Oct/Dec 2021

Fertilizer View

PROVIDE VALUABLE INFORMATION OF GLOBAL FERTILIZER INDUSTRY

P07: Fertilizer Makers Look to Sea for Green Growth

P34: Global Fertilizer Prices Hit a 12-year High

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Industry Observation

News in Brief

Nitrogen Fertilizer Shortage Threatens to Cut Global Crop Yields -CF Industries

A shortage of nitrogen fertilizer due to soaring natural gas prices is threatening to reduce global crop yields next year, CF Industries, a major producer of the crop nutrient, said on Nov 4.

European gas prices have jumped amid high demand, as economies recover from the pandemic and with below-average gas storage levels at the start of the winter heating season. Natural gas is a key input in the production of nitrogen-based fertilizers and higher costs have caused some producers to cut production.

Prices of nitrogen fertilizer, one of the most commonly used fertilizers to boost production of corn, canola and other crops, are at their highest levels in more than a decade.

Strong global fertilizer demand looks set to last into at least 2023, CF Senior Vice-President of Sales Bert Frost said. *(By Rod Nickel, Source: REUTERS)*

▲ A general view of the CF industries plant in Billingham, Britain September 22, 2021. Picture taken with a drone. REUTERS/Lee Smith/File Photo

Freeze on Fertilizer Prices in Russia Extended Until May 2022

▲ The Factory of Russian fertilizer major URALCHEM. Source: infoindustria.com.ua

According to the statement of the Deputy Minister of Industry and Trade of Russia, Mikhail Ivanov, domestic producers of mineral fertilizers agreed to extend the fixation of prices for their products for Russian farmers until the end of May 2022.

Russia is one of the biggest exporters of nitrogen and phosphate fertilizers in the world.

Prices for nitrogen fertilizers in the world this year reached a maximum since 2008, against the background of this, domestic farmers feared a shortage and rise in prices for fertilizers. The reason for this was the price crisis on the EU gas market: blue fuel is the main source of fertilizer production.

Russian President Vladimir Putin earlier instructed the government to develop a set of measures by 1 November to neutralise the risks of negative consequences of energy shortages in Europe, including the destabilisation of the markets for nitrogen fertilizers, metallurgical products and foodstuffs.

As a result, prices for a number of fertilizers for the Russian domestic market were frozen in July, and in October these measures were extended until the end of the year.

The ministry proposes to add certain categories of fertilizers to the list of goods for which the use of temporary periodic customs declaration, incomplete and periodic customs declaration is prohibited.

According to the document, the changes will affect the export of nitrogen fertilizers (code 3102), as well as diammonium phosphate (DAP), monoammonium phosphate (MAP), and nitrogen, phosphorus, potassium (NPK) fertilizers (code 3105).

“Fertilizer producers announced their decision, which was approved by the government,” said Deputy Minister.

Mikhail Ivanov reports that chemical companies decided to extend the fixation of mineral fertilizer prices to support domestic farmers amid a complicated situation with world prices for natural gas and fertilizers. *(Source:rg.ru, by Анастасия Селиванова)*

Ethiopia, Morocco Agree to Establish 6.1 Billion USD Integrated Fertilizer Complex

September 18, 2021 (ENA) Ethiopia and Morocco have inked an agreement that enabled them to execute over 6 billion USD joint fertilizer development project in the eastern city of Dire Dawa.

The agreement was signed between OCP Group, a Moroccan state-owned phosphate rock miner, phosphoric acid manufacturer and phosphate fertilizer producer, and the Government of Ethiopia to implement the project, according to Ministry of Finance.

The project will have an initial estimated investment of approximately 2.4 billion USD during the first phase and USD 3.7 billion in the second phase, it was learned.

In the first phase the project could develop 2.5 million-ton fertilizer production unit and produce could reach 3.8 million tons per year in the second phase.

The project is expected to have significant contributions in meeting Ethiopia's continuously growing demand for fertilizers, primarily Urea and NPS+. As from 2022, fertilizer imports in Ethiopia will represent 1 billion USD, and could potentially reach 2 billion USD in 2030.

The agreement was reached during a high-level delegation visit to Morocco led by Finance Minister Ahmed Shide , according to Ministry of Finance.

The agreement is based on feasibility, conceptual, environmental and social impact assessment and hydro and geotechnical studies that have been conducted, the source stated.

According to the agreement the integrated fertilizer complex will be using local resources such as Ethiopian gas and Moroccan phosphoric acid. ***(Source: MLN MOROCCO LATEST NEWS)***

Water Crisis, Fertilizer Shortage Worry Brazilian Farmers

It has rained in Brazil's south and the forecast is for more water coming to the southeast and mid-west, regions that were more severely affected by the recent water crisis.

Between high fuel prices and problems in fertilizer supply, the Brazilian GDP won't escape this double whammy to the economy. Estimates for 2022 already show a drop of 1% (from 2.3% to 1.3%) in expected GDP growth, caused by the effects of the lack of energy.

Brazil's ongoing issues will likely cause a slowdown in economic growth. ***(Photo: Getty/iStockphoto)***

Last season, Brazil's corn crop was impacted by inconsistent weather. The drought devasted nearly half the production expected in some locations. Now, the threat to crop yield is from lack of fertilizers.

Overall, Brazil's soybean planting, including fertilizer supplies, has been okay so far this year. But supplies available for second crop corn are worrying. Farmers are already thinking about reducing the amount of fertilizer they apply, which will directly affect yield. This is driven by two points: the fear of not getting fertilizer supplies, and the exchange ratio (soybean price vs. fertilizer price), which is at a historic high. ***(By Julio Bravo, Source: FarmFutures)***

U.S. Fertilizer Industry Commits 70-million Acres to Nutrient Stewardship

TFI looked to the future in announcing an industry-wide commitment to commit 70 million acres under 4R Nutrient Stewardship management by 2030.

Acres managed under the 4R concept incorporate practices that use the right fertilizer source at the right rate, at the right time, and in the right place. When the 4Rs are put into practice, growers can achieve higher yields, lower input costs, and fewer nutrient losses to the environment.

"The sustainable use of fertilizer is not only a priority for the fertilizer industry but millions of farmers across the nation," says Corey Rosenbush, TFI president and CEO. "A key goal for the industry is a commitment to a healthy environment and setting this goal to improve nutrient stewardship is an important step in meeting that goal."

A 4R acre is defined as an acre of U.S. cropland under management using 4R practices, such as organic sources and removal rates, variable technology, split applications, the use of cover crops, accounting for the weather during the application, and several others.

Fertilizer is a key component of sustainable crop production systems, and the fertilizer industry recognizes the need to use these nutrients efficiently.

Practices based on the right source, rate, time, and placement of fertilizer application can lead to improved on-farm profitability, improved water quality, and reduced loss of greenhouse gas. ***(By Rusty Halvorson, Source: KFGO, NAFB News)***

Uralchem to Develop Cooperation with Nigeria

Elected in May 2021 as the chairman of the Russia-Nigeria Business Council, Dmitry Konyaev told the attendees that Uralchem intends to open an office in Nigeria.

Also, Nigeria plans to build a plant and launch its own production at a local site.

Dmitry Konyaev believes that such intentions are due to the great potential of the Nigerian market for the supply of mineral fertilizers.

Plans for the development of cooperation between Russia and Nigeria were discussed in Moscow at a meeting at the Russian Chamber of Commerce and Industry. ***(Photo: Uralchem)***

"Nigeria is the largest market in Africa. Agriculture must meet the ever-growing demand for food, for which it has to use modern fertilizers and advanced technologies. For Uralchem and Uralkali, Nigeria is a strategic market. Today we are preparing to implement a joint project for the production of fertilizers with a Nigerian partner," Dmitry Konyaev said.

In addition to developing bilateral relations in the field of economics and business, Dmitry Konyaev highlighted the importance of sharing experience in such areas as science and agriculture. One of the tools for developing cooperation can be education and practical training for students from Nigeria in Russian agricultural universities.

In turn, Ambassador Abdullahi Y. Shehu noted the maintaining of stability between the two countries.

The diplomat showcased Uralchem as a positive example of mutually beneficial and active cooperation and invited other Russian companies to actively participate in the development of relations not only through the export of their goods but also through their production in Nigeria. ***(Source: Uralchem)***

Fertilizer Makers Look

to Sea for Green Growth

Two of the world's biggest fertilizer producers, CF Industries Holdings Inc and Yara International Asa, are seeking to cash in on the green energy transition by reconfiguring ammonia plants in the United States and Norway to produce clean energy to power ships.

The consumption of oil for transportation is one of the top contributors to global greenhouse gas emissions that cause climate change, and fertilizer producers join a growing list of companies adjusting their business models to profit from a future lower-carbon economy.

By altering the production process for ammonia normally used for fertilizer, the companies told Reuters they can produce hydrogen for fuel or a form of carbon-free ammonia used either as a carrier for hydrogen or as a marine fuel to power cargo and even cruise ships.

The shift may improve their standing with environment-minded investors as fertilizer emissions attract greater government scrutiny in North America and Europe.

But the green fuels are not yet commercial and will require significant investment to turn a profit – a reality that has the world's largest fertilizer producer, Canada's Nutrien Ltd, staying out of the space for now. Oslo-based Yara is seeking government subsidies to proceed.

Still, renewable ammonia represents a 6 billion-euro ($7.25 billion) opportunity for fertilizer producers by 2030, according to Citibank, based on 20 million tonnes of annual sales globally for clean power and shipping fuel compared with virtually none now. Global ammonia sales currently amount to 180 million tonnes.

"We absolutely could be known more for being a clean energy company than an ag supplier," CF Chief Executive Tony Will said in an interview, speaking of long-term prospects for the Illinois-based company.

'EVERYBODY IS LOOKING FOR SOLUTIONS'

Fertilizer plants separate hydrogen from natural gas and combine it with nitrogen taken from the air to make ammonia, which farmers inject into soil to maximize crop growth.

Production generates carbon emissions that CF says it can avoid by extracting hydrogen instead from water charged with electricity. It can then combine that hydrogen with nitrogen to make green ammonia, which the marine industry is testing as fuel.

CF is in discussions about selling green ammonia to a Japanese power consortium including Mitsubishi Corp, but buyers will break most of it down to pure hydrogen for use in transportation sectors.

“This is a market that easily can exceed what the total ammonia (fertilizer) market is,” Will said. “We’re going to grow into that over the next 20-25 years.”

