilizers use is so ubiquitous that around 48 percent of the global population are fed with crops grown with synthetic nitrogen[1]. This made "reducing GHG emissions associated with nitrogen fertilizers an essential contribution to meeting the 1.5°C global warming target, while also ensuring food security", in their view.

From a 2050 baseline for life cycle emissions from nitrogen fertilizers (1,664 Mt CO_2e), the study calculates the maximum mitigation potential of five individual interventions by 2050, if applied in isolation (Figure 3):

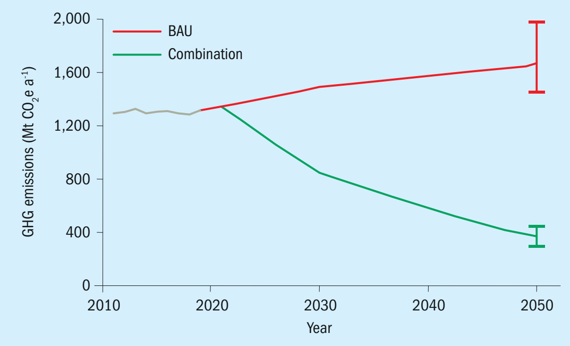
- **Water electrolysis powered by renewables:** 450 Mt CO_2e reduction to 1,214 Mt CO_2e
- **Electrification of production:** 352 Mt CO_2e reduction to 1,312 Mt CO_2e
- **Carbon capture & storage (CCS):** 417 Mt CO_2e reduction to 1,247 Mt CO_2e
- **Demand reduction (improved nutrient use efficiency):** 805 Mt CO_2e reduction to 859 Mt CO_2e
- **Nitrification inhibitors:** 488 Mt CO_2e reduction to 1,176 Mt CO_2e.

They also plotted the GHG emissions trajectory for nitrogen fertilizers out to 2050 for a combination of mitigation options – including the use of water electrolysis for ammonia production, the deployment of nitrification inhibitors and improving nitrogen-use efficiency to reduce fertilizer demand (Figure 4). The resulting combined mitigation potential suggests that total 2050 GHG emissions could be reduced by up to 78 percent to 357 Mt CO_2e.

"We found that approximately two-thirds of fertilizer emissions take place after their deployment in croplands," say the authors, adding: "Increasing nitrogen-use efficiency is the single most effective strategy to reduce emissions."

This strategy includes micro irrigation, sowing crops that are able to use nitrogen fertilizers more efficiently due to improved plant breeding, and 4Rs nutrient stewardship – applying the right fertilizers at the right rate and time in the right place.

Fig 4: GHG emissions trajectory for nitrogen fertilizers out to 2050 showing business as usual (BAU, red line) versus a combination of mitigation options (Combination, green line) – including the use of water electrolysis for ammonia production, the deployment of nitrification inhibitors and improving nitrogen-use efficiency to reduce fertilizer demand.



Source: Gao & Serrenho (2023)

"[While] changing from steam methane reforming to water electrolysis powered with renewables results in a substantial reduction in production emissions. This alone can reduce 75 percent of production emissions by 2050 but only 27 percent of total emissions, owing to the much larger weight of use-phase emissions," the authors conclude.

Next steps

The 2022 Systemiq report[2] urged the fertilizer industry to reflect on its proposals and use these to help set individual company and sector-wide targets. It also called the industry's move to a Sectoral Decarbonization Approach (SDA) "an even bigger step, covering Scope 1, 2 and 3 emissions" because this combines Scope 3 emissions guidance with target setting developed by the Science Based Targets initiative (SBTi)

Systemiq also urged governments to take "action to review and refocus food, farming and fertilizer subsidies and to support collaboration across the food and farming sectors to address emissions"[2].

Finally, a focus on product innovation, with greater investment in research and development, was also needed to set the fertilizer industry and agriculture on a more sustainable pathway, suggested Systemiq[2]:

"Developing and applying existing technologies and producing new ones. Additional products such as urease and nitrification inhibitors and controlled-release fertilizers have the potential to further help reduce emissions. More research and product development are needed to make these technologies more affordable, and to better understand how they work together and their wider environment impacts." ■

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4. Gao, Y., & Serrenho, A., 2023. Greenhouse gas emissions from nitrogen fertilizers could be reduced by up to one-fifth of current levels by 2050 with combined interventions. *Nature Food*, 170-178.

Farm better, farm smarter, farm with a smaller footprint

Levity Crop Science has a growing reputation as a leader in functional fertilizers, offering novel products that boost nitrogen and calcium efficiency and the crop uptake of micronutrients such as boron, molybdenum and silicon. This has culminated in the recent completion of a new research and development centre near Preston in the UK.

"Insanity," Albert Einstein reputedly said, "is doing the same thing over and over and expecting different results."

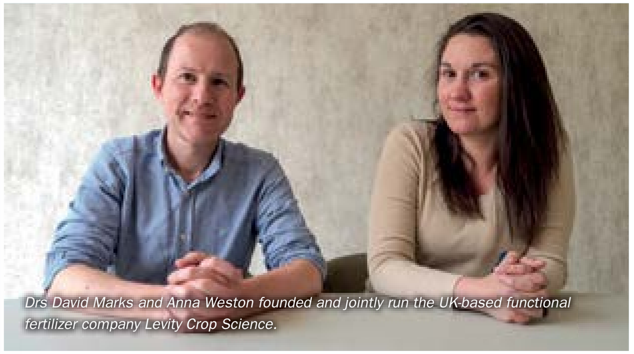
Shame then that this quote is a misattribution – with no proof Einstein ever actually said these words.

That shouldn't detract from its underlying sentiment though: when making the same mistakes, successful change requires you to act differently. That's simply a truism.

This quote, whatever its true provenance, certainly resonates with Dr David Marks. A plant biologist by training, David has always been fascinated by the inner workings of the handful of plants – wheat, barley, rice, soybeans and maize – that form the basis of the world's food production

"Having productive, high-yielding crops, free from pests and diseases, is the cornerstone of world agriculture," he explains.

PHOTO: LEVITY



Drs David Marks and Anna Weston founded and jointly run the UK-based functional fertilizer company Levity Crop Science.

"But I always thought we were going about it in totally the wrong way."

Same old, same old

What Dr Marks is referring to is the basis of the global crop protection industry: the endless screening of hundreds and thousands of candidate molecules to identify those with potential as insecticides, fungicides or herbicides.

"As the screening process becomes more drawn out, because more and more chemicals need to be screened to meet the ever-more stringent regulatory requirements, so too the cost of developing new products becomes ever more expensive.

"Fewer and fewer products are successfully registered, yet even these are essentially reinventions of the same thing," he reflects.

"It's like this: we see the arrival of a new active ingredient. Promising to outperform whatever previous molecule it's superseding, it gives farmers a few years to get ahead of the pests and diseases before the single mode of action is inevitably overcome by resistance, and the cycle starts again.

"When the replacement arrives, there are more caveats on its use, in a bid to add some more years to its useful life before the inevitable tail-off in performance."

Dr Marks says he's frustrated with this crop protection orthodoxy. "It's almost impossible to make this system work forever. By its very nature, it is not sustainable. The cost of development is too high. The model is flawed.

"So why do we keep on the same route?"

Right industry, wrong model?

While Dr Marks' believes the crop protection industry is heading in the wrong direction, his criticisms are of its 'flawed model'. His frustration does not mean he is pushing for an agrochemical-free future.

"There's an idea that we can pursue an organic future and make our crops sufficiently productive without using agrochemicals. I'm no advocate for that. We don't have enough land. We can't afford to be 'relaxed' about the challenge facing agriculture, to feed the world: it must be productive, and that means coaxing and nurturing our crops to reach their full yield potential."

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SUSTAINABILITY

Agrochemicals – as crop inputs – play a vital role, he says. But not at any cost. "When we see the same mistakes, repeatedly, surely it's time to do things differently."

Dr Marks has very much put his money where his mouth is: he's the founder of Levity Crop Science, a British firm that's building a steadily increasing range of 'smart' crop input products in markets around the world. The company's objectives are simple: to improve crop production, reduce waste, increase yield, and contribute to farmers' profitability.

It's noticeable that not one of those objectives references, or focuses on, 'agricultural sustainability'. Dr Marks says that's for good reason.

"Many farmers want to farm differently. Yes, they say 'sustainability' is a key driver. But they must square that with the need to remain profitable; they're also wary of products that overpromise.

"If we can develop products that satisfy each of those objectives, with science-led solutions, the farmers who use them will already be farming more sustainably: they'll produce increased yields of higher quality crops, improving their returns and their resource-use efficiency.

"Although we're developing crop inputs from a different start point and with a different mentality, at the point of use there's no difference.

"We want to allow farmers around the world an opportunity to use fewer harsh chemicals – and to avoid the inevitability of declining performance, because of resistance – while continuing to pursue an otherwise conventional crop production programme."

Inputs that work with the crop

Levity's approach is heavily reliant on science, drawing strongly on Dr Marks' background in plant biology. Understanding how plants work – their physiology, their biochemistry, the role of hormones – is central to making inputs work with the crop more readily, explains Dr Marks. He says we've become conditioned to accepting that crop inputs should be defined into categories – insecticide or fungicide, for example.

But plants are not only very complicated organisms, they're also very adept at multi-purposing the products of photosynthesis and the hundreds of different biochemical pathways they employ, he adds.

"So you don't have to have a product that's exclusively one thing or another, and that's Levity's thinking. A lot of our products are classified as fertilizers, but they're 'functional' in that they have properties that go beyond what you'd expect from a conventional, 'passive' fertilizer."

Science-based, then, but a very different kind of science. "There's no shortage of people who are set on making agriculture more sustainable, and who have products to show for it. The difference is that many of those don't really know what's in their products, why or how they work, and – in some cases – even if they do work."

Levity's modus operandi could be described as 'the third way', says Dr Marks. "We're not into testing thousands and thousands of chemicals to try to find the incremental 0.5%, nor are we packing uncertain, inconsistent organic derivatives into bottles and attaching dubious claims to it.

"The best way to describe us is that we're not content to accept the status quo.

"The spirit of gravity is to believe that everything has already been done. It's the opposite of the spirit of levity – irreverence and a belief that it's possible to do something better."

Radical solutions to known problems

Approaching known problems in crop production by looking for radically new ways of solving them is key to understanding Levity's products. It also explains, Dr Marks adds, why Levity doesn't yet have a 'full range' of products.

Every problem needs a different solution, he stresses, and while Levity has already established itself as a leader in nitrogen and calcium efficiency, bolstered by novel products to tackle inefficiencies in micronutrients such as boron, molybdenum and silicon, he says there's no point in being seen to have a full range merely for the sake of it.

Nevertheless, he says that Levity's portfolio will grow over the next few years, a promise given considerable credibility by the recent completion of a new research and development centre near Preston, UK (see box). Under full family control – Levity is jointly owned and run by Dr Marks and his wife, Dr Anna Weston – Dr Marks hopes the new facility will give his team the continued freedom and ability to pursue avenues of research without being beholden to anyone.

"We set our own targets. Yes, we can end up in a blind alley, but even that's valuable. Most of the time, we make things work, and while not every challenge is successful, the most important point is the challenge. Orthodoxies are there to be challenged," he says.

Setting the right targets

'Making agriculture more sustainable' works as a strapline, but for Dr Marks it's not specific enough. "What does it mean at the farmer level? What does it mean for resource use? What about food waste?"

Product development at Levity therefore focuses on a few key metrics, such as environmental impact, improvements to fresh produce shelf life, increased marketable quality, reduced crop stress, or measurable effects on disease incidence.

"From the farmer's perspective, these translate into finding ways to help him or her farm better, farm smarter, farm with a smaller footprint," Dr Marks explains.

"For example, can we reduce their reliance on, or usage of, pesticides? Agriculture accounts for 70 percent of the world's freshwater usage: can we find ways to help them use lower-grade water resources?

"Can we help them harvest crops that can travel long distances without loss of quality, or which don't need refrigeration or controlled atmospheres? Can we help reduce waste in the food chain, by raising the quality of produce and eliminating non-marketable grades?"

"What we don't do is to set ourselves boring targets," laughs Dr Marks. "We can't rewrite the rule book on agriculture if we're only looking at conventional targets."

Real nutrient use efficiency

Levity isn't alone in wanting to improve agriculture's use of precious resources and challenge accepted norms.

"We use too much nitrogen," points out Dr Marks. "We're still using forms of nitrogen that create pollution. And often, that nitrogen takes too much resource in its manufacture."

Much of the pollution is because crops can't make use of much of the nitrogen that's applied – Dr Marks says around two-thirds more nitrogen is applied to fields than is used in the crop, even when precision applications are made.

Dr Marks believes we shouldn't simply be talking about 'nitrogen' anyway – preferring the term 'nitrogen-containing molecules' instead.

"These nitrogen-containing molecules are not created equal. Some are more stable than others, but more importantly they're processed differently in the plant, requiring differing amounts of energy."

Every plant has a finite energy budget. If a particular process – nitrogen processing, for instance – consumes energy inefficiently, then there's less energy available for other purposes.

This is the thinking behind one of Levity's most widely used products, Lono. It contains a stabilised amine nitrogen (SAN) which, says the company, consumes twelve times less photosynthetic energy than an equivalent amount of nitrate.

"Lono allows farmers to be 'smart' with their fertiliser use," Dr Marks explains. "Not only does the crop make better use of all the nitrogen applied, farmers can also target applications to ensure the crop has access to nitrogen at key times – tuber bulking in potatoes, for example – to help manipulate and optimise quality, yields and marketable grades."

As a testament to Levity's appeal across crops and continents, Dr Marks cites Australian pineapples and Dutch onions as evidence for Lono's abilities. Growing on sandy soils on Queensland's Pacific coast presents a particular environmental challenge: damage to the Great Barrier Reef is exacerbated by high nitrogen levels. A commercial trial of Lono saw the nitrogen application rate plummet, from 400 kg/ha down to just 3 kg/ha.

And in the Netherlands, where farmers are coming under intense political pressure to reduce nitrogen applications – or even to stop farming altogether – Levity's SAN provided the opportunity to slash nitrogen applications in onions, from 150 kg/ha to just 4 kg/ha.