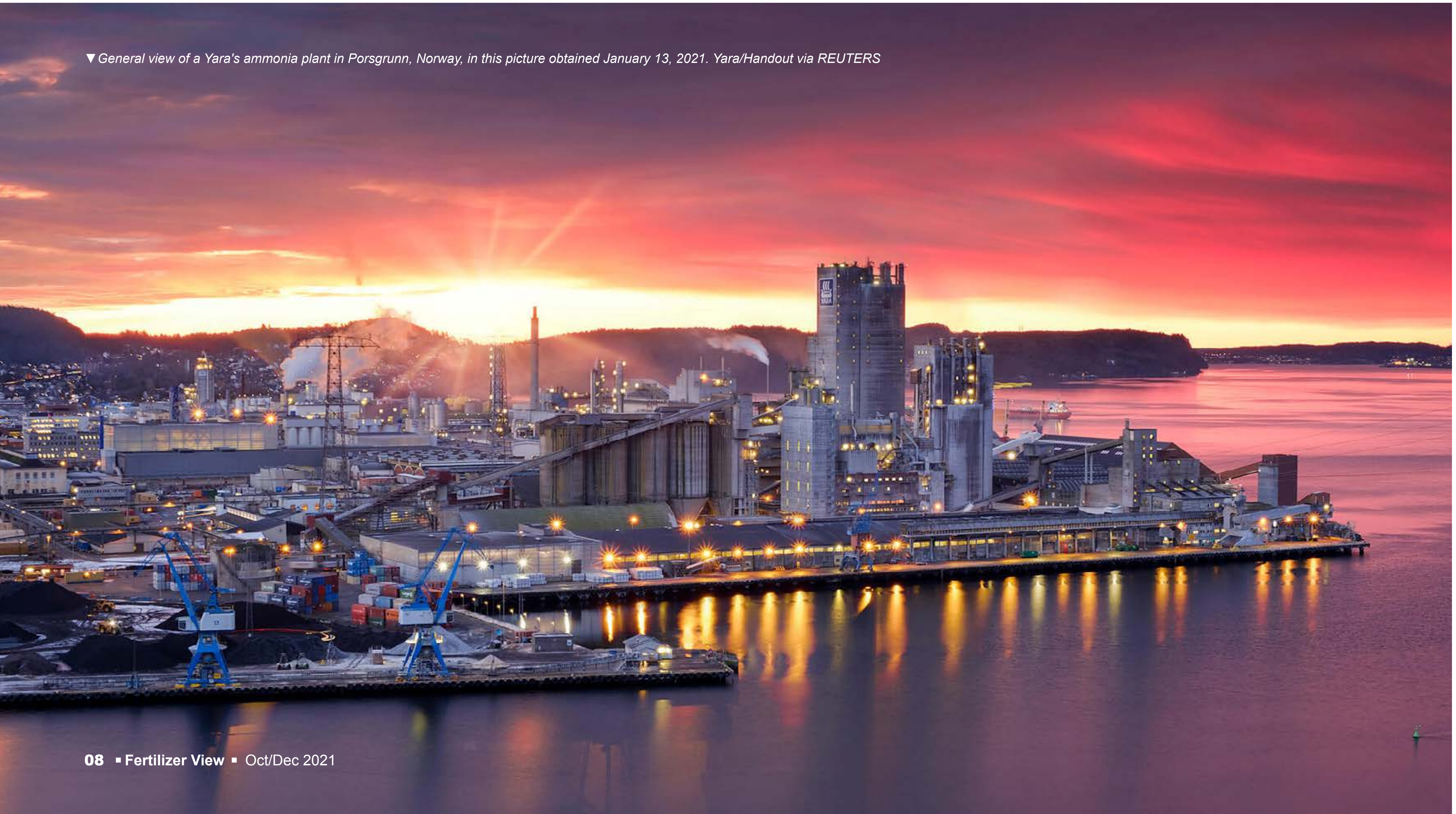
Adopting green ammonia or green hydrogen to replace crude oil-based fuel would help the International Maritime Organization (IMO) meet a target to reduce emissions, and is suited to both short- and long-haul vessels.

Methanol and liquefied natural gas (LNG) are other clean alternatives.

“Everybody is looking for solutions and I think the jury is still out,” said Tore Longva, alternative fuels expert at Oslo-based maritime advisor DNV GL. “Of all the fuels, (green ammonia) is probably the one that we are slightly more optimistic on, but it’s by no means a given.”

Ammonia remains toxic and corrosive, requiring special handling on ships, Longva said.

Furthermore, combusting ammonia may produce nitrous oxide, a greenhouse gas, that ships would need to neutralize to prevent emissions, said Faig Abbasov, shipping director for European Federation for Transport and Environment, an umbrella group of non-governmental organizations. Fuel cells are another potential marine use for ammonia and hydrogen.



▼General view of a Yara's ammonia plant in Porsgrunn, Norway, in this picture obtained January 13, 2021. Yara/Handout via REUTERS

Still, Abbasov sees ammonia and hydrogen as the greenest and most practical shipping fuel alternatives, and cheaper than methanol.

Development of ammonia and hydrogen for shipping fuel holds decarbonization potential but is at the pilot stage for small vessels, while LNG and methanol are in use on ocean-going ships, an IMO spokeswoman said.

One of the world’s biggest shipbuilders, South Korea’s Daewoo Shipbuilding & Marine Engineering , plans to commercialize super-large container ships powered by ammonia by 2025, a spokesman said.

THE PLANS

CF is reconfiguring its Donaldsonville, Louisiana, plant to produce green ammonia. It plans to spend $100 million initially to enable the plant to produce by 2023, about 18,000 tonnes. By 2026, production across its network could reach 450,000 tonnes, and 900,000 tonnes by 2028, Will said.

The hydrogen it will sell may have nearly 10 times the margin of ammonia fertilizer, according to CF, making the 75-year-old farm company’s newest product its most profitable.

Yara is developing a green ammonia project with power company Orsted in the Netherlands and also has green projects running in Australia and Norway.

Unlike CF, Yara is seeking government subsidies because green ammonia costs could be 2-4 times higher than conventional production, “The technology behind this is not mature enough today,” said Terje Knutsen, Yara’s head of Farming Solutions.

Yara, which aims to cut all CO2 emissions from its 500,000 tonnes-a-year Porsgrunn ammonia plant in Norway, wants funding from the Norwegian government to switch the plant’s production process to electricity by 2026.

Norway already supports hydrogen and green ammonia through a tax exemption on electricity used to produce hydrogen, Minister of Climate and Environment Sveinung Rotevatn said in an email.

“Hydrogen and hydrogen-based solutions, such as ammonia, will be important in reducing greenhouse gas emissions in the future,” Rotevatn said.

Global ammonia production would need to multiply five-fold if it is to replace all oil-based shipping fuel, Abbasov said. But given the abundance of nitrogen in the air, potential supply is almost unlimited if production costs drop, he said.

Nutrien is looking into green ammonia, but sees high costs and insufficient prices as major obstacles, Chief Executive Chuck Magro said.

Industry efforts underway to produce small volumes of green ammonia are largely “window-dressing,” said Nutrien Executive Vice-President, Nitrogen, Raef Sully.

“The reason (for Nutrien) to look at it is to position ourselves for when people are willing to pay,” Sully said.

“The problem is we’re just right at the start of development.” *(Source: REUTRES, By Rod Nickel and Victoria Klesty)*

To Ensure a Stable Supply

of Grain, China Has Curbed the Rapid Rise in Fertilizer Price

The price of chemical fertilizer has increased significantly this year. According to the official notification, among main kinds of chemical fertilizer products, the lowest increase has reached more than 30%, and the prices of some products have doubled. In other words, with the price of chemical fertilizer rising by more than 30%, the important cost of farmers this year has been further increased. In the words of some farmers, this year's grain is "unable to afford to grow".

How to alleviate the decline in farmers' enthusiasm for growing grain caused by the price rise, the relevant person in charge of State Council Information Office of China said that the export of domestic chemical fertilizer was one of the reasons of the rise of price.

In fact, since last year, the price of chemical fertilizer has increased greatly. This year, the price of chemical fertilizer has soared again, which has obviously increased the planting cost. Considering that this situation will directly affect farmers' enthusiasm for growing grain, and then affect the stable supply of grain, it is necessary to find out the reasons for the sharp rise in the price of chemical fertilizer and make effective adjustments in time.

Why is there a big increase in chemical fertilizer price this year?

According to customs data, from January to September this year, China's total export of chemical fertilizers reached about 26.11 million tons, a year-on-year increase of about 31%. The large export of chemical fertilizers makes the domestic market in short supply to a certain extent, which drives up the fertilizer price. This 26.11 million tons of chemical fertilizer exported is equivalent to nearly twice the total amount of chemical fertilizer used in the three major grain growing provinces of Henan, Shandong and Anhui in 2019.

At the same time, the price growth of chemical fertilizer raw materials this year is also very obvious, especially coal and sulphur. This is not only because these two raw materials themselves will have an impact on the environment, so they can only be produced in quota. More importantly, in the current good market, many raw material suppliers also adopt a reluctant attitude to sell in order to obtain higher profits. In this case, with the continuous rise of production costs, fertilizer manufacturers transfer the pressure of production costs to farmers.

Generally speaking, the sharp rise of price this year is the result of the comprehensive influence of many factors, but the high export volume and the sharp rise in the price of raw materials are the main reasons. In fact, the stability of domestic grain production is the foundation to ensure that people eat enough and safety. Under the influence of various factors such as the epidemic situation, imported grain is not reliable. Therefore, it is very important to "cool" the price of chemical fertilizer at this stage.

What intervention does China plan to make in the face of the soaring price of chemical fertilizer?

The relevant person in charge of State Council Information Office of China made it clear that it will effectively ensure the stable production of fertilizer manufacturers, smooth the logistics and transportation channel of fertilizer, and put in fertilizer reserves in due time. This measure is to start from the production side of chemical fertilizer to provide a stable supply of chemical fertilizer to meet the current agricultural demand. It is worth mentioning that with the timely release of reserve fertilizer, the "rapid progress" of fertilizer price is likely to come to an end.

20 billion RMB one-time grain subsidies will be implemented to alleviate the impact of the rising cost of agricultural materials on agricultural production, and reiterated that the minimum purchase price of wheat next year will rise by two cents per kilogram. This measure starts from the demand side of chemical fertilizer and gives cash support to farmers through the one-time distribution of grain subsidies. The rise of the minimum purchase price of wheat again can also balance the rise of chemical fertilizer prices. *(Source: Zhangnongchi)*

How to Feed Plants

While Polluting Less?

Introduction:

Is it possible to fertilize crops while respecting the environment?

This question, at the heart of our society's environmental concerns, has no simple answer. Plants have an imperious need for mineral elements to grow, live and reproduce. They draw these elements from the soil through their root system. However, the availability of mineral elements in the soil is highly variable: it depends on multiple interactions between the physico-chemical parameters of the soil, the numerous microorganisms that live in it and the biology of the plants themselves.

Understanding these phenomena sheds light on agronomic practices for mineral fertilization of crops. Until recently, crop nutrition was done element by element, based on a prognosis of productivity resulting in fertilization that was often excessive and sometimes dangerous for the environment.

How can more efficient fertilisation be achieved through more precise adjustments of inputs, and therefore more integrated fertilisation practices that generate less pollution?

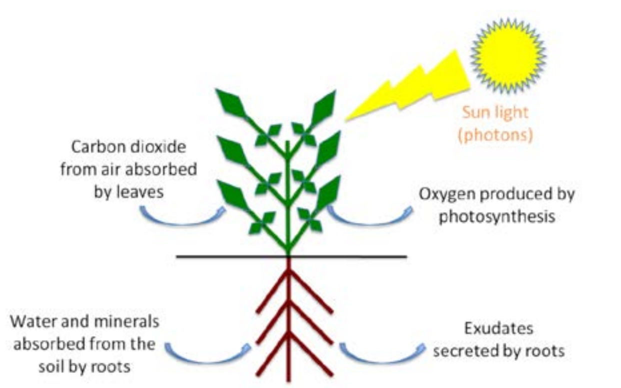


Figure 1. Nutrient requirements of chlorophyll plants. ***(Scheme © Briat J.F.)***

1. Minerals essential to plant life

The carbon of plants represents 40% of their dry matter. It is assimilated from carbon dioxide in the air by photosynthesis which takes place in leaves. Oxygen is the second major component of plants, representing 45% of their dry matter. It is supplied to the plant by water drawn from the soil by the roots. Plants are also the main entry for many minerals into the biosphere via their absorption from the soil (Figure 1).