"In both instances, substituting the high applications of conventional nitrogen product with the stabilised amine saw no loss of yield, while the drastic reduction in application rates prevented any kind of pollution," notes Dr Marks.

Levity's intricate understanding of plant physiology and biochemical processes that led to Lono's development have also been applied in pursuit of other key nutrients where inefficiencies are well-documented. With calcium, for example, Levity formulated a synthetic transport stimulant that emulates the essential plant hormone auxin, to ensure sufficient absorption in tissues that can't otherwise absorb it at crucial times – and to help farmers reduce the rate at which conventional applications of calcium are otherwise made.

Inspecting strawberry fruit with a handheld colorimeter during a growing trial.

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Boron is another essential micronutrient that presents a challenge to farmers. That's because there's a fine line between deficiency in the fruit (where it's needed) and excess in the leaves (where it's toxic). Again, Levity's research pursued the development of an 'active' product applied at a low-rate (addressing toxicity and optimising resource-use) using another bespoke transport stimulant.

And it was another transport stimulant that allowed Levity to solve the silicon problem: why do plants readily absorb silicon, only for it to become inert so quickly?

Micronutrients and stress

Abiotic stress may become the biggest 21st century challenge to growing crops, thanks to changing weather patterns.

"Stress affects crops in different ways," notes Dr Marks. "Wheat, for instance, is resilient enough to produce some yield except in extreme drought. But for fruit and vegetables, stress can completely wipe out a crop."

Then there's biotic stress. "Walk past a wild plant and you'll rarely find it riddled with disease. But when crops are pushed to their limit, to produce the yield we need, we create a world in which disease thrives. And that's why we've become so dependent on fungicides."

Dr Marks says Levity's aim is to develop 'anti-stress' products that work in tandem with pesticides and reduce fungicide use.

He cites the troublesome banana disease, black sigatoka. Despite regular fungicide applications, producers must resort to removing leaves to reduce disease. But they must preserve enough leaves to maintain optimal yields.

"Big gains would result from keeping one more leaf, which we can do if we improve the plant's stress resilience. Improved resilience reduces their reliance on fungicides."

This is the thinking behind Indra, Levity's first 'anti-stress' product. Indra is based on an understanding of biochemistry and functions by increasing the plant's production of cell-wall stabilisers. These 'mop up' the oxidative toxins which accumulate during stress periods and harm the plant's ability to fight off disease.

Micronutrients and quality

'Quality' has many aspects, especially for fresh produce. Cosmetic appearance and shelf life are perhaps the most important post-harvest aspects, while in the field it's measured in marketable grades and uniformity of ripening.

"We've proved that appropriate use of nutrients such as calcium and molybdenum can have a major influence on these quality aspects," says Dr Anna Weston, Levity's managing director. "Of course, calcium's well-known for being a 'problem' nutrient, and molybdenum's much the same – deficiencies are short-lived and almost impossible to detect."

Levity is again challenging the orthodoxy here. "Ethylene is the accepted ripening agent, but it's a crude tool. Its mode of action is to remove calcium from fruit cell walls. Yes, it softens the fruit for 'ripeness' but it also leaves their shelf life in tatters."

Dr Weston's research instead focused on abscisic acid (ABA), another plant hormone influencing maturity. It ripens fruit and increases sugar content without removing calcium. However, as its production relies on molybdenum, the plant can sometimes struggle to synthesise enough.

Levity's novel solution this time was a metabolic stimulant. The end result was the development of one of its building block technologies, Blush, to 'turbocharge' crop metabolism.

"The crop responds by making use of what it finds in abundance," explains Dr Weston. "When formulated with molybdenum, we force the plant into using Mo more quickly, producing high levels of ABA."

Dr Weston has commercially trialled Levity's molybdenum-based product Sulis – which also contains boron to help increase sugar production – on apples grown for one of Britain's premium supermarkets. "Typically, apple growers will conduct three picks," Dr Weston explains. "The first pick is the prime crop, the second pick will be juiced, and the third pick is simply to clean the tree. Each pick represents a third of the total crop.

"When Sulis was applied, the first pick proportion increased to 70%, thanks to improvements in colour and brix, and no 'cleaning pick' was required. There's more marketable fruit for the farmer, he's picking earlier so he gets a better price, and he also saves the cost of hiring labour for that third pick."

Another fruit prone to quality issues is the tomato. Highly susceptible to damage during picking, packing and transportation, losses of up to 50 percent are common. Further losses occur at the retailer and after sale, when soft, damaged or rotting fruit is thrown away.

"Calcium's known to improve firmness," says Dr Weston, "but difficulties in its absorption and transport would necessitate a rate of tens of kilos per hectare to generate any measurable effect.

"But when we used our calcium transport stimulant – LoCal – on pre-harvest tomato plants, we found fruits from treated plants were significantly firmer than fruit from either untreated plants, or those from plants treated with calcium alone. They maintained this firmness for as long as 10 weeks post-harvest."

When the tomatoes were subjected to simulated handling damage, those that had received the LoCal treatment maintained their firmness for more than two weeks after the damage was inflicted – exceeding even untreated fruits that had not been damaged.

"This is ground-breaking research," says Dr Weston. "A well-timed product in the field can influence shelf life. We're used to living in a country with reliable electricity for cold storage. What if you live and farm somewhere else? And anyway, what's the carbon footprint for refrigeration and controlled atmosphere storage?

"Here's a crop input – based on a micronutrient – that becomes a substitute for technology and infrastructure."

What's next for Levity?

It's not just quality and stress where micronutrient applications play a role. They can also make food more nutritious. It's the next focus for Levity, says Dr Marks.

"At the moment, we're looking more closely at zinc. It's an important nutrient in the human diet, but zinc deficiencies are common in areas of the world where rice is dominant. That's because the rice husk – usually discarded during processing – is a zinc sink, with little remaining in the grain itself.

"We've a product in development that can address this, but crucially it also raises yield – so there's something in it for the farmer, as well as the consumer. And that's not the only nutritional target we're working on."

Speaking more generally, agriculture is unique, says Dr Marks, and not just because it provides us with food.

"It's the only primary industry that we can manipulate to produce more. When we use the right inputs, we can produce more of a crop than there would have been otherwise. We can apply inputs that help crops grow in areas previously unsuitable.

"That's why making agriculture more sustainable is so important. It's a source of wealth generation both now and in the future. And while Levity's one of the companies that has some of the answers, we don't have them all – so we all need to do this together." ■

Acknowledgement

Interview and reporting by Adrian Bell of Agromavens.

NEW R&D CENTRE FOR THE UK

Crowhall Farm, five miles outside Preston, Lancashire, is the site of Levity Crop Science's new research and development centre.

The site comprises more than 3,000 sq ft of office space and nearly the same again for greenhouses and laboratory facilities. The first phase of building works was completed in early 2024 following construction approval in 2021.

"Moving into our own, purpose-built headquarters is a milestone for Levity," says Dr Marks. "With the expansion in greenhouse facilities, we can massively expand our development programme. When fully equipped, our labs will allow advanced diagnostics and analysis of plant tissues and compounds in-house."

The new HQ also has the physical space for an expansion in staff needed for the company's latest development – the establishment of a dedicated company to service the growing demand for Levity's products in the Netherlands and other northern European markets.

"Our business has always been export-driven: more than 70 percent of our revenue comes from overseas markets. Interest from the Netherlands has been especially strong for our nitrogen reduction products, because of the intense agri-political situation." ■

PHOTO: LEVITY

Dr David Marks monitors the progress of a pot trial at the expanded greenhouse facilities at Levity Crop Science's Crowhall Farm R&D centre, Lancashire, UK.

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U.S. Borax operates California's largest open pit mine in Boron, California – one of the richest borate deposits on the planet.

PHOTO: U.S. BORAX.

Boron: what do we really know?

Today's agronomists and farmers recognise the importance of boron in agriculture. But what do we know about why plants need boron and how boron deficiency affects crops? **Fabiano Silvestrin**, Principal Advisor, Global Market Development, Agriculture, at U.S. Borax has some answers.

Introduction

Boron was first recognised as an essential plant nutrient by the pioneering botanist Dr Katherine Warington of the Rothamsted Experimental Station in 1923. We therefore have 100 years of research and field trials showing the importance of boron in agriculture. This includes boron's significant role in:

- The strength of plant cell walls
- Membrane function and cell division
- Stimulation/inhibition of metabolic pathways
- Development of flowers and fruits
- Both new and reproductive growth.

Adequate boron is a crucial factor in high crop yields and quality. Depending on the crop, boron deficiency can cause:

- Misshapen, thick, small, brittle leaves – typically affecting the youngest leaves first
- Short, shrunken stems and stunted or reduced growth points
- Cracked or watery tissue or fruit
- Malformed or irregular fruit or kernels.

In addition, boron also affects the availability of other nutrients for plant uptake, such as potassium, nitrogen and calcium.

So, what do you really know about this essential micronutrient?

Types of borate and their solubility

While it is clear that crops need boron, there is still debate about what sources of boron function best in agriculture. There are basically two classes of borates:

- **Refined borates** are those where the original source material has gone through a refinement process. Examples include boric acid, disodium octaborate tetrahydrate, borax decahydrate, borax pentahydrate, and anhydrous borax.
- **Mineral or unrefined borates** which have had no refinement process. Examples include hydroboracite, colemanite, and ulexite.

Borate solubility by type

How available boron is to the plant is partly determined by borate solubility. The solubility of borate products, in turn, depends on the source material and the interaction of the boron with sodium (Na), calcium (Ca), and magnesium (Mg). Borates containing more Mg and Ca are generally less soluble.

Most of the boron fertilizers used in agriculture are derived from the following borate ores, in order of increasing solubility:

- **Hydroboracite** ($CaMgB_6O_{11}6H_2O$), calcium and magnesium borate, is practically insoluble in water (solubility of 0.8 g/l at 20° C)
- **Colemanite** ($Ca_2B_6O_{11}5H_2O$), calcium borate, has low water solubility (4.7 g/l at 20° C)
- **Ulexite** ($NaCaB_5O_98H_2O$), calcium and sodium borate, is partially soluble in water (10.9 g/l at 20° C)
- **Kernite** ($Na_2B_4O_74H_2O$), sodium borate, is water soluble (19.0 g/l at 20° C)
- **Tincal** ($Na_2B_4O_710H_2O$), sodium borate, also known as borax, is water soluble (26.5 g/l at 20° C)

Refined borates such as boric acid (H_3BO_3) and disodium octaborate tetrahydrate ($Na_2B_8O_{13}·4H_2O$) are highly water soluble compared to unrefined types. Their water solubility ranges between 47.2 g/l and 97.0 g/l at 20° C, respectively. Because of this, refined borates are widely used to produce liquid fertilizers for foliar fertilization and fertigation.

Why solubility matters

Plant roots take up boron from the soil solution as uncharged boric acid (H_3BO_3). Boric acid is a small molecule and is the only crop nutrient which isn't absorbed from soils as an ion by plant roots. Boric acid is transported through the soil to plant roots via mass flow – meaning that without water H_3BO_3 cannot move through the soil.

Once applied to the soil, borates undergo chemical transformation into H_3BO_3. Regardless of the type of borate applied – ulexite, colemanite, or borax pentahydrate – plant roots will always uptake boron in the form of H_3BO_3 by mass flow. The H_3BO_3, once absorbed, is translocated to the whole plant via the xylem.

It might be assumed that directly applying boric acid to the soil offers the best way of fixing boron deficiency. But boric acid also has a greater potential to cause plant toxicity compared to other boron sources. That's because boric acid is readily available for uptake via roots – therefore plants can more quickly absorb boron.

When partially soluble ulexite is applied to the soil, only 35-46 percent of the boron present in this mineral will be released within 40 weeks, due to the strong bond between boron and calcium.

In contrast, when a refined sodium tetraborate pentahydrate product (such as Granubor® from U.S. Borax) is applied to the soil, almost 100 percent of boron present in this fertilizer will be gradually released in the soil within 40 weeks.

Summing up, if the applied borate product is only partially soluble in the soil solution, growers will be leaving a valuable fertilizer in the field – one that is unavailable to crops.

Take a look at the soil

Once the importance of boron solubility to crops is properly understood, growers then need to look at the make-up of the soils in their fields to ensure they have proper levels of available boron throughout the growing season. The following soil characteristics plays a major role in determining the plant availability of boron:

REFINED BORATES FROM U.S. BORAX

U.S. Borax agriculture products are fully refined to remove impurities and maximize potential plant uptake. This process results in a pure, natural product designed to optimise crop nutrition throughout the growing season.

The U.S. Borax refining process involves the following important steps:

- We mine high-quality sodium borate ore that is naturally low in calcium and other contaminants
- We dissolve the ore in water
- We settle the dissolved borate liquor to remove impurities
- We cool the liquor and then further wash and filter the resulting crystal slurry
- We dry the refined slurry to produce dry borate crystals
- We check our products for purity, solubility, consistency, and optimal granulation
- We constantly conduct and review field tests and other research to improve our products and services.

Many U.S. Borax products are OMRI® listed and approved for organic farming.

Questions to ask when buying boron

The best way to measure the value of a boron supplement is to look beyond the initial price point. Low-quality, unrefined products can quickly eat up any cost savings by being ineffective – and even risk creating new problems. When evaluating products, U.S. Borax therefore recommends that growers ask about the following before making their buying decisions:

- How much useable, water-soluble boron does the product contain?
- Has the product been refined to remove contaminants such as arsenic, lithium, and aluminium?
- Does the product support multiple types of application?
- What is the product's bulk density?
- Can the product make boron available throughout the growing season?
- Is the product durable (e.g., crush resistant during transport)?
- What is the typical particle size (for granulated boron products)?
- What is the price per useable measure of boron?

Types of borate ore

Hydroboracite

PHOTO: ROB LAVINSKY, IROCKS.COM

Colemanite

PHOTO: U.S. BORAX

Ulexite

PHOTO: U.S. BORAX

Kernite

PHOTO: U.S. BORAX

Tincal

PHOTO: U.S. BORAX

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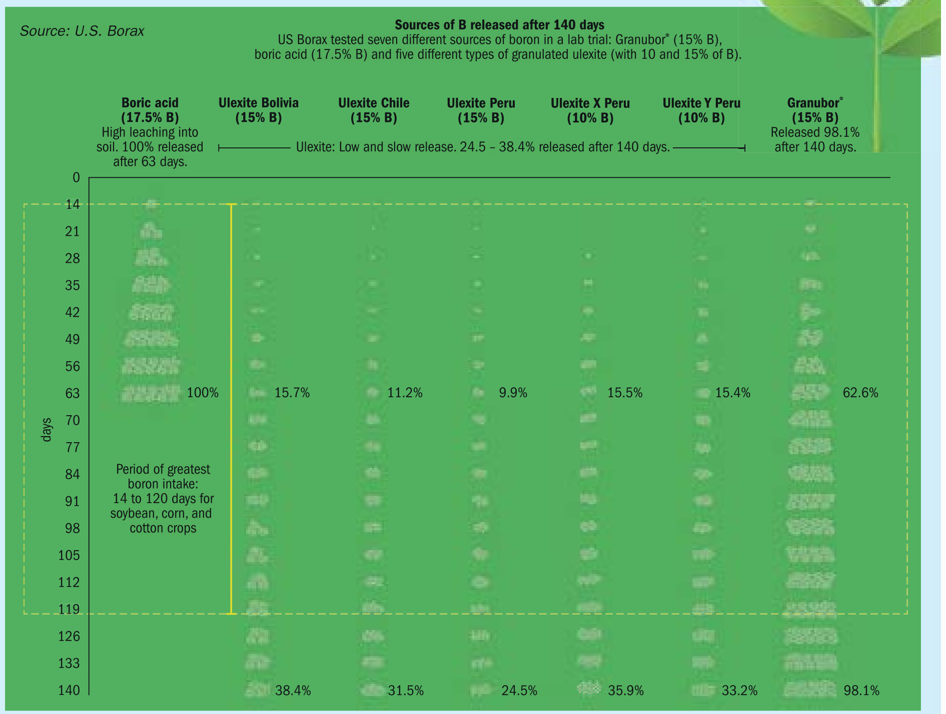
Fig 1: **Lab trial showing the release rates of seven different boron sources after 140 days**



- **Texture:** Well-drained, sandy soils in high rainfall regions are most likely to be boron-deficient because of their greater leaching potential.
- **Organic matter content:** Most of available boron in soils is found in organic matter. This is because boron forms a complex with organic matter – removing it from the soil solution when levels are high due to boron fertilization.
- **pH:** Boron availability to plants generally decreases with increasing soil pH, especially above 6.5. Acidic soils (pH less than 5.0) also tend to be low in available boron.

Soil testing is a very good predictor of boron levels. Test methods used today can accurately reveal the amount of plant-available boron within soils at an average precision of +/- 0.1 ppm. U.S. Borax therefore recommends that growers work with local agronomists to test their soils, before and during the growing season, as the best way of determining their specific boron needs.

Boron application

Boron can be applied: Directly to soil, through fertigation, or as a foliar spray. The timing and frequency of application are important considerations – as is the selection of the most suitable boron source.

Timing. Boron applications can be carried out at planting and in coverage, depending on the crop. The timing of applications must be adjusted to meet the boron needs of crops during the vegetative and reproductive phases – the latter being the period of highest crop demand.

Frequency. Growers should pay special attention to boron applications in soils with a sandy texture (i.e., less than 15 percent clay) as their low retention may reduce levels of this micronutrient in the soil solution. Split doses of boron are therefore recommended in sandy soils to maximise fertilization efficiency and plant uptake. More generally, application frequency will also depend on the crop fertilization programme. Soil applications can be used to complement foliar applications, especially in plant growth stages associated with strong boron demand, such as flowering and fruit formation.

Selecting the right source. For effective soil fertilization, growers should select efficient boron sources capable of releasing 100 percent of their content and making boron available when plants need this nutrient most. Not all boron sources are equal. Indeed, U.S. Borax lab trials shows that different boron sources of the same particle size release boron into solution at different rates during the growing season (Figure 1). ■

Micronutrients – their unquestionable crop benefits

Dr **Setareh Jamali Jaghdani** and professor **Jóska Gerendás** of K+S Group outline how micronutrient management, by positively influencing plant physiology and development, helps maximise crop yields.

Introduction

The need to secure high quality food in ever larger amounts has been an almost permanent challenge for global agriculture. Consequently, numerous studies since the 19th century have focussed on delivering greater crop yields by optimising plant nutrition[1].

The increased application of commercial fertilizers since the late 1950s[2] has undoubtedly led to higher crop production. However, meeting growing food demand from an increasing world population still poses problems, especially with expectations that the world's population will reach 9.2 billion by 2050[3]. To feed this rising population, there is a consensus that integrated water, soil, and nutrient management is necessary to ensure sustainable crop production[4].

The 14 mineral nutrient elements which are vital for plant growth are divided into two groups: macro (major) nutrients and micronutrients[5]. Major nutrients are required in large quantities by plants (> 1 ‰ dry matter, DM) as they are 'building block' constituents of the macromolecules which form cell structures. Micronutrients, in contrast, are needed in smaller quantities (< 0.1 ‰ DM) and mostly activate plant enzymes. Still, this much lower plant requirement for micronutrients does not mean that they are less important. Indeed, crops cannot function properly and complete their growing cycle without them.

Micronutrients include the metal cations iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), and nickel (Ni) and the anion-

Table 1: **Adequate micronutrient removal rates (g/ha) for the harvested produce of major crops, at a given yield level**

Crop at yield (t/ha)	Boron	Manganese	Zinc	Copper
Cereals, grains (8 t/ha)	30	450	150	35
Sugar beet (600 t/ha)	300	350	175	55
Sugar cane, canes (100 t /ha)	150	1000	370	200
Rapeseed, seeds (3.5 t/ha)	375	1900	550	45
Maize, whole plant (450 t/ha)	190	3000	345	150
Maize, grains (10 t/ha)	120	530	210	60
Potato, tubers (400 t/ha)	110	55	120	60
Soybean, seeds (4 t/ha)	50	40	70	20

Source: K+S Group

Fig 1: **Mn deficiency in (clockwise from top left) barley, potato, apple and tomato**

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forming nutrients boron (B), chlorine (Cl), and molybdenum (Mo), listed in decreasing order of plant demand (Table 1). From a global perspective, the micronutrients Mn, Zn, and B are most relevant and are therefore the main focus of this article.

Manganese, enzymes, and photosynthesis

Manganese (Mn) has several vital roles within plants. When deficient, interveinal necrosis (Figure 1), leaf epinasty, inhibition in root lignification, and reactive oxygen species (ROS) formation can be observed. The main impacts of Mn deficiency in plants are summarised in Figure 2.

One of the main functions of Mn is to act as a metalloenzymes cofactor. Up to 101 Mn-containing enzymes have been identified in plants. Some 37 of these enzymes exclusively contain Mn, while the remaining can exchange Mn with other divalent metals[6]. One noteworthy Mn-dependent enzyme is Mn-superoxide dismutase (Mn-SOD) located in the mitochondria and peroxisomes of plants. This catalyses the dismutation of superoxide radicals (O_2-) into oxygen (O_2) and hydrogen peroxide (H_2O_2) when water is present[7]. Mn plays a major and valuable role by catalysing ROS (in this case, O_2-) as these are toxic and can cause cell death.

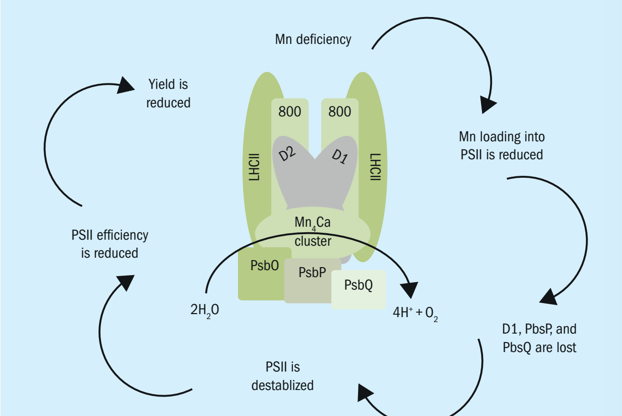
Zinc, oxidative stress, and membrane integrity

Zinc (Zn) has numerous roles within the biochemical and biological processes in plants. Growth is inhibited when plants are zinc deficient due to effects on specific hormones. Interveinal necrosis and chlorosis, and light-induced chlorosis and necrosis are also common consequences of Zn deficiency (Figure 3).

A zinc-containing enzyme (Cu/Zn-SOD) is involved in the scavenging of ROS. Consequently, higher concentrations of toxic ROS can accumulate in Zn-deficient plants exposed to high light intensity. Moreover, the activity of catalase (another ROS scavenging enzyme) is reduced when zinc is deficient, leading to the accumulation of damaging H_2O_2 (Figure 4).

Zinc is also required for the structural and functional integrity of plant biomembranes. Zinc protects lipids and proteins within membranes against oxidative damage from ROS, as it binds to the sulfhydryl and phospholipid groups of the membrane constituents, or forms

Fig 2: Mn loading into photosystem II (PSII), the vital place for plant photosynthesis, is reduced when Mn is deficient. This causes the loss of D1, PbsP, and PbsQ proteins, which have specific roles in photosynthetic electron transfer, and leads to the destabilization of PSII. This reduces overall photosynthetic efficiency and, consequently, results in an unavoidable loss of biomass and yield.



Source: K+S Group, redrawn from Schmidt et al. (2019).

tetrahedral complexes with cysteine residues from a polypeptide chain. The permeability of these membranes also increases due to higher rates of O_2- when Zn is deficient. This can lead to a leakage of low-molecular-weight solutes via roots[8]. An optimal Zn supply is therefore required to lower membrane permeability and avoid these losses from cells.

Fig 3: Visual Zn deficiency symptoms in maize

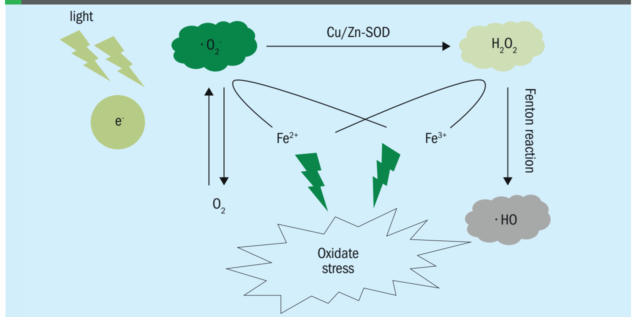
Boron – essential for cell wall structure and function

Boron (B) was first identified as an essential nutrient for plant growth in 1923 – yet its precise role in plant metabolism is still being investigated over a century later. While the role of boron in carbohydrate metabolism and sugar transport, in cell wall synthesis and structure, in lignification, and several other processes has been proposed, for example, only its role in cell walls has been demonstrated definitively. Interestingly, and unlike all the cationic micronutrients (Fe, Mn, Zn, Cu, Ni), boron is not an enzyme constituent.

Soil boron is available for plant uptake as boric acid. This weak acid (std pK_a 9.25) is predominantly present as free acid [H_3BO_3 or $B(OH)_3$] in soils under neutral and acid conditions and as the borate anion [$B(OH)_4$-] in alkaline soils. Uptake is therefore strongly pH dependent. Boric acid, as an uncharged molecule, easily permeates root membranes in acidic conditions but its movement is restricted in alkaline soils. When boron concentrations in the soil solution are below sufficiency levels (<1 µM), plants activate specific transporters to regulate its uptake to meet their growth requirements.

MICRONUTRIENTS

Fig 4: The activity of the enzymes Cu/Zn-SOD and catalase is reduced in zinc-deficient plants. The combination of Zn deficiency and higher light intensity triggers the production of toxic reactive oxygen species (ROS).



Source: K+S Group, redrawn from Lilay et al. (2024)

Fig 5: Boron deficiency symptoms in potato (left) and as shown by 'crinkle leaf' in oil palm (right) are related to boron's function in cell wall growth.

Boron transport within plants is a complex process that varies significantly between species, as it is influenced by the type of carbohydrates produced and transported within individual plants. In plants that generate and transport polyols like sorbitol or mannitol (e.g., many members of the rose family, including pome and stone fruits), boron can move freely in both the xylem and phloem, mirroring the behaviour of phloem-mobile elements such as potassium and magnesium.

In contrast, boron is not phloem-mobile in all the major field crops which use sucrose as their main carbohydrate. Movement is instead restricted to the xylem and driven by transpiration. Weakly transpiring plant parts and organs – like the shoot tip, buds, flowers, and fruits – are therefore prone to boron deficiency. Consequently, boron applied through the foliar fertilization of field crops, although immediately available for uptake, also stays where it is applied and does not translocate from mature leaves to the sites of new growth. Foliar applications of boron will therefore only have a limited effect in field crops unless repeatedly applied.

Boron's role in plant nutrition – despite its importance – is still the least understood of all the nutrients. While its significance for cell wall integrity is well-established, boron does not appear to be involved directly in the synthesis of the cell wall itself.

The association of boron with pectins (heterogeneous polygalacturonates) through ester bonds is a key factor in its function within cell walls. The pectin matrix between the walls of adjacent cells is vital for structural tissue integrity. Its presence enhances the mechanical properties of the cell wall, such as stiffness and low porosity, which are essential for maintaining plant cell shape and vigour.

Monocots, like cereals and grasses, generally have a much lower boron requirement during exponential growth (typically 5-10 mg/kg DM) than dicotyledonous plants (typically 30 mg/kg DM), which include a wide variety of broad-leaved crops. This is because the cell walls of cereals contain much lower amounts of pectins (particularly rhamnogalacturonans II) that bind with boron and form stable structures.