Essential mineral ions for plants have been classified according to their relative abundance into two categories, macroelements and microelements (Figure 2).

The macroelements, also called major elements, (N, P, K, S, Ca, Mg) represent for each at least 0.1% of the dry matter of the plant and generally do not exceed 2% of it.

Microelements (Mn, Zn, Cu, Fe, Ni, Cl, B, Mo), also called trace elements, represent an insignificant part of the dry matter of plants (from 0.01% to 0.00001%), despite their essential role in plant physiology.

Elements	Functions involved
Group 1: N, S	Constitution of carbon-containing compounds (amino acids, nucleic acids...)
Group 2: P, Si, B	Energy conservation and structural integrity (sugar-phosphates, nucleic acids, phospholipids, ATP...)
Group 3: K^+, Ca^{2+}, Mg^{2+}, Cl^-, Mn^{2+}, Na^+	Osmoregulation, enzymes cofactors, signalling... (under ionic forms)
Group 4: Fe, Cu, Zn, Ni, Mo	Redox reactions (components of cytochromes, oxidases...)

Figure 2. Functions of mineral elements in the plant.

These functions of mineral ions reveal their essential importance for the functioning of plants. In order for this to be optimum, ions must be in a window of ideal concentration.

2. Basis of plant nutrition

Mineral fertilization of crops is the practice of adding certain mineral elements to the soil to:

● Correct soil deficiencies in certain elements that limit plant growth and crop yield;

● Regularly returning to the soil the quantities of elements exported by crops in order to maintain soil fertility over the long term.

Fertilization can be carried out in organic form, can also be carried out with mineral fertilizers of different ionic forms. For plants, there is no fundamental difference between the two types of fertilization. Ultimately, they both result in the same ionic forms being absorbed by the plants.

3. Availability of minerals in the soil

The absorption of minerals by plants depends on their availability in the soil. This is determined by interconnected dynamic balances (Figure 3).

3.1. Importance of mycorrhizae and microbiota

Most species of agricultural interest form endomycorrhizae, also known as arbuscular mycorrhizae.

Arbuscular mycorrhizae are known to significantly improve plant phosphorus nutrition from the free orthophosphate ions, H_2PO_4 and HPO_4 (noted Pi) from soil solution. The

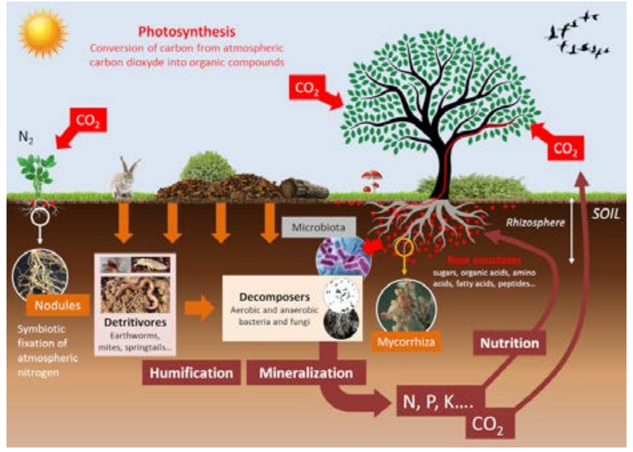


Figure 3. Cycle and mineralization of organic matter in the soil; plant-living organism interactions and mineral nutrition of plants. ***(Source: EEnv diagram adapted from Salsero35 / CC BY-SA 4.0, via Wikimedia Commons)***

small diameter of mycelial hyphae (on average 10 µm) combined with their length, which can represent up to 1 m per millimetre of root, explains the better phosphorus nutrition of mycorrhizal plants compared to non-mycorrhizal plants.

A significant part of the carbon fixed by the leaves through photosynthesis is secreted by the roots into the rhizosphere in the form of organic molecules. These root exudates represent between 5 to 30% of the products of photosynthesis, i.e. between 1 and 3 tons of C/ha/year. They feed a large microbial community at the soil-root interface: the root microbiota.

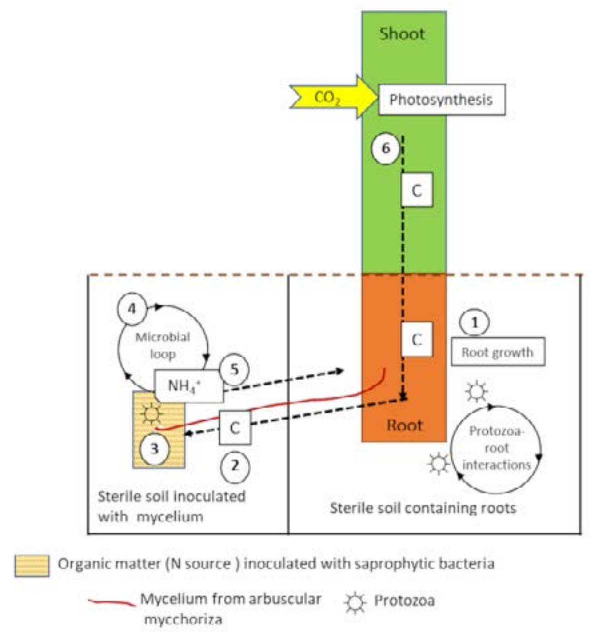


Figure 4. Possible interactions between protozoa, arbuscular mycorrhizae and roots. ***(Source: Diagram © Plassard C. and Briat J.F.)***

3.2. Interactions between soil organisms

Independently of their direct action described above, the bacteria of the microbiota and the fungi of the mycorrhizae are involved in processes of mineralization of nitrogen and phosphorus that will ultimately be absorbed by plants.

Protozoa and nematodes feed on the bacteria and mycelium of the mycorrhizae, releasing mineral nitrogen into the soil. These interactions between protozoa, arbuscular mycorrhizae and roots lead to increased biomass and N accumulation in plants.

4. How do plants absorb minerals?

4.1. Acquisition of minerals by roots and distribution in the plant

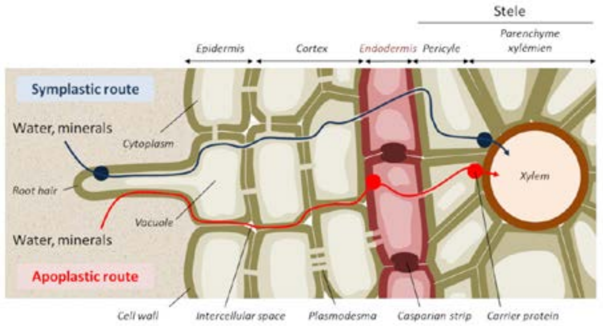


Figure 5. Radial transport of mineral elements in the root by the apoplasmic and symplasmic routes. ***(Source: EEnv diagram)***

Mineral ions are absorbed by the roots through complex mechanisms. Diffusion causes them to enter the root for radial transport from the outer cell layers to the cells in the centre forming the stele. The stele contains the xylem conducting vessels, which distribute nutrients from the root to the aerial parts, and the phloem vessels responsible for the opposite transport from the leaves to the roots.

4.2. Interactions between minerals and plant mineral nutrition

Different mineral ions of opposite charges interact in the soil. Many of them are then less mobile and become less available to feed plants. This has negative effects on their growth and development. These interactions also exist within plants. The perception of soil nutrient availability by plants allows them to adapt to this availability.

There are strong relationships between plant responses to different nutrients taken in pairs. For example:

In the case of a zinc deficiency there is an increase in phosphate concentration;

Single iron deficiency, known to decrease chlorophyll accumulation in leaves, does not have this effect in a double deficiency of iron and phosphate;

Root growth under phosphate deficiency conditions also depends on the availability of other nutrients such as nitrogen.

5. Towards integrated and reasoned fertilization: dialogue between biology and agronomy

5.1. An essential concept for improving fertilization: nitrogen dilution

Studies have shown that there is a so-called allometry relationship between the critical nitrogen removal from a crop (called Nc and expressed in kg N/ha, i.e. the minimum amount of nitrogen that the crop must remove to achieve maximum growth) and the maximum dry matter accumulation or Wc (expressed in t/ha):

$N_c = aW_c^b$

The value of coefficient "a" represents the minimum amount of nitrogen that the crop must absorb to produce a biomass of W = 1 t/ha. The coefficient "b" which is <1 indicates that the amount of N required to produce the following units of biomass decreases as the biomass of the crop increases.

This translates into an expression of the decrease in the plant's nitrogen concentration (%N) during crop growth, a phenomenon called "nitrogen dilution":

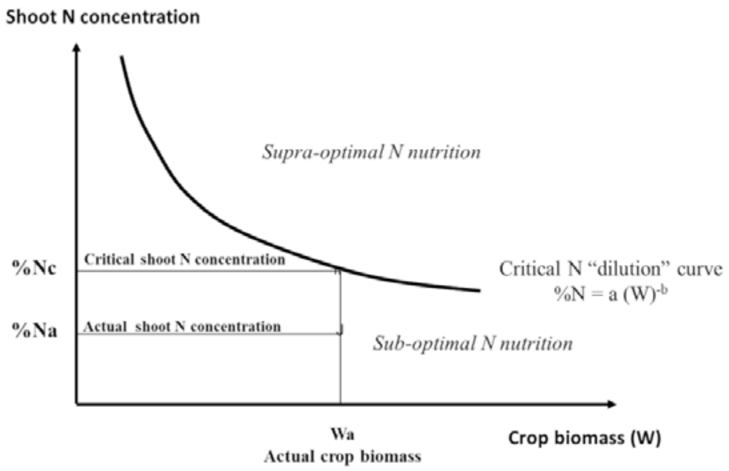


Figure 6. Representation of a nitrogen critical dilution curve of a culture and the determination of a Nitrogen Nutrition Index: INN = % Na / % Nc. ***(Source: Scheme adapted from Lemaire et al., Ref.))***

5.2. Biological and agronomic significance of nitrogen dilution

How can we functionally interpret this dilution of nitrogen during plant growth observed in all species? Several phenomena contribute to this dilution:

● Plants are essentially composed of two types of tissue:

photosynthetic leaf tissues rich in nitrogen which capture light and assimilate CO_2 (N concentration of 4 to 5%);

Supporting tissues that are used for plant architecture and are poor in nitrogen (N concentration of 0.5 to 0.7%).

● As the plant increases in size, the mass growth of the support tissues increases faster than that of the leaf tissues. This is all the more accentuated when the plant is in a dense plant canopy in which it has to grow more in "height" and "thickness" to be able to position its leaf surfaces in the lit strata.

● The mass of nitrogen-rich 'metabolic' tissues (leaf surfaces) therefore increases relatively less rapidly than the mass of nitrogen-poor 'supporting' tissues as the canopy develops.