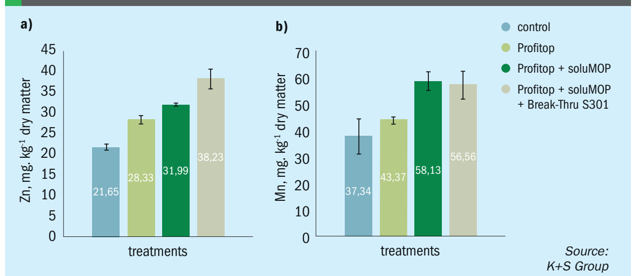
Understanding these subtle intricacies and the different boron requirements of crops (Table 1) is vital for optimal plant nutrition and growth. The growth of pollen tubes is a particular developmental process that is highly sensitive to insufficient boron supply – this having serious consequences for pollination, fruit set, yield, and quality of all crops where generative organs are harvested.

While its role in some metabolic processes is still being explored, boron deficiency is known to significantly disrupt the cell walls of plants (Figure 5), leading to a series of metabolic challenges. Boron deficiency can result in unusually thick and brittle cell walls, for example, that lack flexibility and strength. These defects can impede normal cell expansion, affecting tissue integrity and overall plant development. They typically interfere with the development of expanding tissues – like stems, bulbs and fruits – and results in cracks that provide entry points for pathogens and pests. Similarly, root elongation is also severely impaired by boron deficiency.

K+S trials and products

The following field trial results demonstrate the practical benefits of applying micronutrient enriched products to crops:

Fig 6: Oat plants treated with 10 kg/ha of epsoPROFITOP®, 1.5 kg/ha of soluMOP®, and the adjuvant Break-Thru S301 (0.15 l/ha) show a pronounced increase in Zn (a) and Mn (b) uptake (means ± SE, n=4).



Source: K+S Group

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The micronutrient enriched fertilizer epsoPROFITOP® (12% MgO, 14% S, 5% Mn, 2% Zn and 1% Cu) was applied to an oat crop at 10 kg/ha. In an additional treatment, soluMOP® (60% K_2O) was applied at a rate of of 1.5 kg/ha. Micronutrient uptake and translocation within the plants was then investigated by sampling and testing newly expanded leaves two weeks after these treatments. The results showed a pronounced increase in leaf zinc and manganese content (Figure 6).

Other field trials examined the effects of boron-containing fertilizers on the yield and boron status of oilseed rape (OSR) and sugar beet – two boron-loving crops (Table 1). As mentioned previously, the translocation of boron within arable crops after foliar application is limited unless applied several times.

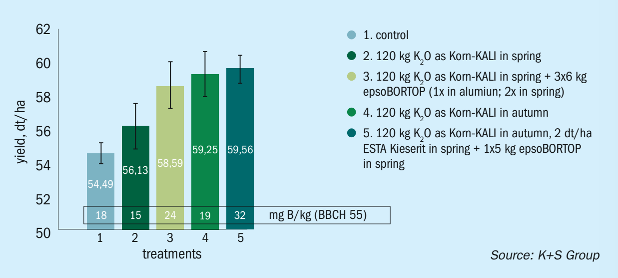
The OSR trial was conducted on a loamy sand with optimal phosphorus status, very high magnesium status, and very low boron levels. All plots received:

- 196 kg/ha of nitrogen from urea, diammonium phosphate (DAP) and calcium ammonium nitrate (CAN)
- 45 kg/ha sulphur as ammonium sulphate nitrate (ASN)
- Potassium at a rate of 120 kg K_2O/ha apart from the control
- Boron as either foliar-applied epsoBORTOP® spray or soil-applied Korn-KALI®+B.

Results demonstrated that foliar fertilization using epsoBORTOP® effectively increased both OSR yield and the crop's boron status, with soil-applied boron using Korn-KALI®+B resulting in an even better yield response. Combining both these foliar- and soil-applied approaches proved most effective (Figure 7).

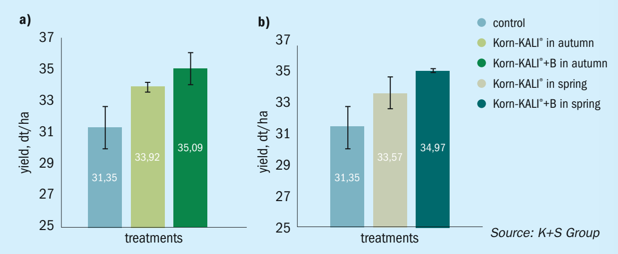
Positive yield responses were also observed in other trials on OSR and sugar beet, irrespective of whether boron was supplied in autumn or spring (Figures 8 and 9).

Fig 7: **Yield and boron status of oilseed rape (OSR) in response to soil and foliar boron fertilization (means ± SE, n=3-4).**



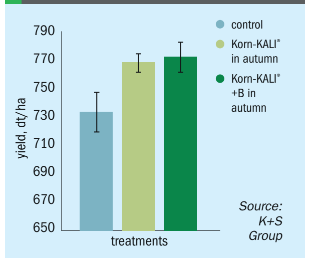
Source: K+S Group

Fig 8: **Yield response of oilseed rape (OSR) to applications (400 kg/ha) of standard Korn-KALI® vs boron-enriched Korn-KALI®+B: (a) autumn application at BBCH 17 (means ± SE, n=4); (b) spring application at BBCH 20 (means ± SE, n=4).**



Source: K+S Group

Fig 9: **Yield response of sugar beet to boron to the autumn application (400 kg/ha) of standard Korn-KALI® vs boron-enriched Korn-KALI®+B at BBCH 0 (means ± SE, n=4).**



Source: K+S Group

Micronutrient-enriched fertilizers from K+S Group

When crops have a deficiency, foliar fertilization can help provide the required nutrients to crops efficiently and rapidly. The epso family of products from K+S Group (Table 2) are water-soluble, highly efficient, and contain micronutrients at higher concentrations than typically seen in soil fertilizers.

As well as micronutrients, epso fertilizers also contain magnesium and sulphur. Magnesium is vital for chlorophyll biosynthesis, photosynthesis, translocation of photoassimilates, and root growth. Sulphur, meanwhile, is necessary for nitrogen use efficiency and protein synthesis.

K+S Group offers the following four micronutrient foliar fertilizers:

- **epsoPROFITOP®** is suitable for crops such as potato, spring and winter cereals, and corn. 1-3 applications (5 kg/ha) at 2.5 percent concentration are recommended for optimum yields. Recommendations do, however, vary in different regions according to the nutrient content of the soil and crop yield expectations.
- **epsoMICROTOP®** dissolves well in water without leaving residues and can be easily mixed with plant protection products. Recommendations are: 3-4 application at a rate of 5-15 kg/ha for oilseed rape; 2-3 applications at 5-15 kg/ha for fruit crops; four application at 5-10 kg/ha for potato.
- **epsoCOMBITOP®** is suitable for various crops. Two applications of 10 kg/ha are recommended for optimum maize yields, whereas 2-3 applications of 5-10 kg/ha are recommended to efficiently deliver the nutrient requirements of cereals and vegetables.
- **epsoBORTOP®** is recommended for crops with medium to high boron demand. It can be mixed with plant protection products. Reducing the pH value of the spray tank is also welcomed. 2-3 applications at a rate of 5-7.5 kg/ha are recommended for optimal oilseed rape and sunflower growth. In sugar beet, 2-3 applications at 5-10 kg/ha are recommended.

Additionally, K+S offers Korn-KALI®+B as a multi-nutrient, granular fertilizer containing K, Mg, S, Na and B. Its application, which is usually governed by the potassium requirement of the crop, also supplies a range of the other valuable nutrients in water-soluble, plant-available form. It is suitable for many chloride-tolerant crops. Korn-KALI®+B does not affect soil pH and its efficacy is not pH-dependent either. ■

Table 2: **K+S Group offers the following fertilizers containing micronutrients***

Product/ Element	epsoPROFITOP	epsoMICROTOP	epsoCOMBITOP	epsoBORTOP	KornKALI
MgO	12	15	13.5	12.6	6
K_2O					40
Na_2O					4.5
S	14	12.4	13.8	10	5.2
Mn	5	1	4		
Zn	2		1		
Cu	1				
B		0.9		4	0.25

Source: K+S Group

*All nutrients shown as a percentage

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IFA 2024 Annual Conference

Drone display against Singapore's iconic skyline. Conference welcome reception and dinner at the Marina bay Cruise Centre.

PHOTO: IFA

Some 1,265 delegates from 552 companies and 72 countries gathered in Singapore for the 9lst International Fertilizer Association (IFA) Annual Conference, 20-22 May 2024. **Claire Newell**, IFA's Director of Communications & Marketing, reports on the main highlights of this three-day flagship event.

Singapore was the host city for this year's International Fertilizer Association (IFA) Annual Conference, which brought together industry leaders, experts, and stakeholders under the theme of 'Nourishing the Planet, Powering the Future'.

The three-day event explored the fertilizer industry's pivotal role in addressing food security while transitioning to a low-carbon economy, and featured market analysis as well as topical presentations on issues such as the role of artificial intelligence (AI) and gender diversity in the fertilizer industry.

With the generous support of ten member company sponsors and the Singapore Board of Tourism, the 2024 Conference was an enormous success, featuring participation from 1265 delegates, who between them represented 552 companies from 72 countries across the world.

Day one highlights – a global, regional and industry overview

The Annual Conference opened on Monday 20 May with a two-part keynote session, which set the scene with a high level overview of international and regional trends impacting the fertilizer industry.

First, **Caroline Yap**, Managing Director of Global AI Business and Applied Engineering at Google provided an exciting perspective on the potential of AI in improving global food security and combatting climate change, while **Carsten Müller**, Regional Industry Director of Manufacturing, Agribusiness and Services Asia at the International Finance Corporation (IFC) shared a regional manufacturing outlook for Asia, which is attracting increasing foreign investment in the high-tech, food/beverages, and chemical industries.

Dr. Kazuki Saito from the International Rice Research Institute (IRRI) discussed the concerns and potential solutions for the future of sustainable rice farming in the context of global economic shifts, urbanization, climate change and greenhouse gas (GHG) emissions, water scarcity and soil health, against the backdrop of increasing rice consumption. A CEO panel convened by **Alzbeta Klein** subsequently explored how the industry must continue to navigate geopolitical tensions, climate change, a dynamic stakeholder landscape, and the adoption of AI in order to meet both present and future challenges.

In the second part of Monday's keynote session, 'Navigating the choppy seas', **Rahul Kapoor**, VP and Global Head of Shipping Analytics and Research at S&P Global discussed the varied challenges facing the global shipping industry. The war in Ukraine, high inflation, interest rates, and conflict in the Middle East continue to impact shipping routes and markets, with ships being diverted via the Cape of Good Hope, which is leading to longer transit times. The higher costs caused by these disruptions are set to persist during the remainder of 2024.

The second expert panel of the morning featured speakers from across the value chain – namely **Hans-Christian Olesen**, Chief Executive of Ultrabulk, **Alexander Chumakov**, Chief Operating Officer (Fertilizers) at Ameropa, **Jaine Chisholm Caunt** OBE, Director General of the Grain and Feed Trade Association, **Edward Weiner**, Chief Executive of Trammo and **Murali Srinivasan**, SVP & Global Commercial Head, Clean Ammonia at Yara International – who agreed that in the future, more disruption is likely both in terms of geopolitical turbulence and the energy transition. By 2030-2040, ammonia, methanol, nuclear and other low-carbon fuels are likely to be widely adopted for shipping. Digitalization, e-documentation, and clear regulations for the shipping industry's decarbonization were also confirmed by the panel as being critical issues in the near term.

Day one continued with IFA's Market Outlook session, a perennial highlight of the IFA Annual Conference program. **Laura Cross**, IFA's Director of Market Intelligence and **Armelle Gruère**, Demand Program Manager within IFA's Market Intelligence Service, presented the latest five-year outlook for fertilizer supply and demand. They highlighted the global south's leading role in fertilizer use in the medium-term and the changing capacity investment cycle, which has entered a new phase driven by the need for decarbonization and the shifting strategies of governments and companies.

Day two – exploring gender diversity and AI

Along with IFA's statutory meetings, the second day of the Conference featured further insightful sessions in plenary.

The Gender Diversity session explored the industry's journey towards a more inclusive and diverse workforce, five years on from the very first such session at an IFA Annual Conference. In an engaging keynote speech, **Fernanda Lopes Larsen**, Executive Vice President for Africa & Asia at Yara International, shared her perspectives on the three I's of diversity – namely intention, involvement, and inclusion.

An expert panel moderated by **Alzbeta Klein** and featuring **Seelan Gobalsamy**, CEO of Omnia, **Jana Plananska**, Director of EU and Government Affairs at Norge Mining, **Priyanka Jain**, General Manager at Valency International and **Simon Thomas**, Vice President Projects - Potash at BHP then shared insights on how best to build on the progress that has already been achieved.

Moving on to inclusion outside the factory gates, delegates heard from two further speakers who emphasized the importance of diverse hiring, inclusive workplaces, and establishing measurable representation goals. **Fawad Mukhtar**, CEO of Fatima Fertilizer, showcased a vital program run by his company that supports women farmers, and provided details of the company's mission to highlight the many contributions women make in Pakistani society, particularly within agriculture.

Hiti Taluja, Chief Commercial Officer at Agriflex presented the company's deliberate approach to community engagement and how this additionally supports the inclusion of women within the company.

Tuesday's final session focused once more on AI, with an expert line up of speakers exploring the potential of AI adoption in the factory and on the

PHOTO: IFA

Expert panel discuss progress on gender diversity with (left to right): Alzbeta Klein, IFA CEO and DG, Jana Plananska, Director of EU and Government Affairs at Norge Mining, Priyanka Jain, General Manager at Valency International, Seelan Gobalsamy, CEO of Omnia, Simon Thomas, VP Projects – Potash at BHP.

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farm, and discussing how different AI technologies can be used to optimize fertilizer production operations, increase yields, reduce the negative environmental impacts of fertilizer, and drive industry innovation. IFA's Sustainability Director and co-chair of the Association's nascent AI Working Group, **Volker Andresen**, moderated the discussion.

Spencer Low, Head of Regional Sustainability (APAC) at Google provided a 'view from the top' of AI applications in data interrogation, conversational interactions, and information synthesis. Case studies from **Alec Asbridge**, Senior Director at EY Parthenon and **Roslyn Chua**, Head of Digital Farming Asia Pacific at Bayer provided an insightful 'view from the outside' of the industry, while **Majda Moumni**, General Director of OCP Solutions and **Lior Frimet**, Head of Artificial Intelligence at ICL completed the presentations with an 'inside' / industry perspective.