● In addition, the nitrogen contained in shaded leaves is not very efficient for photosynthesis in low light conditions. It is recycled back into the plant in the young, well-lit leaves at the top of the canopy.

The result of this set of architectural adaptation phenomena for access to light is that the plant's elementary nitrogen demand, dN, to develop an additional unit of biomass, dW, decreases as the plant allocates an increasing proportion of its biomass to nitrogen-poor "support" tissues. This results in a "nitrogen dilution" generated by the growth of the plant canopy. This is an emerging property of the plant population competing for the light that a crop provides.

This emergent property is therefore determined by the crop biomass. Consequently, to compare the mineral nutrition status of two crops, their difference in biomass must be taken into account. This is equivalent to comparing them to equivalent biomass (W)b, which represents the metabolic compartment of the plant. The homeostasis of plant nitrogen nutrition (i.e. the ability of a plant to maintain a constant nutritional state) is therefore not achieved at the scale of the whole plant, but of its metabolic compartment only.

Similar results were obtained for the other elements strongly involved in the metabolic tissues of the plant, showing a dilution of P, K and S of the same nature as that of N.

6. Messages to remember

Plants absorb mineral elements from the soil through membrane proteins in their roots. The minerals are then distributed in the plant by the sap carried in the conducting vessels.

The absorption of minerals from the soil depends on their availability. This is determined by the physico-chemical parameters of the soil and by the interactions between the soil, the microorganisms it contains and the plants.

Plant growth determines their demand for minerals and in turn controls their absorption. This regulation involves long-distance signalling from the leaves to the roots.

The transport of mineral elements and the fertilization of crops have long been considered element by element. Crop fertilization was then based on soil analyses that (a) did not take into account the interactions between elements and (b) considered the availability of elements as a variable external to the plant.

During its growth, the plant maintains its homeostasis only in the "metabolic" compartment (leaf surface) that determines its growth. But it is obliged to invest in its architecture (supporting tissues poor in N, P, K…) in order to have access to light.

The dilution of mineral elements is therefore determined by the indispensable allometry between "metabolic tissues" (surface) and "support tissues" (height, thickness). The "larger" the plant is, the more support tissues it needs in relation to the metabolic tissues…

The recent evolution of fertilization is based on this concept of dilution curves. They make it possible to overcome the dilution effects caused by differences in crop biomass. They should encourage the use of mineral fertilizers only in the case of a proven nutritional deficit, and thus limit excess fertilization that is detrimental to the environment. ***(Source:Encyclopedia of the Environment, By BRIAT Jean-François, LEMAIRE Gilles)***

Industry Observation

Scientists Have Designed

a New 'Coating' to Protect Seeds from Droughts

As the world continues to warm, many arid regions that already have marginal conditions for agriculture will be increasingly under stress, potentially leading to severe food shortages. Researchers at MIT have come up with a promising process for protecting seeds from the stress of water shortage during their crucial germination phase, and providing the plants with extra nutrition at the same time.

The process, undergoing continued tests in collaboration with researchers in Morocco, is simple and inexpensive, and could be widely deployed in arid regions, the researchers say. The findings are reported in the journal Nature Food, in a paper by MIT professor of civil and environmental engineering Benedetto Marelli, MIT doctoral student Augustine Zvinavashe '16, and eight others at MIT and at the King Mohammed VI Polytechnic University in Morocco.

The two-layer coating the team developed is a direct outgrowth of years of research by Marelli and his collaborators in developing seed coatings to confer various benefits. A previous version enabled seeds to resist high salinity in the soil, but the new version is aimed at tackling water shortages.

"We wanted to make a coating that is specific to tackling drought," Marelli explains. "Because there is clear evidence that climate change is going to impact the basin of the Mediterranean area, we need to develop new technologies that can help to mitigate these changes in the climate patterns that are going to make less water available to agriculture."

*Seed coatings could help plants to grow in arid conditions. **(Photo: Felice Frankel)***

The new coating, taking inspiration from natural coatings that occur on some seeds such as chia and basil, is engineered to protect the seeds from drying out. It provides a gel-like coating that tenaciously holds onto any moisture that comes along, and envelops the seed with it.

A second, inner layer of the coating contains preserved microorganisms called rhizobacteria, and some nutrients to help them grow. When exposed to soil and water, the microbes will fix nitrogen into the soil, providing the growing seedling with nutritious fertilizer to help it along.

"Our idea was to provide multiple functions to the seed coating," Marelli says, "not only targeting this water jacket, but also targeting the rhizobacteria. This is the real added value to our seed coating, because these are self-replicating microorganisms that can fix nitrogen for the plants, so they can decrease the amount of nitrogen-based fertilizers that are provided, and enrich the soil."

Early tests using soil from Moroccan test farms have shown encouraging results, the researchers say, and now field tests of the seeds are underway.

Ultimately, if the coatings prove their value through further tests, the coatings are simple enough that they could be applied at a local level, even in remote locations in the developing world. "It can be done locally," Zvinavashe says. "That's one of the things we were thinking about while we were designing this. The first layer you could dip coat, and then the second layer, you can spray it on. These are very simple processes that farmers could do on their own." In general it would be more economical to do the coatings centrally, in facilities that can more easily preserve and stabilize the nitrogen-fixing bacteria.

The materials needed for the coatings are readily available and often used in the food industry already, Marelli says. The materials are also fully biodegradable, and some of the compounds themselves can actually be derived from food waste, enabling the eventual possibility of closed-loop systems that continuously recycle their own waste.

Although the process would add a small amount to the cost of the seeds themselves, Marelli says, it may also produce savings by reducing the need for water and fertilizer. The net balance of costs and benefits remains to be determined through further research.

Although initial tests using common beans have shown promising results by a variety of measures, including root mass, stem height, chlorophyll content, and other metrics, the team has not yet cultivated a full crop from seeds with the new coating all the way through to harvest, which will be the ultimate test of its value. Assuming that it does improve harvest yields under arid conditions, the next step will be to extend the research to a variety of other important crop seeds, the researchers say.

"The system is so simple," Marelli says. "And we can design the seed coating to respond to different climate patterns." It might even be possible to tailor coatings to the predicted rainfall of a particular growing season, he says.

"This is very important work," says Jason C. White, director of the Connecticut Agricultural Experiment Station and a professor of epidemiology at Yale University, who was not associated with this study. "Maintaining global food security in the coming decades will be among the most significant challenges we face as a species. ... This approach fits the description of an important tool in that effort; sustainable, responsive and effective."

White says, "Seed coating technologies are not new, but nearly all existing approaches lack versatility or responsiveness." The new work, he says, is "both novel and innovative," and "really opens a new avenue of work for responsive seed coatings to mediate tolerance to a range of biotic and abiotic stressors." ***(Source: MIT News, David L. Chandler)***

Industry Observation

Phosphorous Is a Finite Resource

so Researchers are Recovering It from Sewage

> *A world without phosphorous is a world without life. Which means that your sewage is valuable muck.*

The phosphorous crisis is perhaps the least well-known emergency in the world today. The Norwegian research news website forskning.no says that many scientists are warning of a state of "Peak phosphorus ".

The adoption of recycling and a circular economy are thus essential if we are to ensure that this vital element is not lost. This is where a research project called Recover comes in. With SINTEF as a research partner, collaborating with NTNU and the Norwegian University of Life Sciences (NMBU), this vital element can be recovered.

"SINTEF's role in the Recover project is primarily to develop wastewater treatment processes that ensure that phosphorous is recovered using as little energy as possible", says Herman Helness, a Senior Researcher at SINTEF.

"We're working on a forward osmosis-based approach that may be suitable for coastal sewage cleaning plants," he says.

A finite resource

Currently, a sludge residue that remains after the cleaning of wastewater is used for spreading on fields to improve soil quality. However, experiments demonstrate that this is not a particularly effective way for soils to exploit the phosphorous and nitrogen contained in the sludge.

Moreover, Norwegian statutory regulations that govern fertiliser manufacture place strict requirements on the treatment and use of sludge. These quality requirements address issues associated with odour, heavy metal concentrations and the removal of bacteria.

"Future regulations will probably place restrictions on farmers' ability to use sludge as agricultural fertiliser due to requirements related to the maximum content of phosphorous in the sludge," says Helness.

"This is a sufficient additional incentive for finding methods that enable the recovery of phosphorous from the sludge and to exploit it more effectively than in the past," he says.

Suitable for coastal sewage cleaning plants

SINTEF has arrived at the idea that forward osmosis may offer opportunities for a more optimal exploitation of phosphorous. During this process, the water molecules move from a solution with a higher water concentration to one with a lower water concentration.

In particular, the method is suited to coastal sewage cleaning plants where high concentrations of salt in the seawater enable water in the wastewater to pass easily through the membrane. All organic particles and elements such as N and P are kept back on the wastewater side.

"The principle of osmosis means that there is no need to input additional energy to achieve the desired effect," explains Helness. "The water that passes into the sea is very well cleaned, and we are left with a concentrated flow of sludge on the wastewater side from which we can recover the phosphorous".

Mitigating water shortages

We have adequate supplies of freshwater in Norway, but water shortages are becoming a growing problem in many parts of the world. Many countries produce fresh water from salt water by using reverse osmosis membrane technology. But this is an energy-intensive process.

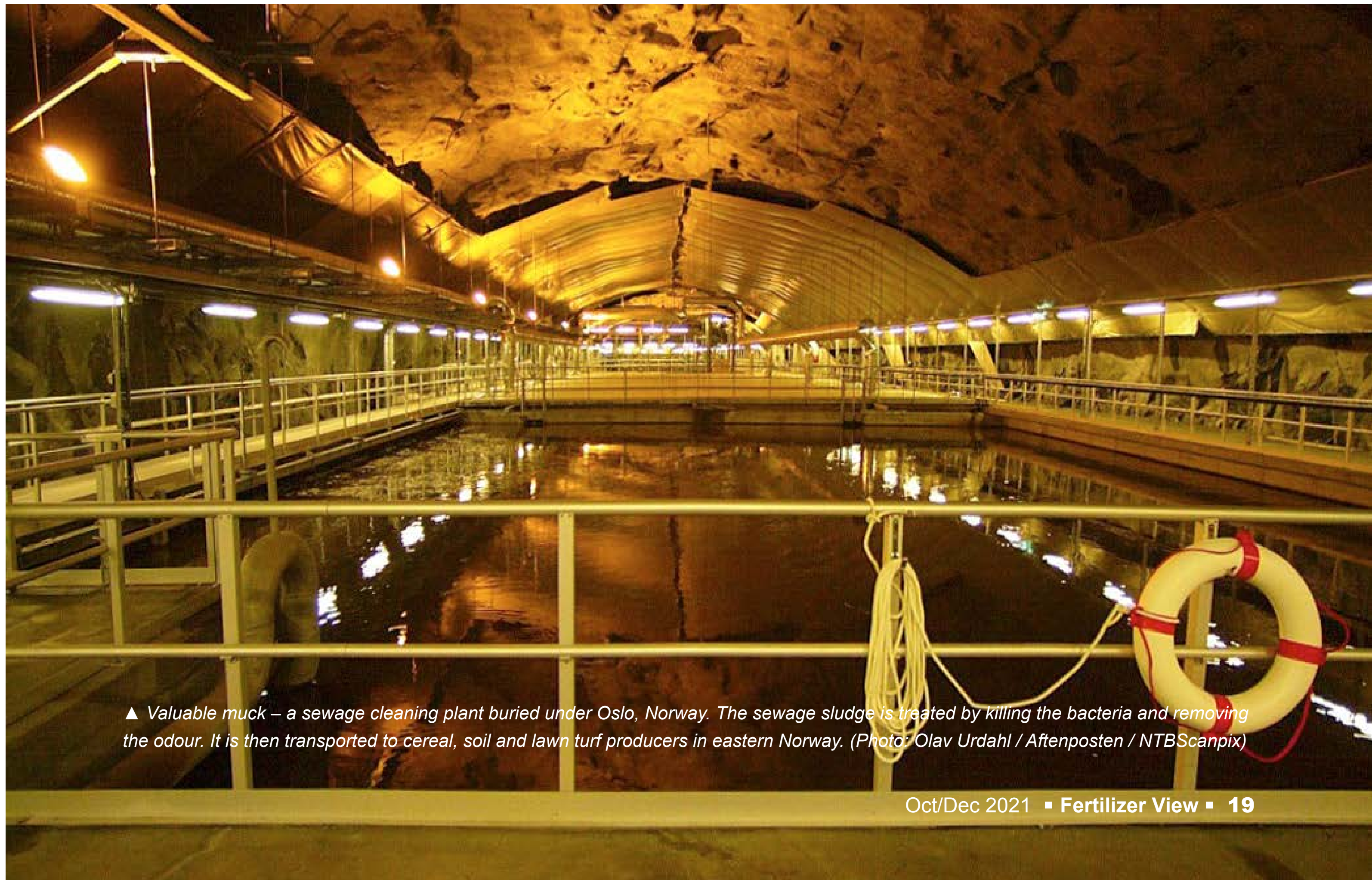
"When the cleaned sewage water mixes with the salt water along the coast, the salt water becomes diluted," says Helness.

"And because there is less salt in this water than in normal sea water, the process of making fresh water is less energy-intensive," he explains.

The researchers are currently working to calculate the costs involved in applying this method. The principle of osmosis means that the wastewater stream, or sludge, is more concentrated. Less volume means that the sewage cleaning plants can be smaller. Less energy is used to recover the phosphorous from the sludge.

For its part, NTNU is conducting experiments on the biological recovery of phosphorous. This method, which is currently being applied at a full-scale plant in Hamar, involves the cultivation of a group of phosphorous-accumulating microorganic bacteria. NTNU aims to optimise this approach.

"Our short-term vision is to adapt Norwegian and global value chains to the idea of resource recycling and achieve a viable market," he says. ***(Source: ScienceNorway, By Lisbet Jære)***



▲ *Valuable muck – a sewage cleaning plant buried under Oslo, Norway. The sewage sludge is treated by killing the bacteria and removing the odour. It is then transported to cereal, soil and lawn turf producers in eastern Norway. (Photo: Olav Urdahl / Aftenposten / NTBScanpix)*

Industry Observation

A Soil Scientist's Perspective:

Carbon Farming, CO_2 Certification & Carbon Sequestration in Soil

Carbon farming is a new buzz word, hotly debated in the EU Commission, in European Ministries and Chambers of Agriculture, and the subject of numerous projects and movements. It is in fact proposed as an ecoscheme by the Commission. So far, however, there is no binding definition of "carbon farming" and there seem to be many different understandings of the term.

What most approaches have in common is the objective of storing carbon in the soil in some way.

In my opinion, when it comes to humus and soils, the focus must be on soil fertility, ecosystem services and greater resilience to climate change, and not on CO2 sequestration, certificate trading and carbon storage.

Considering an isolated factor within an agricultural ecosystem in purely economic terms does not put enough value on ecosystem services and risks incentivising the adoption of one-sided measures.

The priority - Reducing GHG emissions in Agriculture

The lion's share of climate gasses in the atmosphere is caused by the extraction of fossil carbon deposits in solid or gaseous form (energy for industry, transport, heating, cooling, etc.). Agriculture is both a driver of climate change as well as its dramatic victim. And, depending on the type of agricultural system, it has a crucial mitigation potential too.

Agriculture's largest contribution to climate change stems from the production and application of synthetic nitrogen fertiliser. By reducing the use of chemical fertilisers and substituting it with high-quality organic fertilisers, half of all agricultural greenhouse gas emissions could be prevented while simultaneously building humus.

Another major intervention point is the reduction of animal numbers. Because of the humus stored underneath grasslands, this measure in particular would contribute to climate protection. Apart from soils in permafrost regions, peatlands and grasslands contain the largest part of the carbon stored in soils. Protecting these biomes must be a priority. Next to forests, grasslands are the largest biome on our planet and cover about 40 percent of the vegetated land area.

Ruminants are essential for the protection of grassland because only grazed grassland will persist and the more regularly it is grazed, the more humus is built up. Therefore, ruminants cannot just be evaluated according to their methane emissions.

Healthy agricultural soils contribute substantially to the functioning of our ecosystems. What is needed are a high humus content and an active soil life. However, it cannot be the task of agriculture to "capture" greenhouse gases caused by industrial production and permanently store them in soils. An active soil life means humus is built but also always decomposed and transformed (processes that will also release CO2 as well). Soils are not suitable to serve as permanent storage for carbon sequestered from the air.

Climate relevance of carbon sequestration in soils

No one will object to building humus in the world's soils. When done correctly, it will have a positive effect on soil structure and substance exchange. However, it is highly questionable to justify the necessity for more humus in soils by arguing that other industrial sectors should be exempted from doing their homework and reduce CO2 emissions.

This line of argument reduces humus building to a tool in the CO2-certificate logic and that is not an expedient argument, at least not for agriculture. It does not do justice to the huge relevance humus building has for the maintenance of soil fertility, for soil eco-system services and for global food security. To ensure soil fertility, we need living soils with high biological activity and diversity – and this diversity would not exist without decomposition processes.

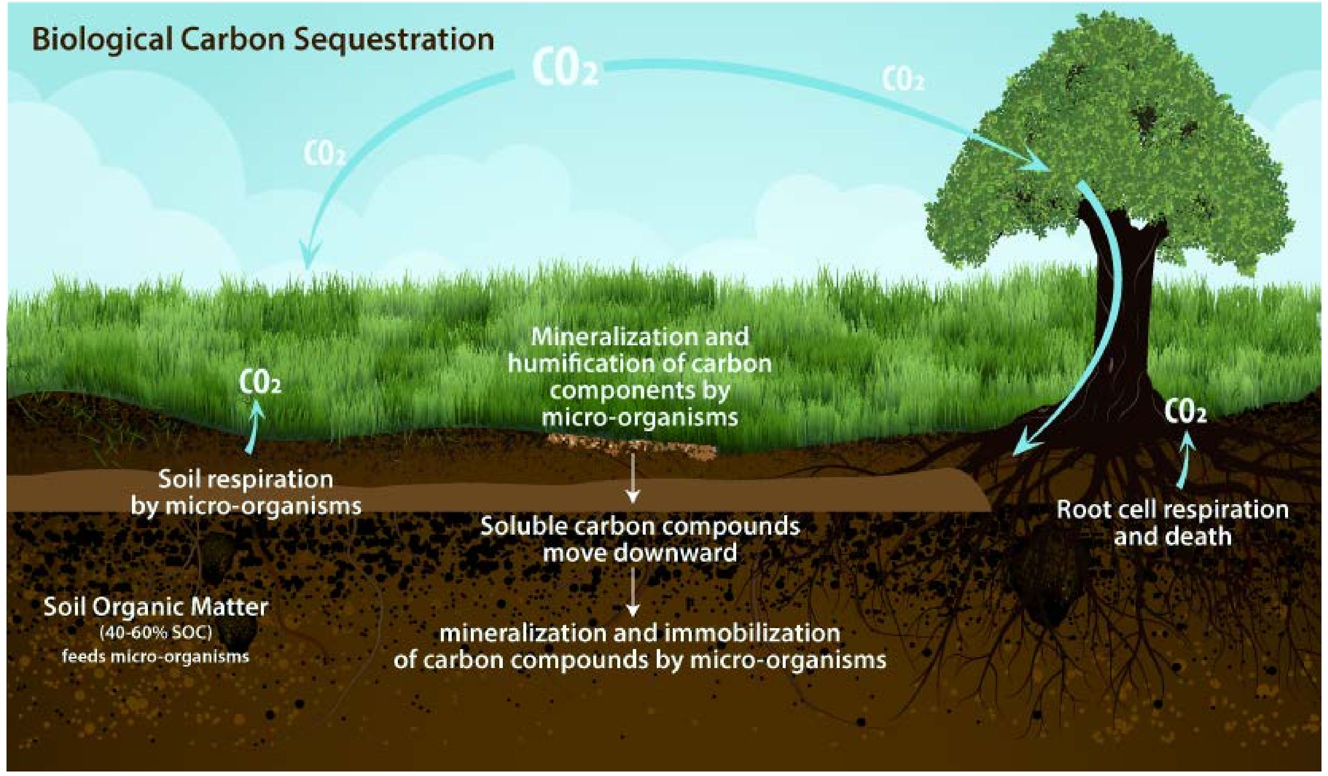
In 2012, the Federal Research Institute for Rural Areas, Forestry and Fisheries (Thünen) in Germany wrote in regard to the potential of carbon sequestration in soils for the purpose of climate protection:

"The additional storage of soil organic carbon in the course of sustainable humus management is generally limited in time and quantity because the humus reservoir develops a new equilibrium. Once soil management is changed again, even organic carbon that may have been stored for decades can be mineralised in a short time".

The Thünen Institute draws the conclusion that building humus is important for soil fertility, erosion protection, groundwater formation and flood protection and it renders agriculture more climate resilient. But it is not suitable for CO2 certificates. This point is reiterated in the Thünen Institute's 2018 response to the "4-Permille Initiative".

In terms of humus building and positive effects on soil ecology, the introduction of "biochar" into the soil is clearly inferior compared to techniques such as a balanced crop rotation with diverse and deep root penetration, permaculture, agroforestry, the recycling of organic matter through the application of solid manure, crop residues and compost. All of these techniques have been tried and tested in agriculture for hundreds of years and organic farmers have optimised them further.

The positive effect of carbon-rich fertilisers in the soil is highly dependent on the form in which the carbon is introduced into the soil. Not every organic fertiliser is suitable for soil life (for example, slurry or large amounts of fresh matter are not beneficial to soil life). Compost is particularly well suited to improve soil, increase its humus content and its fertility. ***(By Andrea Beste, originally published by ARC2020)***



Food and Farming

Could Stymie Climate Efforts, Researchers Say

"The food system emits so much greenhouse gas that the world will exceed international climate targets—even if all other sources are eliminated"

▼ *Tractors, fertilizer, and pesticides all contribute to global warming. (FOTOKOSTIC/ISTOCK)*

Wind power and geothermal heat aren't enough to keep the world cool, according to a new study.

Even if energy, transportation, and manufacturing go entirely green, emissions of greenhouse gases from the food system would put the world on track to warm by more than 1.5°C, a target set in the 2015 Paris climate agreement.

For the world to have a chance of preventing significant harm from climate change, the study authors say, all parts of food production need rapid and significant reform—everything from reducing deforestation for new fields to eating less meat.