The session provided some fascinating insights into AI's real-world application and potential for use in precision agriculture, supply chain optimization, worker safety, sustainability monitoring, and improving farmer communications. During an engaging fireside chat-style discussion with audience Q&A, topics such as the need for ethical AI governance and human oversight, consideration of potential data biases, and the role of public-private collaboration for responsible AI adoption were also covered.

PHOTO: IFA

CRU Group analysts Lewis Walters and Carrie Whymark pause momentarily between back-to-back client meetings.

Day three – IFA AGM and Green Leaf Awards

As is customary, the final day of the IFA Annual Conference featured the Association's Annual General Meeting (AGM), during which the activities of the Association over the past six months were shared with members, and Association business enacted. This year, the AGM additionally boasted the presentation of the biennial IFA Green Leaf Awards for excellence in safety, health, and the environment (SHE) to two deserving member companies.

In the phosphate/potash producer category, **IMACID** (a joint venture of OCP Group, CFCL Group, and TATA Chemicals) in Morocco was recognized for its proactive safety culture, embracing the Bird pyramid approach, and integrated ISO certifications. In the nitrogen producer category, **Engro Fertilizers Limited**, Manufacturing Division in Pakistan, was honored for its comprehensive SHE management approach, including the innovative ECO-GREEN project aimed at enhancing plant energy efficiency and reducing emissions.

The runners-up, **Pakphos Maroc Phosphore (PMP)**, a joint venture of OCP Group and Fauji Group, and **Fauji Fertilizer Company Limited**, Goth Macchi, Pakistan, were commended for their exceptional SHE initiatives, such as PMP's digitalization through Operational Safety Management Systems platform and Fauji Fertilizer Company's environmental initiatives like NH3 and H2 recovery, N2 plant replacement, and the installation of solar power. IFA commends each of the winners and runners up for their diligent commitment to excellence in SHE practices within the fertilizer industry.

As the Conference drew to a close, the General Assembly of the membership elected seven new representatives to its Board of Directors:

- **Bruce Bodine**, President and CEO of Mosaic
- **Soufiyane El Kassi**, Chief Growth Officer of OCP Nutricrops
- **Xiaofeng Hou**, President, Chief Executive Officer, and Executive Director of China BlueChemical
- **Dmitry Konyaev**, General Director of Uralchem, JSC
- **Jahangir Piracha**, Chief Executive Officer of Fauji Fertilizer Company Ltd
- **Edward Weiner**, President & Chief Executive Officer of Trammo, Inc.
- **Kelvin Wickham**, Chief Executive Officer of Ballance Agri-Nutrients

Additionally, IFA welcomed 34 new members to the Association – five Ordinary Members, 24 Associate Members, two Affiliate Members and three Correspondent Members.

After three packed days of business, information-sharing, exhibitions and networking with peers across the industry, the Conference concluded. IFA would like to once again thank everyone who participated, from sponsors to speakers, delegates and exhibitors.

As the fertilizer industry continues to play a crucial role in nourishing the planet and powering the future, it is our belief at IFA that events such as the Annual Conference foster vital opportunities for collaboration, knowledge-sharing, and the adoption of best practices, all in support our mission of helping to feed the world sustainably. ■

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What's new in fertilizer products

We highlight recent innovations, including fertilizers recovered from industrial residues, novel controlled-release coatings, and products that incorporate biological components designed to benefit both crop nutrition and soil heath.

CINIS

'Upcycled' SOP from Cinis Fertilizer

Cinis Fertilizer started production at its inaugural 100,000 t/a capacity potassium sulphate (SOP) plant at Örnsköldsvik, Köpmanholmen, Sweden, on 4th June. The plant will also produce 65,000 t/a of sodium chloride as a co-product. The plant has taken around 15 months to construct following ground breaking at the site in February 2023.

PHOTO: CINIS

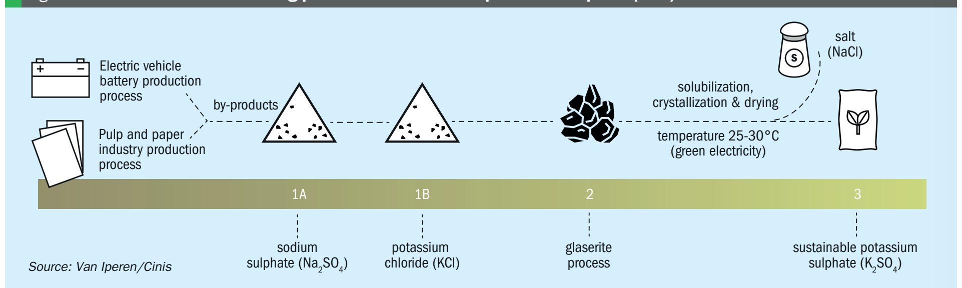
Cinis Fertilizer inaugurated its first SOP production plant in Sweden in early June. The plant upcycles industrial residues.

This Örnsköldsvik plant is powered by renewable energy and upcycles industrial residues – including sodium sulphate (Na_2SO_4) from electric car battery manufacturing and ashes from pulp mills – to produce SOP using patented technology (Figure 1). This first-of-its-kind production method uses half as much energy as conventional SOP production, according to Cinis.

The company quotes an energy consumption of 50,000 MWh for its production process versus 100,000 MWh for conventional manufacture, based on a 100,000 tonnes of SOP production. The result, says Cinis, is a fertilizer with a low carbon footprint making a "unique and circular contribution" to sustainable agriculture.

The SOP obtained at Örnsköldsvik will be sold and marketed by Van Iperen International as GreenSwitch Potassium Sulphate, a pure and fully water-soluble SOP product, with significantly reduced CO_2 emissions, that is suitable for foliar and fertigation applications.

Fig 1: **Cinis Fertilizer's manufacturing process for GreenSwitch potassium sulphate (SOP)**



"Cinis Fertilizer addresses a critical challenge for mankind – how we in a sustainable way are able to continue to supply enough food for a growing population. Mineral fertilizers have – and continue to be – crucial for the world's food production. As an agronomist, I am extremely proud to be part of the development towards high-quality mineral fertilizers with a low climate footprint. Van Iperen is ready to distribute potassium sulphate from Cinis Fertilizer under our 'GreenSwitch' concept," commented Erik van den Bergh, Managing Director of Van Iperen International.

"Thanks to everyone who made it possible for us to inaugurate Cinis Fertilizer's first production facility today. I am proud of what we have achieved, and I am grateful for the support I have received since the start of the company. Today we have reached an important milestone with the production of potassium sulphate and sodium chloride. We have achieved this in record time," said Jakob Liedberg, founder and CEO of Cinis Fertilizer, at the inauguration ceremony in June.

Cinis has plans to build similar SOP production plants in Hopkinsville, Kentucky in the US (300,000 t/a capacity) and Skellefteå, Sweden (200,000 t/a capacity), with first production scheduled for late 2025 and late 2026, respectively.

Cinis Fertilizer uses the Glaserite process to manufacture SOP (Figure 1). This should have a low technical risk – as a tried and tested method of producing SOP that dates from the 1950s. The two input materials for the process are sodium sulphate (Na_2SO_4) and potassium chloride (KCl, also known as muriate of potash, MOP). The 'circular' production process runs on renewable electricity, generates no emissions and recycles all its water, according to Cinis.

In September last year, Cinis Fertilizer signed a long-term purchasing and delivery agreement with German potash producer K+S for the supply of potassium chloride to its Örnsköldsvik and Skellefteå production plants in Sweden. This could see K+S offtake SOP from Cinis in future.

"We are pleased that K+S chooses to confirm the previous declaration of intent regarding cooperation [on] our important input product, potassium chloride. The agreement safeguards our production plan. Furthermore, K+S confirms their interest to take the potassium sulphate fertilizer produced by Cinis Fertilizer from further plants," said Jakob Liedberg. ■

ICL

The 'revolutionary' Nova Humic product line from ICL

The new Nova Humic range from ICL has a unique formulation that integrates essential NPK (nitrogen, phosphorus, and potassium) nutrients and micronutrients with the transformative properties of humic acids. They are described by ICL as: "Revolutionary products in the realm of fertigation, marking a significant innovation in plant nutrition and soil enhancement."

Humic acids are the key component in this product line. These acids – derived from the natural decomposition of plant, animal, and bacterial matter – are known for their complex structure and their role in soil conditioning. Nova Humic products, by leveraging the properties of humic acids, sets a new standard for crop nutrient products and their agronomic capabilities, suggests ICL.

This product line is formulated for precision use, dissolves readily in water and integrates well with a wide range of fertigation systems. The aim is to ensure harmony within agricultural ecosystems by optimising nutrient delivery to crops while nurturing soil health.

ICL believes that Nova Humic products, with their focus on sustainable, effective plant growth, represent a step forward in agricultural practices. Their introduction to the market, say the company, represents a "commitment towards enhancing plant nutrition and improving soil health in a sustainable manner".

Key benefits of the Nova Humic line:

- **Formulation synergies**: products combine essential NPK nutrients, micronutrients, and humic acids, offering a comprehensive solution for plant nutrition and soil enhancement.
- **Soil quality improvements**: Humic acids modify the colloidal structure of the soil, enhancing the physical, chemical and biological properties critical for sustained agricultural productivity. Products also enhance soil characteristics by increasing water holding capacity, raising cation exchange capacity, and boosting the microbial population and enzymes.
- **Increase soil nutrient availability** to promote soil health and fertility.
- **Support for early plant development**: humic acids provide polyphenols during critical plant growth stages. These act as respiratory catalysts to support robust plant growth.
- **Products works in harmony with plant growth**: they ensure optimal plant health by enhancing nutrient uptake without resource competition or mineral depletion.
- **Sustainable plant nutrition**: products have the dual aim of achieving both healthier plants and soils.

Example Nova Humic formulations:

- **Nova Humic NPK**: chloride-free formula, ideal for chloride-sensitive crops
- **20-20-20+TE***: Balanced NPK formula designed to enhance overall plant health, vigour and promote optimal growth
- **19-19-19+2MgO+TE***: Balanced NPK formula enriched with magnesium
- **16-8-35+TE***: High K formula is particularly beneficial during fruit development and ripening stages to enhance crop quality
- **13-40-13+TE***: High P formula is recommended for early growth stages to promote robust plant establishment and root development
- **30-10-10+TE***: High N formula is recommended during vegetative growth phases to support vigorous plant growth

These formulations illustrate the versatility of Nova Humic products which, being tailored to meet specific crop nutrient needs, ensures high quality yields and optimal plant development throughout the various growth stages of crops. ■

*TE = enriched with trace elements (micronutrients)

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PURSELL AGRI-TECH

PURSELL AGRI-TECH: UNLOCKING NEW POSSIBILITIES

Joe Brady, CFO, Pursell Agri-Tech

PHOTO: PURSELL

A Pursell controlled-release fertilizer (CRF) manufacturing plant

The need to maximise crop productivity while minimising impacts on the environment is fuelling significant R&D expenditure covering all aspects of agriculture inputs. It is also a challenge the fertilizer industry is working diligently to address.

Global food demand is expected to be 60 percent higher than current levels by 2050, according to Dr Upendra Singh, Vice President, Research, at the International Fertilizer Development Center (IFDC), a trend which will require much greater agricultural production while using less resources. Fertilizer innovations that increase yields while safeguarding the environment are undoubtedly needed to play a large part in meeting rising food demand and ensuring a food-secure world in future.

Need for Next Gen Innovation

Pursell Agri-Tech is a manufacturer of controlled-release fertilizer (CRF) based in Sylacauga, Alabama, USA.

Pursell's CRF products deliver nutrients in a precise, prescriptive manner, helping growers achieve a high level of efficiency. They function by improving the synchronisation of fertilizer nutrient release with plant nutrient uptake, and significantly reduce nutrient losses via volatilization and leaching, when compared to uncoated urea.

Multiple years of agronomic testing by universities and growers have shown that PurYield® – Pursell's broadacre CRF product – can deliver a 3-7 percent bushel/acre increase in corn yields.

In 2020, the EPA, in partnership with USDA, introduced two fertilizer industry challenges aimed at accelerating the development and use of affordable product technologies that reduce the environmental impacts of US corn production.

Pursell was named a winner of the *Next Gen Fertilizer Innovations Challenge.* This recognises currently marketed fertilizers that help reduce the environmental impacts from row crop agriculture while maintaining or increasing agricultural productivity and profitability. Pursell also has advanced to Stage 2 of the *Enhanced Efficiency Fertilizers* (*EEF*)*: Environmental and Agronomic Challenge*, which identifies EEFs that reduce the environmental release of nitrogen and phosphorus.

CRF challenges on the horizon

Despite the significant environmental benefits CRFs bring, versus their uncoated alternatives, they are under increased scrutiny due to the polymer composition of the coating shell. Consequently, Pursell Agri-Tech and its industry partners are proactively seeking alternative approaches to eliminate the potential risk of microplastic accumulation in the soil that can occur with the use of controlled-release fertilizers.

"Developed in collaboration with coating formulation experts, our urethane chemistry allows us to apply a thin, pliable and durable coating membrane which minimizes the amount of urethane polymer being added to soil," said Tim Holt, Pursells Director of Research and Development. "In one year of applying PurYield to corn at an application rate of 200 pounds of nitrogen per acre, the polymer would make up only 0.00024 percent of an acre ($ft.^3$) of soil."

Polymer encapsulation systems for fertilizer, like the system used by Pursell Agri-Tech, are currently within the scope of a restriction established by the EU (European Union) Fertilizing Products Regulation. Outside of the EU, there are no government regulations or timelines for the implementation of regulations applying to non-biodegradable coated fertilizer. However, new biodegradability standards are expected in the EU in the next two years and both the US and Canada are performing internal reviews to evaluate whether plastic coated fertilizers are a major contributor to microplastic pollution.

Biodegradable technology unlocks new possibilities

In December 2023, Pursell filed a patent on a technology that will enable the company to produce polyurethane-coated fertilizer specifically engineered to incorporate a microbe consortium that degrades the coating shell, reducing it to carbon dioxide, water and organic matter – once the product has delivered nutrients to the plants in a controlled manner.