Peter Smith, a soil scientist at the University of Aberdeen who was not involved in the work, agrees. "In addition to a complete transition away from fossil fuels in the coming decades, we will also need a dramatic food system transformation."

Michael Clark, a food systems modeler at the University of Oxford, and his colleagues tallied the climate-harming gases likely to be released by agriculture from 2020 to 2100 if it continues with business as usual.

Carbon dioxide comes from many sources, such as cutting down tropical forests to make way for fields and pastures, running farm machinery, and manufacture of agrochemicals. Fertilizer also emits nitrous oxide, another greenhouse gas. And cows release methane, a powerful warming gas, in their burps and manure.

The team assumed no radical changes in how food is produced, but continuing increases in efficiency.

They also took population forecasts from the United Nations and applied standard assumptions about how diets change when nations become wealthier. As incomes rise, people tend to eat more overall and consume more meat, dairy, and eggs—and animal products have a larger climate footprint than plant-based foods.

The researchers then performed a thought experiment in which all other sources of greenhouse gases were immediately halted. Think: a complete transition to electric vehicles, geothermally heated buildings, renewable power, and so on. Given that climate utopia, but no change in how food is produced, the situation is still "very frightening," Clark says.

The simulation suggests the food system alone would contribute enough climate-harming gases that the planet (the hypothetical one with no other emissions, that is) would probably warm above the 1.5°C target sometime between 2051 and 2063, the researchers reported in Science.

Food policy experts and researchers already knew that food production holds sway over warming. For example, the researchers looked in more detail at the impact of methane, which doesn't last nearly as long in the atmosphere as carbon dioxide.

"The good news is that there's a lot we can do," Clark says. "But we have to do a little bit of everything."

The researchers looked at the impact of five agriculture-related strategies. They include boosting crop yields more rapidly, which could reduce deforestation; shifting to diets with fewer animal products; and halving food waste.

None of these strategies alone results in a 67% chance of keeping global warming below 1.5°C, they found, even if all nonfood emissions have been eliminated. But starting right away and making significant progress on all five strategies could put that goal within reach.

That makes sense to Benton. "There is no silver bullet," he says. He also agrees that the threat of climate change demands new attention to how people farm and eat. "The solution is not just about having electric vehicles and photovoltaics. It is also necessarily about dietary change."

(Source: Science, by Erik Stokstad)

Soil Nutrients: The Key to

Meeting the Triple Global Challenge of Food and Nutrition Security, Climate, and Biodiversity

Soils are generally understood to be needed to produce food. Less common is the notion that soils also are crucial to produce nutritious foods, close water and nutrient cycles and serve as a major sink for atmospheric carbon. Moreover, soils are the most important resource for farmers to earn a living.

Despite warnings by the scientific community, decades of undervaluing the importance of soil health and plant nutrition have caused significant soil degradation worldwide. Therefore, heightened attention is needed to regenerate soil health to nutritiously feed the world, mitigate climate change and enhance the resilience of agricultural systems.

Why soil nutrients?

Soil nutrients, primarily nitrogen (N), phosphorus (P), and potassium (K) but also sulphur (S), calcium (Ca), zinc (Zn), iron (Fe), and eight other micronutrients, are building blocks for soil microbes and plants to grow and essential for human health through food consumption. Nutrients are naturally supplied by the soil or can be added via mineral and organic fertilizers. Approximately 50% of all food produced globally is derived from the use of mineral fertilizers, which makes the fertilizer industry a key player in global food and nutrition security. In many parts of the world, mineral fertilizers are used in excess, leading to losses to the environment that must be addressed. On the African continent, however, average fertilizer use is about 10% of the global average, and the continent's soils, particularly those in sub- Saharan Africa (SSA), are among the most nutrient-deficient in the world. The amounts of nutrients applied are less than the amounts extracted by plants, which causes rapid depletion of soil nutrients (up to 50kg of N, P, and K per hectare), degradation of organic matter and increased erosion. This largely explains the continent's low and even declining agricultural production and the resulting downward spiral into hunger and poverty.

In SSA, per capita food production has been decreasing over the past decades, while food imports continue to increase. More than 70-80% of the food production increase in SSA over the past decades has been due to the expansion of agricultural land at the expense of nature and biodiversity. Land clearing is the largest source of greenhouse gas emissions on the continent. Further expansion would be detrimental and has reached its limit in many countries, especially those in the Sudano-Sahelian zone. Therefore, agricultural intensification in

Africa is the only sustainable way forward, as reverting to pre-green revolution farming will not meet the food and nutrition security challenge of the rapidly growing population.

Reinforcing organic or agroecological production systems without raising the overall soil nutrient levels will worsen hunger and poverty on the African continent. The amount of nutrients internal to the current production system that can naturally be supplied by soils to plants is inadequate to raise the crop yields and profitability of farming systems. Efforts should certainly be made in recycling organic waste to complete the nutrient cycle and get nutrients back to farms where they are needed, which will simultaneously prevent nutrient pollution in urban areas and concentrated feedlots, but efficient use of mineral fertilizers in combination with organic amendments in SSA is needed to restore and rehabilitate degraded ecosystems and soil functions for sustainable and profitable food production.

Managing Nutrients

Nutrient use, either mineral or organic, needs particular attention in SSA. Poorly managed nutrient applications can decrease profitability and increase nutrient losses, potentially degrading water and air quality. In contrast, properly managed fertilizers support cropping systems that provide economic, social, and environmental benefits. Optimized use of the Right mineral fertilizers at the Right rate, at the Right time, and in the Right place (the 4R principles), in combination with organic amendments, is the foundation to achieving food system goals, i.e., increased production of nutritious food, increased farmer profitability, enhanced environmental protection, and improved sustainability.

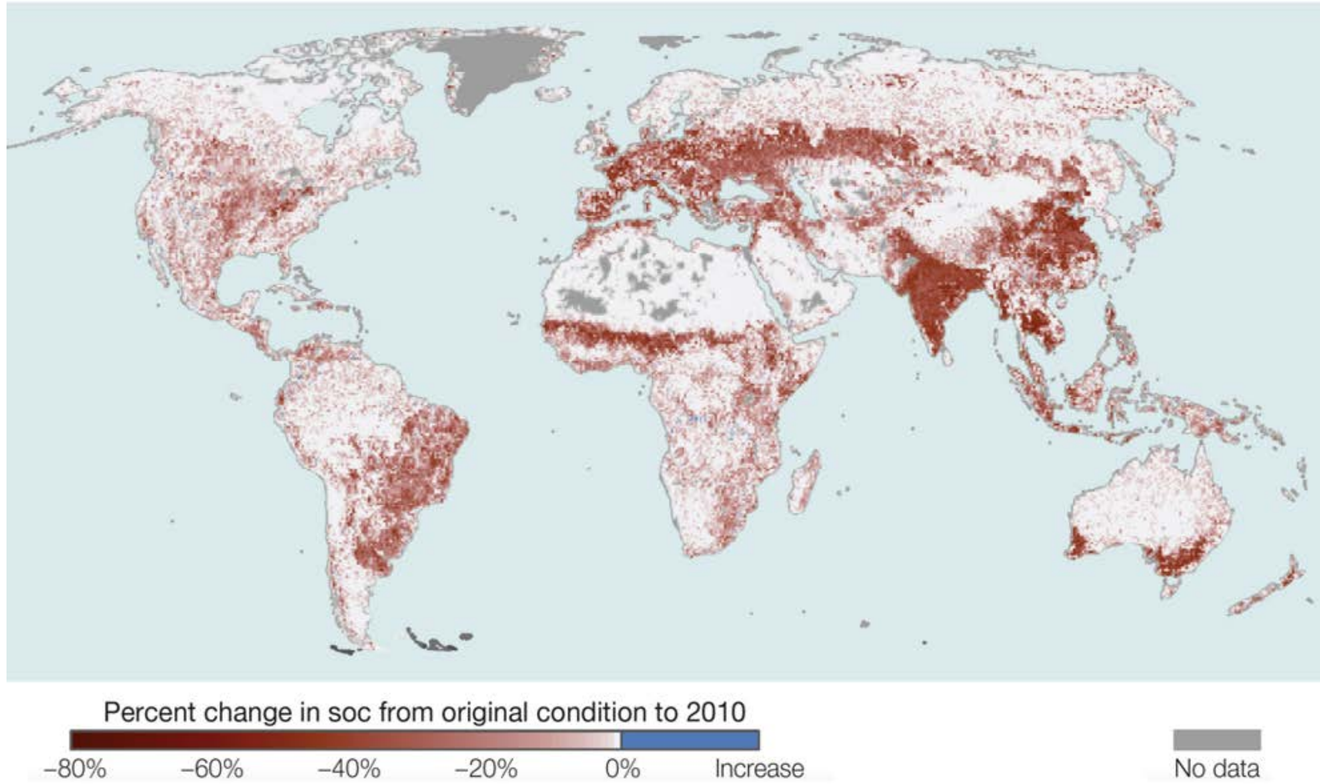
Sustainable food systems produce more with less: increased efficiency of land, water, nutrients, and labor make it possible to increase productivity and profitability per unit area. This prevents unnecessary expansion of agriculture into pristine lands, averting deforestation and loss of biodiversity. Responsible and efficient use of mineral fertilizer protects natural ecosystems from conversion of pristine lands for food and feed production and allows farmers to manage existing food production systems sustainably, to the benefit of both nature and people.

Most currently used fertilizers were developed at least 50 years ago, and their efficiency is largely dependent on their management. Erratic climatic conditions, poor water- and nutrient-holding capacity and therefore low buffering capacity of soils (due to low organic matter content) cause low fertilizer use efficiency with low returns on investments for smallholder farmers in Africa. This hampers farmer adoption.

Increasingly, the public and private sector are collaborating to develop fertilizers and fertilizer recommendations that are better tuned to these location-specific conditions to maximize efficiency. Yet, novel, climate-smart, and higher efficiency fertilizers, and management practices and products that utilize integrated fertilizers, organic amendments, and biofertilizers will also be needed to enhance uptake by plants, reduce losses to the environment, and improve soil health. While some novel products are available or underway, public and private sector partners must increase investment in the development of smart fertilizers that feed soils, plants, and people safely with minimal trade-offs.

Soil Carbon

A strong driver of soil health and productivity is the amount of soil organic matter (SOM) contained in the soil. Since most soils on the African continent have low SOM content, often only 0.5-1.0% or even less, any improvement on SOM will have direct beneficial effects. Building and restoring SOM is key to improving soil health and productivity. The most effective and sustainable way to sequester carbon (C) is with in-situ SOM buildup – most practically with root biomass and crop residues, in combination with tree crops when feasible. An aboveground biomass of 10 metric tons (mt) produces 2-3 mt of root biomass and 4-5 mt of crop residue throughout the crop cycle, but to produce this biomass, most soils in SSA will require enhanced soil nutrient levels via mineral fertilizers. The principles of regenerative agriculture remain important, but the limited amount of nutrients in most African soils cannot catalyze this process of additional biomass production and, therefore, more SOM. There will be no increase in SOM and no improvement in soil health without external nutrient input. To store soil C, we need carbon from the atmosphere (C), nitrogen (N), phosphorus (P), and sulfur (S) at a ratio of roughly C:N:P:S = 100:10:1:1. Soil C sequestration may be feasible at an annual rate of 100-300 kg C ha^{-1} when accompanied by mineral fertilizer amendments of 10-30 kg N ha^{-1}, 1-3 kg P ha^{-1}, and 1-3 kg S ha^{-1} (though part of the S may come from deposition). Therefore, we must raise the ecosystem carrying capacity through improving soil fertility and soil health by increasing SOM through external nutrient input, namely, mineral fertilization.



This map demonstrates decline in soil organic carbon (SOC), an indicator of soil degradation, relative to an estimated historical condition that predates anthropogenic land use.

Global carbon trade is in its infancy, but it has the potential to become part of the solution. New methods to aggregate carbon credits from millions of smallholder farmers and new satellite imagery-based technologies for third-party verification of increases in soil organic matter stocks, will create on opportunity for the fertilizer industry to buy carbon credits, leading to new financial flows to support African farmers with input and/or market access financing, and to drive pre-investments for the buildup of soil organic matter and healthy soils. This opportunity has great potential to contribute to the triple challenge of food and nutrition security, climate mitigation, and resilient food systems. While global carbon pricing mechanisms are being developed, leading IT and logistics companies have become frontrunners in voluntary investments in carbon credits, increasingly supported by the banking sector; this may be source of inspiration for the fertilizer sector.

Plea for collective soil health investments

Soil restoration and rehabilitation is 10 to more than 100 times slower and more difficult to attain than degradation of soil and soil organic matter. So how do we ensure food and nutrition security and protect our ecosystem? Science, evidence-based data, and decision support tools can identify management scenarios and their outcomes for specific land and cropping/grazing systems. Such tools utilize data on soil properties, hydrology, topography, weather, and land capability classification to assess the suitability of a given land and, when combined with modeling, determine the long-term productivity and sustainability of a given practice. Land planners, policymakers, and the private sector, guided by global bodies, must act on those recommendations, considering social, economic, and cultural issues and balancing trade-offs. In the end, we researchers, implementers, governments, and other partners are responsible for maintaining the health of this resource.

Ample scientific evidence shows that more and better fertilizers are needed on the African continent to develop farming systems that guarantee food and nutrition security, mitigate climate change, and protect the environment. This will require coordinated action from governments, industry, the research community, and donors/investors to positively impact the livelihoods of 2 billion people in Africa by 2050. It can be done – together! ***(Source: IFDC, by Prem Bindraban, Rob Groot, and Upendra Singh)***

International View

The World's Smallest Farms

Feed More People Than You Might Think, Research Shows

• 81% of global crops are grown on farms less than 199 hectares.

• China leads the world production of rice, wheat and many vegetables and operates mainly small farms, to supply its own growing population

• Big farms have a minority share in crop production, only contributing to 5% of worldwide crop growth.

84 percent of a total of estimated 570 million farms worldwide were cultivating less than two hectares of agricultural land in 2018.

Due to the low labor productivity and grueling work conditions on small farms, their yield stands in stark contrast to their total numbers: Only 29 percent of the global production of crops for food, animal feed and fuel come from land cultivated by smallholders according to Our World in Data.

As our chart shows, most of the crops still are generated on farms smaller than 200 hectares or 500 acres though.

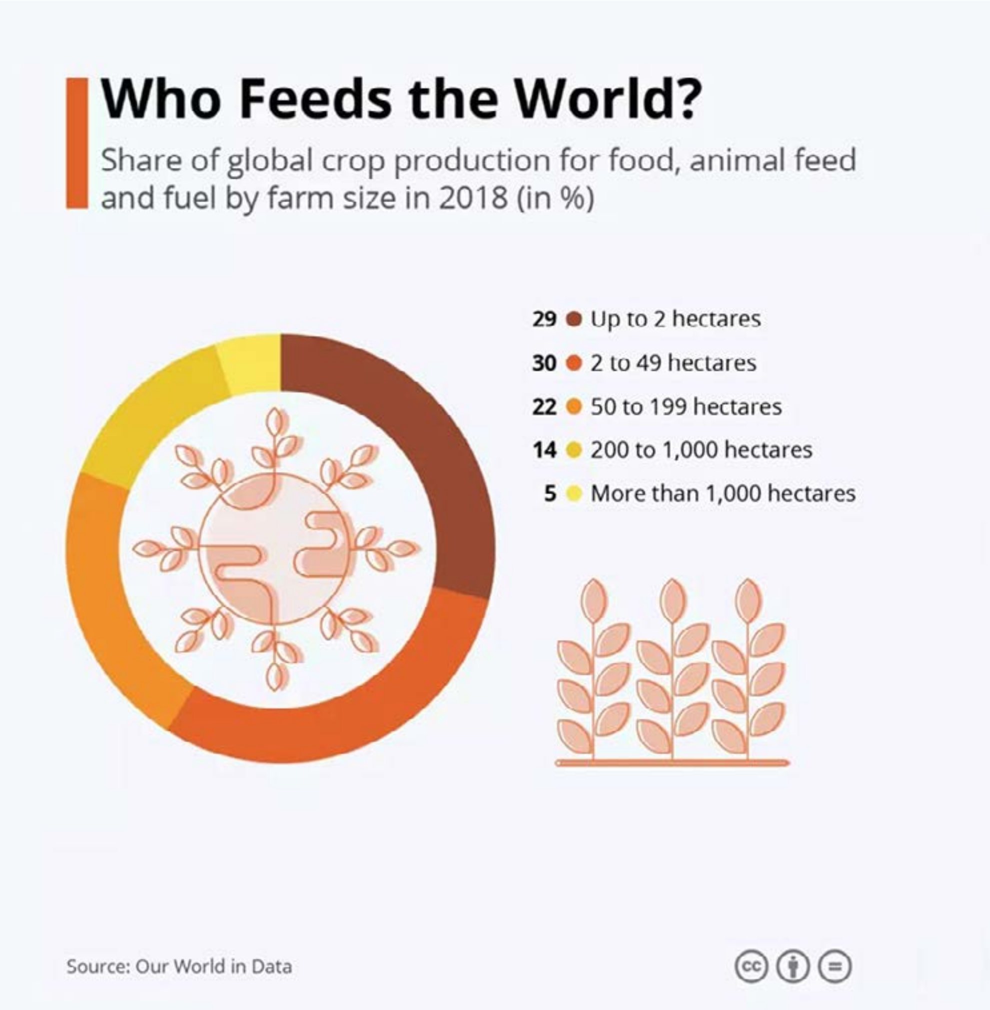
Roughly 81 percent of all food, feed and fuel crops were grown on farms of up to 199 hectares. Taking into account the average farm sizes of the biggest crop producing countries in the world, this number becomes less surprising.

China leads the world production of rice, wheat and many vegetables and operates mainly small farms, often smaller than half a hectare, to supply its own growing population.

The roughly two million farms in the U.S., which is the biggest producer of maize, soybeans and almonds, have an average size of 444 acres or 180 hectares on the other hand. Only five percent of the total amount of crops are grown on big farms larger than 1,000 hectares like the family farm of world-leading almond and pistachio producers Stewart and Lynda Resnick with roughly 77,000 hectares or 190,000 acres.

This divide also shows a discrepancy in terminology: The term "family farms" is often used to describe smallholdings, while in reality, it can be any farm owned by one individual or a group of individuals where the labor is mainly supplied by the family. *(Source: World Economic Froum, by Florian Zandt, Data Journalist, Statista)*

▲ *Small farms worldwide contribute to the majority of crops produced, like this worker who is harvesting grapes with little space or machinery. (Image: REUTERS/Pascal Rossignol)*



Brazil Starts Planting

Grain Crop with Forecast of a New Record

A Brazilian soybean farm. ***(Photo: Charlesricardo / Pixabay)***

Farmers in Brazil began planting in September for what is expected to be a recording-breaking 2021-2022 harvest. The projection from CONAB (National Supply Company in Brazil) projects farmers will produce 289.6 million tons of soybeans, corn, cotton, rice, and beans – accounting for nearly 95% of the total grain produced in Brazil.

About 99 million acres are expected to be devoted to soybeans, and about 51 million acres to corn, both records. The projections are based on high international prices and profits in 2021, depreciation of the Brazilian real relative to the U.S. dollar, an expected increase in exports, and the profitability forecast for 2022.

Market Scope

Soybean Acreage and Production

Brazil is likely to remain the world leader in soybean production in the next crop year, followed by the United States and Argentina. Brazilian soybean acreage is expected to grow 3.6%, to 98.62 million acres, according to CONAB.

Most of the acreage increase is expected to be the conversion of pasture to soybean acre. The 2021-2022 soybean crop in Brazil is projected to be 5,190 million bushels, the highest in the history, an increase of 3.9% over the previous harvest (Figure 1).

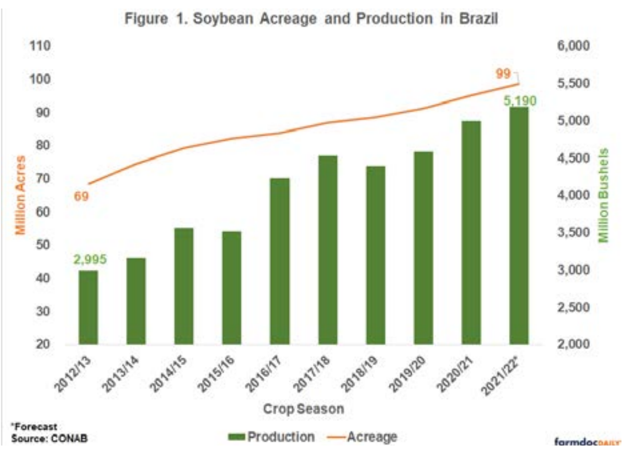


Figure 1: Soybean Acreage and Production in Brazil (2012-2021). ***(Source: CONAB)***

Historically high prices and profits in 2021, coupled with optimistic expectations for the next harvest and the depreciation of the real relative to the dollar, are motivating farmers to increase the acreage they plant.

It is important to highlight that the price of soybeans in the Brazilian market is formed by the three following factors: international prices, port premium, and the dollar. All three factors are expected to remain high in 2022 because of the low world stock-to-consumption ratio, and the increase in domestic consumption.

As a result, Brazilian soybean exports and the crush are expected to increase in 2022, driving the increase in acreage planted. The demand for more biodiesel fuel and the high consumption of animal feed also are expected to fuel domestic demand in Brazil next year.

The soybean crush is projected at 1,891 million bushels, a 10.7% increase over this year. Chinese demand and a weak real with a strengthening U.S. dollar will drive an increase in soybean exports. Soybean sales are projected to reach 3,218 million bushels next year, 5 percent higher than this year, according to CONAB report.

Factors that could lower production for next year's soybean crop revolve around weather. Last year, a lack of rain during the planting season delayed the harvest, and the harvest, in turn, was delayed because of excessive rainfall. Despite the weather, Brazil harvested 4,994 million bushels, a record.

Corn Acreage and Production

The 2021-2022 corn crop in Brazil is expected to increase by 3% for an estimated 50.9 million acres planted to corn, according to CONAB. High prices and lower corn supplies in Brazil this year because of weather problems are the main factors behind the projection. Drought reduced safrinha production – corn as a second crop – by 20%. As a result, corn production is expected to increase 33.8% in the next harvest, producing a record 4,563 million bushels (Figure 2).