"Our research has shown that the use of controlled-release fertilizers is an effective approach to improve nutrient use efficiency and reduce environmental pollutants," said Dr Upendra Singh, IFDC Vice President, Research. "We are currently performing degradation tests on Pursell's biodegradable coating technology and are excited about the additional soil health benefits it may offer."

In addition, Pursell's patented, lower-temperature coating process enables the incorporation and survival of biostimulants and microbes. This unique capability allows Pursell to deliver a biodegradable CRF product that combines nutrient uptake with a biostimulant package tailored to a crop's specific needs.

"We believe the coating technology used to produce PurYield, which has demonstrated a proven ability to precisely meter our nutrients synced with plant uptake, is too valuable to the farmer, the population, and the environment to abandon for an alternative coating chemistry or process that is not commercialized or proven," said Holt.

"What makes our biodegradable technology so special and practical is the fact that the fertilizer coating degradation is not dependent on specific microbes being present in the soil or water. Each granule of our biodegradable PurYield product will contain the right amount of specially formulated, safe microbes to degrade the residual coating shell once nutrients have been delivered to the plant," he added.

Initial biodegradable product field trials are being conducted this spring in university and industry grower trials in the US Midwest and Southeast, as well as in Canada. These are targeting corn production. ■

INNOVAR AG

InnoSolve BCT from Innovar Ag

Innovar Ag is an established speciality fertilizer producer based in Bradenton, Florida, USA, and currently market products in over 35 Countries. The company has aggressive international expansion plans and has set itself the goal of doubling its marketing reach to 70 Countries by the end of next year.

Innovar has been eyeing the lucrative and fast growing global biofertilizers market. This was worth $3.1billion in 2023, according to some estimates, and is projected to reach $5.2 billion by 2028, a growth rate of around 10-11 percent per annum.

Unsurprisingly, given its double digit cumulative annual growth rates, the biologicals market is now attracting significant attention.

"Innovar Ag is excited about the biologicals market opportunity," says Andrew Semple, the company's chairman and CEO. "As evidence of that, we recently launched InnoSolve BCT, a new product formula in this category."

BCT stands for 'BioCatalyst Technology', a proprietary enzymatic technology developed by Innovar. InnoSolve BCT is based on a proven prescription formula of 80 species of beneficial bacteria and fungi. It is also filled with crop nutrients.

BCT is a probiotic biological product that functions by accelerating soil microbial activity to stimulate plant growth and establishment. It is offered as a water-soluble powder containing:

- Soil flora and fauna activators with vegetal protein hydrolysates
- Humic and fulvic acids
- Beneficial soil bacteria, fungi and rhizobia.

The product already chimes with customers and their needs, as Carrie Garcia, Innovar's managing director, explains: "The significant market interest from Innovar's existing customer base, has helped to drive the development of our new InnoSolve BCT biological product."

The main benefits from using InnoSolve BCT, according to Innovar, includes its ability to:

- Increase soil fertility by improving soil structure, water retention, and nutrient availability.
- Help unlock and make available micronutrients and minerals for plant uptake.
- Promote plant growth, increase root development, and improve stress tolerance.
- Provide energy for beneficial soil microorganisms, help improve soil structure and nutrient availability.
- Provide beneficial soil bacteria to help fix nitrogen, solubilise nutrients, and protect plants from diseases and pests.

Dr Ray Asebedo, Vice President of Technology at Innovar Ag, was responsible for bringing InnoSolve BCT to market. "InnoSolve BCT combines proven beneficial bacteria and fungi to create the ideal synergistic effect in the rhizosphere for enhancing stress resilience and plant growth," he said. ■

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Nanotechnology – hope or hype?

Indian producers have begun producing nanofertilizers at scale with the backing of the national government, as part of efforts to improve nutrient use efficiency, limit fertilizer subsidies and reduce fertilizer import dependency. But some scientists have questioned the claimed benefits and the overall efficacy of these novel crop nutrient products.

Across the globe, reducing nitrogen inputs to agricultural systems – and therefore their environmental and climate impacts – while maintaining global food production is becoming a major policy goal. The development of more efficient fertilizers, alongside other strategies for improving nutrient use efficiency (NUE), is seen as a stepping stone to agricultural sustainability and securing crop yields and quality (see article on page 16).

Against this backdrop, nanofertilizers have attracted attention in recent times due to their potential to improve NUE, reduce greenhouse gas (GHG) emissions, help prevent nitrogen losses and align nitrogen release with crop demand.

Two Indian fertilizer manufacturers, the Indian Farmers Fertilizer Cooperative (IFFCO) and Coromandel International, have been at the vanguard and pressed ahead with the mass production of liquid nanofertilizers over the last 2-3 years – with the active encouragement of the government in Delhi. This has made the subcontinent a testbed for this innovative technology.

The hope

IFFCO launched the world's first commercial liquid nanofertilizer – nano urea – in June 2021 (*Fertilizer International* 503, p20). The proprietary technology was developed at the company's Nano Biotechnology Research Centre (NBRC) in Kalol, Gujurat.

IFFCO began mass producing half-litre bottles of this pioneering product from three new production plants – Kalol, Gujurat and Aonla and Phulpur in Uttar Pradesh. Initially, these sites were said to

IFFCO nanofertilizer production plant. This manufactures and bottles 500 ml bottles of liquid nano urea. The Indian government changed the minimum nitrogen specification for nano urea from 1-5 percent to 16 percent in April.

PHOTO: IFFCO

provide enough capacity to produce 140 million bottles annually. IFFCO's entry into this new market has received strong backing from India's national government with prime minister Narendra Modi attending the Kalol production plant's official opening ceremony in 2022

Last year, IFFCO and the Indian government announced plans to massively increase liquid nano urea production by building 10 new factories, with an annual production capacity of 440 million bottles by 2025 – and to expand exports of nano urea to 25 countries, mainly in Asia, Africa and South America[1].

Currently, Indian farmers have a financial incentive to overuse urea as it attracts significantly higher government subsidies relative to other types of fertilizer. IFFCO's new nano urea liquid, in contrast, is potentially a much more efficient nitrogen product. Each bottle contains 40,000 ppm of nitrogen and, according to IFFCO, delivers enough crop nutrients to replace at least one 45 kilo bag of standard commodity urea – at least that is what the initial marketing claimed.

IFFCO's liquid nano urea (see Table 1 for specifications) has a typical particle size of less than 100 nanometres, contains four percent nitrogen and has a shelf-life of approximately two years. With a zeta potential of greater than 30mV for stability, it is applied as a foliar spray at a dilution rate of 2-4 ml per litre of water, depending on crop nitrogen requirements and canopy development[2].

IFFCO believes its new nano urea product can avoid many of the environmental problems associated with the excessive use of standard granular urea, such as nitrous oxide and ammonia emissions, soil acidification and water eutrophication.

As well as cutting environmental losses, IFFCO says nano urea is more sustainable in other ways: "It will reduce the input cost to farmer. Due to its small size, the bottle can be kept in the pocket and will significantly bring down the cost of logistics and warehousing also," the company said.

The introduction of nanofertilizers at scale has been heralded as a potential game changer for the Indian market, although this does very much hinge on their widespread acceptance by farmers and the results achieved in the field.

At the start of this year it was reported that IFFCO had produced 77 million bottles of nano urea and sold 54 million bottles to farmers in 2021-22 and 2022-23. IFFCO's current annual production target – 440 million bottles by 2025 – has the potential to curtail annual usage of standard urea by 20 million tonnes, based on company calculations. This would effectively result in Indian self-sufficiency in urea production and eliminate the need for urea imports into the subcontinent. But only if these sums add up.

India consumes produces and imports urea on a vast scale. Of the 35 million tonnes of urea applied by the country's farmers each year, imports typically account for some 8-9 million tonnes.

Due to subsidies, while farmers pay less than INR 300 for a 50 kilo bag of urea, each of these bags reportedly costs INR 3,000 to produce. Consequently, India's fertilizer ministry has estimated that substituting 25 percent of subsidised standard urea with non-subsidised nano urea (INR 225) could save the Indian exchequer up to INR 200 billion ($2.4 billion) every year.

The Indian government therefore has strong financial, trade and agronomic/environmental imperatives that make the mass production of nanofertilizers attractive – as a way of improving urea self-sufficiency, reducing massive expenditure on fertilizer subsidies and preventing nitrogen overapplication and nutrient imbalances.

Nanofertilizer production expands

India is continuing to ramp up nanofertilizer production – with private sector producer Coromandel International opening a new state-of-the art production unit at its Kakinada complex, Andhra Pradesh, on 10th June. This will have the capacity to produce 10 million bottles of nanofertilizers annually. This is additional to Kakinada's two million t/a production capacity for conventional NPK grades.

Table 1: Original specifications of IFFCO Nano Urea liquid

Parameter	Specification
1. Total nitrogen (% by wt.)	1-5 %
2. Particle size in nanometre (nm)*	
a) Physical particle size	20-50
b) Hydrodynamic particle size	20-80
3. Zeta potential in mV (+/- scale)	> 30
4. Viscosity in cps	5-30
5. pH	4.5-6.0

**In one dimension for minimum of 50 percent of the material.*

Source: Kumar et al. (2023)

Commenting on the new production plant, Mr S. Sankarasubramanian, the Executive Director of Coromandel's Nutrient Business, said:

"Coromandel's Nano Fertiliser Plant at Kakinada is a testament to its commitment and dedication to boost nutrient efficiency, reduce environmental impact, and improve the economic viability of farming in India. The government's push for Nano DAP marks a new era in Indian agriculture, where technology and sustainability go hand in hand. This innovative solution aligns with our goals of enhancing agricultural productivity and farm sustainability and we believe that Nano fertilizers will play a crucial role in shaping the future of Indian agriculture."

Coromandel has developed nanofertilizer versions of urea and diammonium phosphate (DAP) at its in-house research and development centre at the Indian Institute of Technology (IIT), part of the Bombay-Monash Research Academy. These are marketed under the brand names Gromor Nano Urea and Gromor Nano DAP, respectively.

"The nano-sized fertiliser particles ensure optimal nutrient delivery and absorption by the plants and have the potential to replace the conventional fertilisers while also increasing the crop yield," Coromandel said in a statement.

Coromandel first unveiled plans to produce a nanotechnology-based phosphate fertilizer in June last year, having received regulatory clearance and completed around 700 crop trials. The Chennai-based company – part of Murugappa Group – said the efficacy, biosafety and toxicity of Nano DAP has also been extensively investigated via field studies (*Fertilizer International* 515, p40).

"Nano DAP will go a long way in driving the sustainability of Indian farms through improving nutrient uptake, lowering water consumption and minimising environmental losses," said Arun Alagappan, Coromandel's executive vice-chairman, speaking last year.

The adoption of Nano DAP should also make farm economics more attractive by driving sustainable fertilizer usage and site-specific nutrient applications, Alagappan said. He also praised the Indian government for its help (*Fertilizer International* 515, p40).

"I would like to thank the government for its continuous guidance, extending policy and regulatory support and providing the requisite impetus for adoption of new technologies in farming," he said.

IFFCO is also scaling-up its production of nanofertilizers. Indian government minister Amit Shah officially launched IFFCO's new liquid nano DAP product in April last year (*Fertilizer International* 515, p40).

Half-litre bottles of nano DAP were made available to farmers from the 2023 kharif season at INR 600, less than half the price of a 50 kg bag of conventional DAP.

IFFCO is setting up production plants for nano DAP at Kalol and Kandla in Gujarat and Paradeep in Odisha. The Kalol plant is already in production with IFFCO planning to manufacture 50 million bottles of nano DAP in 2023, said to be equivalent to 2.5 million tonnes of conventional DAP. The company plans to scale up nano DAP production to 180 million bottles by 2025/26.

"The launch of IFFCO's liquid DAP nano is an important beginning towards making India self-reliant in the field of fertilizers," Shah said. India currently imports around 10 million tonnes of DAP annually, with more than half of this volume sourced from West Asia and Jordan.

The scientific counterblast

In August last year, two researchers, Max Frank and Soren Husted of the Department of Plant and Environmental Sciences (PLEN) at the University of Copenhagen, published a detailed critique of the scientific claims being made in India for liquid nano urea in an opinion paper for the journal *Plant Soil*[1].

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Both Frank and Husted are active in nanofertilizer research. Husted, for example, presented on the technology at the International Fertiliser Society's annual conference in Cambridge last year[3].

Setting the scene, the *Plant Soil* opinion paper noted:

"IFFCO states that there is scientific evidence for distinct beneficial properties in terms of higher crop yields and reduced negative environmental impacts… According to the company, average yield increases of 8% with 50% less N application are possible, thus reducing the costs farmers spend on fertilizers significantly. The product is promoted as being able to reduce nitrate leaching, eutrophication, greenhouse gas emissions, and toxicity to flora and fauna."

But Frank and Husted questioned whether such claims on the effects and sustainability of nano urea (NU) had been scientifically proven[1]:

"We conclude, that NU is a scarcely characterized product with no or poor scientifically proven effects. The product is promoted with misleading and wrong statements about its efficiency as a fertilizer, plant uptake pathways, and environmental friendliness."

The authors also highlighted potential downsides of mass production of nanofertilizers based on partly substantiated or unsubstantiated claims[1].

"There are several serious risks associated to these commercial ambitions: Large scale yield and economic losses to farmers, food insecurity, environmental risks, social disruption and conflicts," Frank and Husted concluded, adding: "Politics and commercial incentives might interfere with the independence of the scientists involved."

The way ahead

The Frank and Husted opinion paper was not entirely negative with the authors stating[1]: "We acknowledge the great benefit that nanofertilizers potentially may have – but seriously doubt the positive impact of NU for farmers, societies and the environment as it stands right now."

Because of this they proposed that independent bodies following a "consistent framework [is necessary] to verify whether novel fertilizer products have indeed beneficial effects for crop growth and yield prior to marketing and applying them widely".

In particular, the *Plant Soil* paper suggested adopting the following four criteria when evaluating the superiority – or not – of nano-based nitrogen fertilizers in the field[1]:

1. The field study must be conducted on a nitrogen-responsive soil
2. Choose control treatments that fit the conclusions to be drawn
3. Describe materials and methods properly
4. Make an adequate amount of randomised repetitions and apply statistics.

New crop recommendations and product specifications

More evidence is also emerging on the most suitable crop recommendation for nanofertilizers. Results suggest that foliar applied nano urea is most effective when used to replace 25 percent of basal urea applications – and not as the complete replacement that was apparently claimed initially.

A comprehensive review of nano-urea versus conventional urea, for example, was recently published in *International Journal of Plant & Soil Science*[2]. This reported findings of wheat, maize, chickpea and mustard growing experiments carried out by the Indian Agricultural Research Institute.

For these crops, the researchers compared the basal application of prilled urea at the full farmer's fertilizer practice (FFP) rate for nitrogen – alongside the full recommended rates for phosphorus and potassium – with foliar nanofertilization for nitrogen and zinc. Comparable yields were achieved with nanofertilizers using a basal N application rate at 75 percent of the FFP, with full P and K rates, supplemented by nano urea and nano-Zn foliar sprays achieved.

"Research has demonstrated that utilizing 75% nitrogen with conventional urea, in combination with either one or two sprays of nano-urea, yields results on par with those achieved through the application of 100% nitrogen supplied via conventional urea," the paper concluded[2].

"When [it was] claimed that one nano-urea bottle of 500 ml is equivalent to one 45 kg bag of granular urea, many farmers believed that and got contrary results after following that prescriptions," commented the Indian agricultural scientist A K Singh. "What the scientists [now] prescribe – using three bags and one bottle in place of 4 bags – cutting conventional urea usage by 25 per cent is different."

IFFCO also launched a new nano urea product – Nano Urea Plus – with a much higher nitrogen content in April. This followed a change in specification for nano urea by government after the expiry of the initial spec (see Table 1) issued in 2021. Under the new specification, which is valid for the next three years, liquid nano urea placed on the Indian market will in future need to have a minimum nitrogen content 16 percent by weight.

The new 2024 specification effectively quadruples the nitrogen concentration in each 500 ml bottle of nano urea – versus the nitrogen requirement of just 1-5 percent under the previous 2021 specification. Other values in the 2024 specification, such as particle size, pH, viscosity and zeta potential (Table 1) have been left unchanged.

IFFCO switched over its nano urea production to the new specification (Nano Urea Plus) from May this year. The selling price of nitrogen-enriched Nano Urea Plus is likely to be same as the original Nano Urea product. This has remained at INR 225 per 500 ml bottle since its launch

U S Awasthi, the managing director & CEO of IFFCO, said: "IFFCO Nano Urea Plus is an advanced formulation … redefined to meet crop nitrogen requirement at critical growth phases. It also enhances the availability and efficiency of micronutrients. It is chlorophyll charger, yield booster and will help in climate smart farming." ■

Author's note

The evidence base on the crop benefits of nanofertilizers is contested and still emerging. A definitive review of the efficacy of nanofertilizers, and the rival claims about their merits, is therefore outside the scope of this article. We'd also like to make it clear that the views expressed or quoted in this article do not represent those of CRU Group, *Fertilizer International* or the author.

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Who's who in pumping equipment

We profile leading suppliers of tailor-made pumps to the phosphate, potash and sulphur industries.

WEIR

Weir – serving the fertilizer industry for over 130 years

Weir has developed an international reputation in the design and manufacture of pumps and valves for the sulphur, sulphuric acid and phosphoric acid industries.

History of Lewis® Pumps

Back in 1891, Charles S. Lewis founded Chas. S Lewis and Co., Inc., a family business that used customised alloys to modify OEM (original equipment manufacturer) pump lines for the beer pasteurisation and bottle cleaning industries.

By the turn of the century, in 1906, the company commenced manufacturing pumps in-house and later developed and manufactured its first sulphuric acid pump in 1914 – the start of a specialisation which has continued to the present day. Expertise and experience in sulphuric acid equipment developed over time and, in 1975, the company manufactured its first sulphuric acid valve.

Lewis® sulphuric acid pumps and valves are used widely in the fertilizer industry, as sulphuric acid is consumed in the manufacture of many fertilizers that are produced today. Because fertilizer producers require operationally reliable sulphuric acid plants with heavy duty equipment installed, they naturally turn to Lewis® pumps and valves.

As the 20th century drew to a close, the company became part of the Weir Group in 1994. The subsequent implementation of Weir's well-established manufacturing excellence programmes at Lewis has delivered even greater levels of quality and high performance.

In 2012, the first Lewis® molten salt pump was manufactured. These highly engineered centrifugal pumps are integral to molten salt circulation systems used in the solar power industry.

"We have developed a full range of pumps engineered for the unique requirements of molten salt. With over 100 years of experience focused on high density and high temperature, we have been able to develop a pump which has a superior feature set to provide high reliability and low operating costs," says Bob Elliott, managing director of Weir's North American operations.

Today, with more than 130 years' experience behind it, Weir still manufactures its trademark wide range of Lewis® pumps and valves – and has made significant investments in developing and enhancing its product line to better serve the industries in which it operates.

Strong customer focus

With customers in more than 100 countries, careful manufacturing planning is the key focus for satisfying customers in Weir's view. This includes identifying the most requested spare parts and ensuring stock is constantly replenished for these needed items.

Maintaining stock levels is an in-depth project that involve collating data on spare parts usage – to truly understand customer requirements – and actively stocking items that will meet customer expectations during emergency situations. To successfully deliver on these guarantees, Weir has adopted a LEAN manufacturing strategy that shares global best practices and training between all Weir factories.

The company's most recent improvement efforts include moving 92 percent of all factory equipment into product cells. This links-up the most requested spare parts with new replenishment techniques, creating close bonds with key suppliers and reducing the overall lead-time to target and strengthen spares availability.

The Lewis 18HTH sulphuric acid pump.

Investment

Weir recently invested in the modification of its test stand area for axial flow pump testing. This enables engineers to test all pumps extensively, under real-life working conditions, before they leave the facility.

In addition to the 42,000 square feet of manufacturing and office space, the company has opened a new 57,000 square feet distribution centre that allows Weir to ship products to customers around the world with ease.

"We have streamlined our process to allow all departments to review the orders on a daily basis. This allows all departments to ask questions at the time the orders are processed, improving the flow throughout our system," says Elliot.

He concludes: "Throughout the last 130 years, we have remained dedicated to the market and the customers we serve and this can be witnessed through the evolution of our Lewis pumps and valves. Our product innovations and dedicated group of employees will not only provide better service to our valued customers but will enable us to continue to deliver solutions to our customers for another 130 years and beyond."

SULZER

Sulzer – a world leader in pumping and agitation

Sulzer is a global leader in pumping and agitation equipment with a history dating back to 1834. Headquartered in Winterthur, Switzerland, the company operates from more than 180 production sites and service centres located in some 50 countries around the globe.

Rotating equipment, separation and mixing technologies

Sulzer's Flow Equipment division offers dedicated rotating equipment for core fertilizer processes, while its Chemtech division supplies components and services for separation and mixing technologies. The company's portfolio also extends to specific water treatment technologies via its affiliate Nordic Water.

Building on more than 180 years of experience with a wide array of chemical and fertilizer industry applications, Sulzer guarantees high-quality process equipment for an extensive range of applications:

- Phosphate rock beneficiation
- Production of all grades of phosphoric acid
- Manufacture of phosphate, potash, and compound fertilizers
- Production of molten sulphur and sulphuric acid
- Water handling in cogeneration and cooling water units
- Water intake, transport, and treatment including desalination
- Wastewater treatment.

Sulzer's position as the leading pump supplier in the industry derives from decades of continuous product development with industry-leading fertilizer companies, as well as from strategic acquisitions and industry expansions. Sulzer acquired Ensival-Moret in 2017, for example, and continues to develop their renowned range of pumps to complete Sulzer's product offering.

Currently, Sulzer offers a comprehensive portfolio of reliable high performance pumps:

- Vertical and horizontal axial flow pumps (CAHR, CAHR-V)
- Slurry and heavy slurry pumps (AHLSTAR WPP, PLR, EMW)
- Process overhung pumps (SNS, AHLSTAR A, CPE, EMTECH, PRE)
- Between bearing pumps (MBN, ZPP, SMD, MSD)
- Vertical pumps (SJT, SJD, JTS, VA, VM, VAS)
- Liquid ring vacuum pumps (VRN).

Besides pumps, Sulzer also designs agitators (Scaba and SALOMIX™) for applications in molten sulphur, phosphate rock beneficiation, phosphoric acid, potash, and fertilizer production plants. Sulzer offers a complete range of impellers adapted to each application. These are designed to suit the required levels of agitation for clean or slightly contaminated liquids, slurries, high-viscosity fluids, or for gas dispersion.

The endurance of Sulzer's equipment comes from its use of a broad range of construction materials, its decades of accumulated expertise when it comes to optimal pump selection, and the modular construction of its pumps and agitators. All of these factors contribute to significantly longer equipment lifespan and minimal downtime.

Sustainability, innovation and choice

The life cycle and sustainability of process equipment play a major role in Sulzer's vision for the future. The company's customer offering ensures the lowest possible energy consumption, while fulfilling application requirements, and includes: IoT-based digital monitoring solutions like Sulzer Sense; quick spare parts availability; own-brand, high-quality mechanical seals; and comprehensive on-site and off-site maintenance services.

Sulzer supports the development of new technologies and the scale-up of existing processes by designing tailor-made equipment and adapting existing products to new conditions. Two examples of tailor-made high-performing equipment are Sulzer's cooler circulation pump used in phosphoric acid plants and its tower circulation pump used in sulphuric acid plants. For both of these applications, the required capacity has needed to increase constantly to meet customer requirements. Also, the ability to keep operating using one single pump – instead of two or more pumps – has significantly reduced capital and operational expenditures.

Sulzer extensive range provides customers with flexibility when selecting equipment, even when these pumps were originally designed for purposes outside the fertilizer industry. Some purification technologies used in the processing of phosphoric acid and potash, for example, require high-pressure pumps with quite small flows. Sulzer has been able to supply suitable high-pressure pumps for these applications in the required construction materials – thanks to its comprehensive range of equipment developed for the power and oil & gas industries.

With heavy-duty design and wide range of materials of construction, Sulzer's CAHR axial flow pumps are suitable for all liquids with corrosive or erosive properties in phosphate and potash evaporation and crystallization loops.

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DÜCHTING PUMPEN

Specifically designed with corrosion and abrasion in mind

Privately owned German company Düchting Pumpen has more than 80 years of experience manufacturing advanced centrifugal pumps specifically designed for service in corrosive and abrasive conditions.

Delivering quality through experience

Düchting offers best-in-class reliability and performance in challenging environments that expose pumps to severe erosive-corrosive wear. These include industries such as fertilizer production, flue gas desulphurisation, seawater desalination, mining and mineral processing, sand and gravel dredging and chemical pigment manufacturing.

In keeping with its company motto ('Quality through Experience'), Düchting's sophisticated pump products are highly valued by its industrial customers. The company combines expertise in hydraulic design – using high-performance computational fluid dynamics (CFX) software – with strong capabilities in pump construction, machining, assembly, testing and commissioning.

An extensive portfolio

Düchting offers an extensive portfolio of single-stage and multi-stage centrifugal pumps. By providing customers with tailor-made, customised equipment as standard, the company aims to provide the best operational performance possible. Minimising maintenance and energy consumption also ensures the lowest lifecycle costs. Partnership arrangements in strategic global locations have also strengthened the company's reputation for efficiency, reliability, innovation and thorough after-sales service.

Düchting's portfolio consists of:

- Single-stage hard metal slurry pumps
- Multi-stage dewatering and high-pressure booster pumps
- Non-metallic low-pressure slurry pumps – these combining diamond-like abrasion resistance with a lifetime anti-corrosion warranty.

Metallic pumps are offered in either super duplex stainless steel or high chrome iron alloys, depending on the application and individual requirements and parameters. For highly challenging fertilizer production conditions, Düchting offers the SICcast mineral cast pump series together with SIConit after-market coating refurbishment capabilities.

SICcast – a unique technology

SICcast is a unique proprietary technology designed more than 30 years ago to combat erosion-corrosion wear. The material consists of an engineered matrix of silicon carbide particles and epoxy resin binder that is mixed under vacuum and then heat-cured into high precision moulds at Düchting's German production plant.

Once cured, SICcast's finished hardness is close to that of diamond on Moh's scale. SICcast is so hard that machine finishing with diamond-tipped tools is necessary to produce the wet end components for Düchting's MC and MCC pump lines.

SICcast is specifically designed to combine complete corrosion resistance with diamond-like abrasion resistance. SICcast pumps are ideal in challenging slurry mediums that shorten service life and reduce the reliability of hard metal (duplex stainless steel or high chrome/nickel alloys) slurry pumps that are more susceptible to erosive-corrosive wear. All wetted components in Düchting's MC and MCC pump lines are completely constructed of SICcast. This design eliminates any contact between the slurry medium and metallic components during operation.

Aftermarket refurbishment of existing worn equipment is also possible through the company's SIConit refurbishment process. This repair service uses a unique coating technology that combines a SICcast EP135 coating material with a cold curing chemical hardening agent. Once cured, SIConit can also be machine finished with diamond-tipped tools to completely revamp and repair existing worn components (see photo). This returns them to as-new condition with SICcast's superior protection against corrosion and abrasion.

Düchting's SICcast mineral cast slurry pumps and aftermarket SIConit refurbishment capabilities are widely used in both phosphate and potash fertilizer production. This is due to their ability to combine optimal performance with equipment longevity and reliability in highly corrosive and abrasive services. Applications include:

- Phosphoric acid
- Sulphuric acid
- Gypsum slurry
- Phosphate rock slurry
- Tailings slurry
- Silicate/sand slurry
- Brine and salt slurries.

A wide range of fertilizer industry applications can also benefit from SIConit refurbishment. These include worn components from existing metallic slurry pump wet end parts, agitator mixer impellers, piping sections, reducers, collection basins, diverters, etc.

PHOTO: DÜCHTING

A half repaired pump impeller refurbished (left) using Düchting's unique SIConit refurbishment process.

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ITT INDUSTRIAL PROCESS

Durable equipment for overcoming challenges

Fertilizer manufacturing requires equal parts expertise and endurance. Harsh operating environments expose equipment to high levels of erosion and corrosion, meaning operators need durable equipment to overcome the built-in challenges.

For decades, operators have turned to ITT Inc for its iconic pumps that are renowned for durability and performance in transferring, dosing, and mixing chemical solutions. In fact, Goulds Pumps and Rheinhütte Pumpen are manufacturers of pumps for every stage of the fertilizer production process, from sulphuric acid production to mining and phosphoric acid plants to the final manufacture of fertilizers.

The full pump portfolio covers slurry, axial flow and chemical process pumps to ANSI and ISO standards, including sealless pumps. Goulds Pumps and Rheinhütte Pumpen specialize in high alloys for chemical pumps ranging from 316SS to zirconium and other special alloys, as requested, as well as a wide range of elastomeric, ceramic and plastic materials. The company's non-metallic pumps offer distinct advantages when handling severely corrosive materials, while its magnetic drive pumps are designed for applications where leakage cannot be tolerated.

And while the pumps are essential to the fertilizer industry, ITT's provides a comprehensive range of complementary products and services for producers at every stage of fertilizer production. ITT Engineered Valves offers valves that resist corrosion from harsh chemicals, while i-ALERT Solutions offer condition monitoring to identify potential issues before they lead to disruptive downtime, which can be extremely costly to repair. All products and services are backed by ITT's comprehensive support network, featuring preventative maintenance programmes, spare parts management and field services.

ITT's extensive experience handling some of the world's most hazardous and corrosive chemicals allows partners to get the most from their equipment and operations. When something does go astray, operators need a trusted resource who will work with them to identify problems – and then determine the best solutions that can be implemented quickly and efficiently. It's not always the equipment either; sometimes the operation just needs a slight tweak.

PHOTO: ITT

Goulds Model XHD heavy duty lined slurry pump.

PHOTO: ITT

Rheinhütte Pumpen RCNKu chemical pump in plastic.

RCNKu chemical pump in plastic

RCNKu pumps have a horizontal, single-stage, end-suction, top-discharge centrifugal design, standardised to EN 22858, ISO 2858 and ISO 5199. They are used for handling chemically aggressive and/or inflammable liquids within the wide field of chemical processing and environmental technology. The closed impeller of RCNKu units makes them suitable for clean liquids, with options offered for either fluids with a small solids content (RCKu) or for larger solids, the RCFKu version. This versatility makes it a perfect choice for certain fertilizer industry applications.

XHD Heavy Duty Slurry Pumps

The XHD pump range provides the next generation in severe-duty slurry pumping by incorporating the latest technology, including computational fluid dynamics (CFD) analysis. Built-in features offer numerous benefits that help customers address rising operating costs and other challenges. The range, with its large-diameter, high efficiency impellers, thicker liners, and interchangeable metal and rubber wear parts, is designed for use within heavy-duty slurry applications. These features were developed to address customer feedback on 'pain points' from comprehensive surveys. Other notable features include the ease of impeller removal. This is removed via an impeller-release collar in a position where parts would otherwise seize up in rough operating conditions. The impeller has a patented machined thread that provides the user with a reliable method for realignment during assembly to the shaft. ■

SWIFT – a fluorine management game changer?

The newly-patented SWIFT process is designed to sequester fluorine at phosphoric acid plants in an environmentally responsible way. It can also offset the costs of fluorine management by generating a saleable dicalcium phosphate (DCP) end-product as an additional revenue stream. A number of capex and opex advantages provide the SWIFT process with highly favourable economics, as **James Byrd** of JESA Technologies explains.

Introduction

JESA Technologies (JT) launched SWIFT, a new fluorine management technology for phosphoric acid plants, at CRU's Phosphate 2024 event in Warsaw earlier this year (*Fertilizer International* 520, p48). While primarily designed to sequester fluorine in an environmentally responsible way, the SWIFT process can also offset the costs of fluorine management by providing additional revenues. It does this by generating dicalcium phosphate (DCP) as a commercially saleable product. The flexibility of SWIFT is a key advantage as it means the process can be adapted and applied differently to match local circumstances.

Background

Fluorine is a common constituent of phosphate deposits globally and is therefore typically present, to a greater or lesser extent, in the phosphate rock feed consumed at phosphoric acid plants.

Fluorine emissions during phosphoric acid production are becoming an increasingly important Environmental, Social and Corporate Governance (ESG) concern for both fertilizer producers and investors. Controlling these emissions effectively is problematic, however, due to the limited range of fluorine management options available to operators currently.

During phosphoric acid production, fluorine is dissolved during the acidulation of phosphate rock concentrate and, once in solution, can escape as vapour at key points in the process. Vapour pressure, and therefore emissions, are a function of phosphoric acid concentration, system pressure and fluid temperature.

Precisely where fluorine emissions will emerge at a given production plant is determined by the phosphoric acid process technology. Fluorine emissions from dihydrate (DH) plants, for example, are greater during the concentration stage at the back end of the plant, while hemihydrate (HH) plants emit more fluorine during the reaction and filtration stages at the plant's front end.

The primary way to capture and control fluorine at phosphoric acid plants is by recovering as much fluorosilicic acid (FSA) as possible. Fluorine emissions are converted to FSA by transferring these to the liquid phase, usually in barometric condensers or scrubbers, in the presence of adequate silica and water. FSA recovery units can be incorporated in the original plant design. Recovery can also be implemented at existing plants through brownfield projects designed to capture fugitive emissions, although this does require careful evaluation of the recycle and washing chemistry.

What to do with the FSA produced remains a major question though. Historically, it has been necessary to neutralise FSA or convert it into anhydrous hydrofluoric acid (AHF) or aluminium fluoride (AlF_3) as the commercial market for FSA is very limited and low value. Yet all of these options still present difficulties. The production of AlF_3 involves outdated technology, for example, while AHF production involves significant capex and usually requires vertical integration with downstream processes as transporting AHF is potentially hazardous. The other remaining option, typically the neutralisation of FSA with lime, is also an expensive high opex process.

In our view, the new SWIFT process, in contrast to the costly alternatives described above, can help solve the fluorine removal riddle, both responsibly and economically, while also producing dicalcium phosphate (DCP) as a valuable by-product.

Process description

The starting point for the SWIFT concept is the PECO process originally developed by the Phosphate Engineering & Construction Co in Florida in the late 1980s, although it differs in purpose and incorporates major refinements. The PECO process was designed to produce both relatively pure phosphoric acid and a saleable fluorspar as a precipitate. The process, which involves reacting FSA with phosphate rock, was run by one commercial phosphate producer for almost a year. But the phosphoric acid generated was weak and of lower quality, compared to purified

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phosphoric acid (PPA), while the fluorspar obtained was unable to compete with commercial-grades on the open market as it was less pure.

The basic SWIFT process involves four main steps (Figure 1). A phosphate source is initially acidulated with FSA in a reactor. The filtrate obtained is transferred to a primary precipitator and the pH adjusted with quicklime. This results in the formation of fluorspar, which comes close to molar completion, and the precipitation of monocalcium phosphate (MCP). This pH adjusted mixture is then pumped to a clarifier.

Following clarification, the solids are pumped back to the reactor, where MCP is digested and enters solution, while the fluorspar remains as a solid under the reaction conditions. The filtrate from the clarifier undergoes another pH adjustment before entering a secondary precipitator. This generates DCP as a solid and relatively clean water as a filtrate. The latter can be reused within the SWIFT plant or sent to the phosphoric acid plant for use as make-up water in the fume scrubber or cooling tower. DCP can be generated in either anhydrous or dihydrate form by adjusting the pH target.

This is a simplified process description and SWIFT can be altered in response to the actual reaction chemistry and/or the end purpose. In contrast to the PECO process, the fluorspar obtained is classed as waste and is disposed of, possibly with gypsum at the phosphoric acid plant. The presence of impurities within the fluorspar is therefore not a concern and, in fact, may even be beneficial to overall plant operations.

Key advantages

The key advantages of the SWIFT process are its ability to:

- Produce DCP for different purposes
- Accept different and lower grade phosphate feedstocks
- Be applied to any phosphoric acid plant technology
- Offer an attractive net present value (NPV) for both greenfield and brownfield plants.

SWIFT has the potential to produce a relatively pure and saleable DCP product. There is more to the process, though, than simply selling DCP on the open market. Indeed, if the SWIFT process was implemented at phosphoric acid plants globally, it is conceivable that the merchant DCP market could become oversupplied with prices depressed as a result. Fortunately, there are three proven and viable end-use options for DCP:

- Sales on the commercial market
- Integrated use as feed for a phosphoric acid plant producing merchant grade acid (MGA)
- Integrated use as feed for a phosphoric acid plant producing purified phosphoric acid (PPA).

Valuably, because SWIFT is a flexible process, its final flow sheet can be configured differently for each of these three end-uses.

SWIFT offers other advantages too. For example, unlike the PECO process, SWIFT does not require beneficiated ore (phosphate rock concentrate) as a feedstock. Instead, less costly P_2O_5 sources are perfectly acceptable. These include beneficiation wastes (e.g., tailings or coarse rejects) or the lowest incremental cost run-of-mine (ROM) ore. These sources can improve phosphoric acid plant project economics as the P_2O_5 from the beneficiation wastes is generally written off – with any extra P_2O_5 recovery providing an economic bonus.

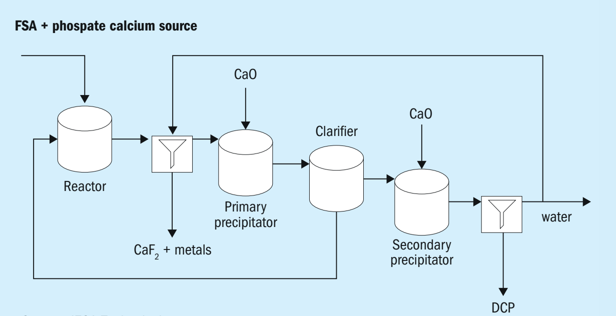
The SWIFT process can be used with any phosphoric acid plant (PAP) technology. In fact, SWIFT can be applied to any industry process, including those completely unrelated to fertilizer production, where fluorine is solubilised and concentrated.

SWIFT's flexibility also means it can be applied to both greenfield (new) and brownfield (existing) plants – although the opportunities for achieving benefits and synergies are more straightforward in greenfield plant design. While brownfield projects can also deliver benefits, the potential synergies generally need more careful study. Typically, by installing SWIFT for fluorine management, fluorine scrubbing will be more efficient and, consequently, total fluorine recovery should increase with a corresponding decrease in fugitive emissions.

In the dihydrate (DH) phosphoric acid process, FSA is normally produced from the flash chamber in the evaporator as this is where the acid vapour pressure is exploited. FSA is generated using a specifically-designed scrubbing vessel that washes vapours until the concentration of FSA in the recirculated water reaches the desired target. More than 90 percent of the fluorine present in the vapour phase can be recovered in a well-designed FSA scrubber. This generates good quality FSA with low impurity levels at a concentration of between 22-24 percent.

In contrast, incorporating the SWIFT process at a greenfield DH plant will allow a much smaller FSA scrubber unit to be installed – because the FSA target concentration is closer to five percent rather than 22-24 percent. Furthermore, the entrainment separator can be omitted as P_2O_5 contamination is not a concern. These design changes can deliver significant capex savings, while the extra P_2O_5 carried through will generate more DCP. Also, because any fluorine-laden stream can be recovered in the SWIFT process, blowdown from the fume scrubber can also be used to generate FSA.

Fig 1: Simplified flowsheet for the SWIFT fluorine management process



Source: JESA Technologies

While the above example is for the DH process, SWIFT can be used with any phosphoric acid plant technology.

SWIFT has a similar capex to a traditional FSA neutralisation unit. The reactor does not require internal heating as the FSA can be heated externally as it is being pumped into the reactor. The steam condensate collected in phosphoric acid plant evaporators can be used for this purpose. It makes an ideal heat source, given that the SWIFT reactor is relatively small with a relatively short residence time.

For the SWIFT process, the lime consumption of the primary and secondary precipitator is also a fraction of that consumed by a traditional neutralisation plant, as both precipitators are also small with short residence times. This means SWIFT can delivers an opex saving. Associated equipment can also to be downsized as well. The two filters used in the process (Figure 1) are smaller compared to the filters in the phosphoric acid plant, for example, as the flow volumes are lower.

These capex and opex advantages, when combined with the benefits of DCP production, favour the economics of the SWIFT process in a big way.

DCP can be used as feed for the phosphoric acid plant (PAP) reactor. This can be a favoured option if the merchant DCP market is oversupplied, or when the phosphate ore has high levels of impurities. The substitution of relatively pure DCP for phosphate rock decreases the minor element ratio (MER) of the feed to the reactor. This helps improve yields, production rates and product quality at both the PAP and fertilizer granulation plant.

Another benefit of using DCP as a reactor feed is lower sulphuric acid consumption due to its reduced calcium to P_2O_5 ratio. Correspondingly, production output and filtration rates will also increase due to lower impurity levels. Steam consumption in the evaporators can even be reduced if the P_2O_5 concentration of the phosphoric acid is raised. Less gypsum should also be generated thereby reducing waste handling costs.

The final end-use option for DCP is as feed for purified phosphoric acid (PPA) plants. This is likely to be an increasingly attractive option in the future as PPA production could double in size over the next 20 years to supply the growing market for lithium iron phosphate (LFP) batteries used in electric vehicles (*Fertilizer International* 517, p46). The acidulation of DCP to generate PPA is a well known process with a long history in the phosphate industry. Advantageously, a DCP-fed PPA plant would have fewer unit operations than a traditional PPA plant and would also produce pure gypsum.

Conclusion

Regardless of the reasons for implementing the SWIFT process, this new technology upholds ESG goals by providing operators with a more sustainable production process that delivers economic benefits. SWIFT's flexibility offers operators a variety of end-use options that can meet site-specific goals and can also deliver potentially valuable synergies at phosphate fertilizer complexes. Consequently, the valorisation of fluorine has never been this affordable, in our view, with far reaching environmental and economic benefits. ■

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