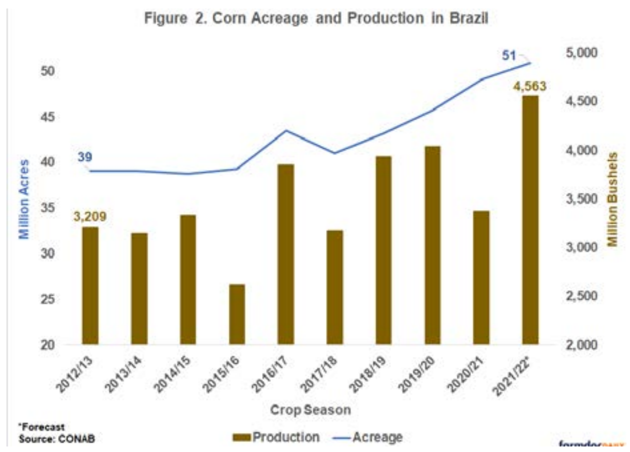


Figure 2: Corn Acreage and Production in Brazil (2012-2021). ***(Source: CONAB)***

The increase in corn acreage should be more significant in the second crop (safrinha), because the increase in soybean production will limit the acreage planted in corn initially. The safrinha crop accounts for 71.7% of the total corn planted area, followed by first crop (26.7%) and third crop (1.6%). Over the past 20 years, second-crop corn production has risen thirteenfold, according to CONAB. In recent years, a third-crop corn season has emerged in north and northeastern Brazil.

The motivation to plant corn in Brazil mainly comes from this year's attractive prices. The cash price for a 60 kg bag of corn has risen more than 100% in 12 months. The uptick in the price of corn in Brazil is directly related to internal and external factors. Corn futures in Chicago this year were the highest since June 12, surpassing $6 bushel.

In addition to high international prices, domestic grain demand in Brazil is expected to remain high in 2022 because of the need for animal feed and for ethanol. Ethanol producers in Brazil's Midwest project increased demand for corn over the next 12 months. In addition, Brazil is expected to remain one of the largest suppliers of chicken and pork to Asia and the Middle East.

Possibility of La Niña

Spring planting started officially in Brazil on September 16 in states such as Mato Grosso, Goiás, and Paraná. The 2020-21 crop year was a hard one for farmers in South America to handle, especially in Brazil. The expectation is that the weather will be more favorable to agriculture this season. The risk of occurrence of the La Niña phenomenon is 70% this year, and the trend is for it to be of low intensity, according to the forecast from Climatempo, a private weather company in Brazil.

The rainy season typically is shorter during a La Niña event – as happened during the 2020-2021 growing season. La Niña-influenced weather also increases the risk of frosts and freezes. Beneficial rains have fallen the past two weeks in the southern states of Rio Grande do Sul and Paraná. The wet season in Mato Grosso, the nation's largest producer of corn and soybeans, typically begins about Sept. 26.

A distinct wet-dry season in Midwestern Brazilian states makes it possible to plant soybeans in the spring and corn in the summer, both in the same area. Soybeans, for example, are planted from September to November and harvested from January to March. The safrinha is planted after soybean season and harvested from June to August. Corn as a second crop is not possible in extreme southern Brazil because of lower winter temperatures. ***(Source: AgFax, by Joana Colussi and Gary Schnitkey)***

Market Scope

Global Fertilizer Prices

Hit a 12-year High

Since the beginning of this year, global fertilizer prices have skyrocketed due to the increase in global food planting area and the increase in chemical fertilizer demand, while the new supply has decreased.

In addition, due to rising energy costs in Europe and other regions and other factors, fertilizer prices have risen to a historical level that has never been seen in the market since the global financial crisis, setting a 12-year high.

According to statistics, the price of monoammonium phosphate increased by 68.78% from the beginning of the year; the price of diammonium phosphate increased by 39.38% from the beginning of the year.

North America

In North America, the index measuring North American fertilizer prices soared to a record high.

This not only further pushes up farmers' planting costs, but may also exacerbate the deteriorating food inflation around the world.

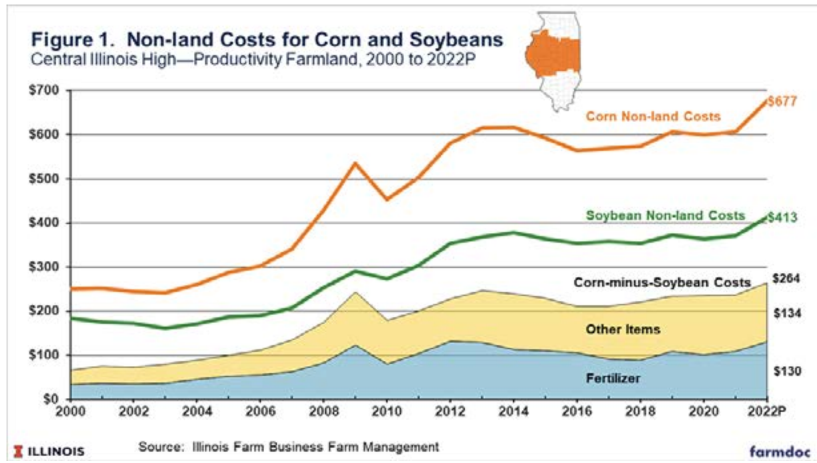
As growers prepare to declare fertilizer purchases in the fall, the price of anhydrous ammonia in the US corn belt has soared.

In addition, the prices of other fertilizers have also risen sharply. The futures transaction price of diammonium phosphate is US $682.50/ton, which has risen 74.3% so far in 2021, and the cumulative increase in the last 12 months is 91.2%.

According to data from the United States Department of Agriculture, the cost of corn fertilizer in Illinois is currently about US $165 per acre, compared to about US $140 this spring, and US $85 to US$90 before 2020.The sharp increase in the price of chemical fertilizers will burden farmers.

Bloomberg writers Kim Chipman and Elizabeth Elkin reported that, "Skyrocketing fertilizer prices could lead U.S. corn profits to drop by about a quarter next year, potentially motivating farmers to shift millions of acres into less cost-intensive soybeans.

"That's according to Terry Roggensack, agriculture specialist and co-owner of the Hightower Report. He predicts corn returns on an operating-cost basis for producers in the U.S., the world's biggest producer, could plummet to roughly $430 an acre. That compares with about $600 this year. The yellow grain uses more fertilizer than other crops like soybeans and wheat."



(Schnitkey, G., C. Zulauf, K. Swanson and N. Paulson. "2022 Planting Decisions, Nitrogen Fertilizer Prices, and Corn and Soybean Prices." farmdoc daily (11):145, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, October 19, 2021).

"Current 2022 estimates of non-land costs for high-productivity farmland in central Illinois are $677 per acre for corn and $413 per acre for soybeans. The $677 per acre estimate for corn is $70 higher than the $607 cost for 2021. The $413 estimate for soybeans is $42 per acre higher than the $371 cost for 2020."

Canada, as the world's largest exporter of rapeseed and a major wheat producer, saw the largest increase in fertilizer prices since 2015 in the second quarter of this year.

According to the agricultural input price index compiled by the Canadian government agency, the total cost of agricultural inputs, including machinery, seeds and feed costs, rose to the highest level since at least 2002 in the second quarter.

Europe

At the same time, the European energy crisis caused the price of natural gas to skyrocket, and the fertilizer industry was severely affected, which has forced a number of nitrogen-fertilizer plants to halt or curtail production, including the likes of Norway's Yara International ASA and top European chemicals company BASF SE. The gas makes up 80% of the cost to produce the nutrients and prices are four to five times higher than normal, according to industry group Fertilizers Europe.

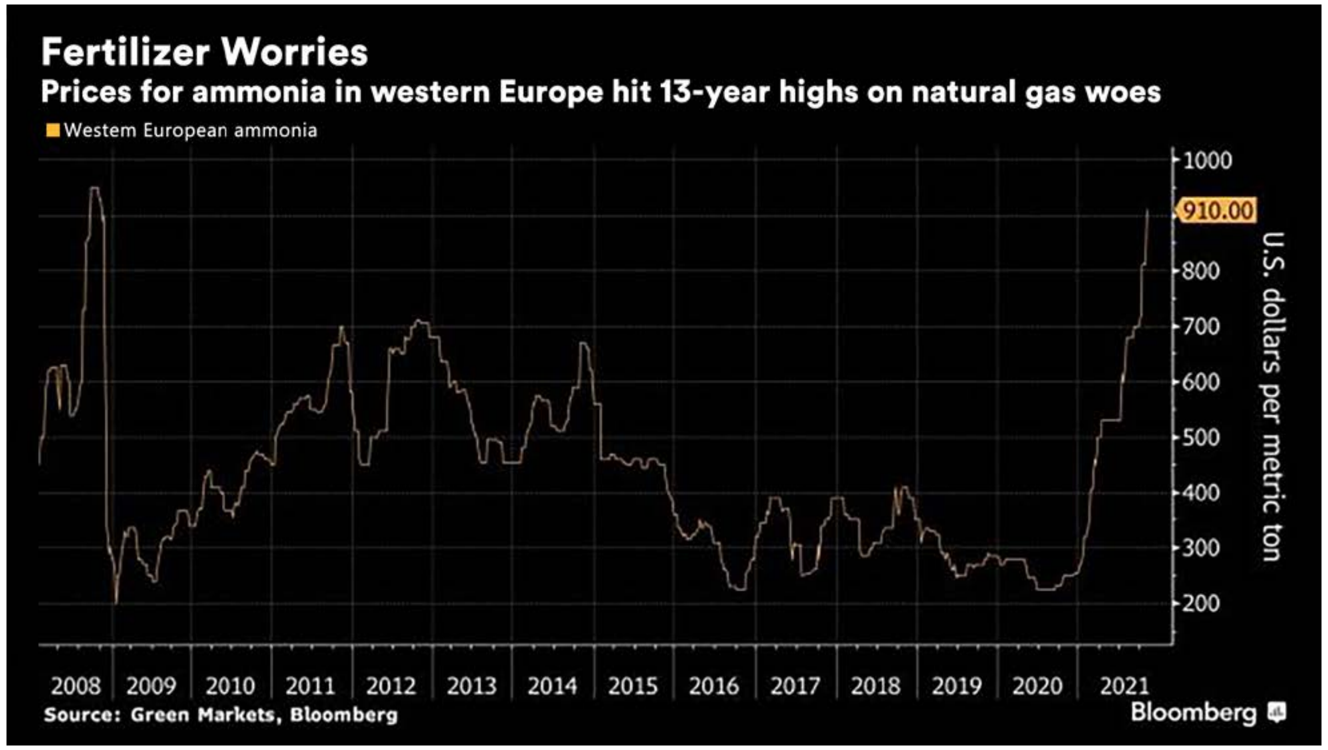
As the price of natural gas rises, the profit of the chemical fertilizer industry has been compressed, resulting in tight supply.

Local farmers are already fretting about securing enough supplies for the spring. Any scarcity risks curbing grain yields and quality in the European Union, the world's biggest wheat exporter and a major barley supplier. Any drops in output could add to concerns about rising food prices.

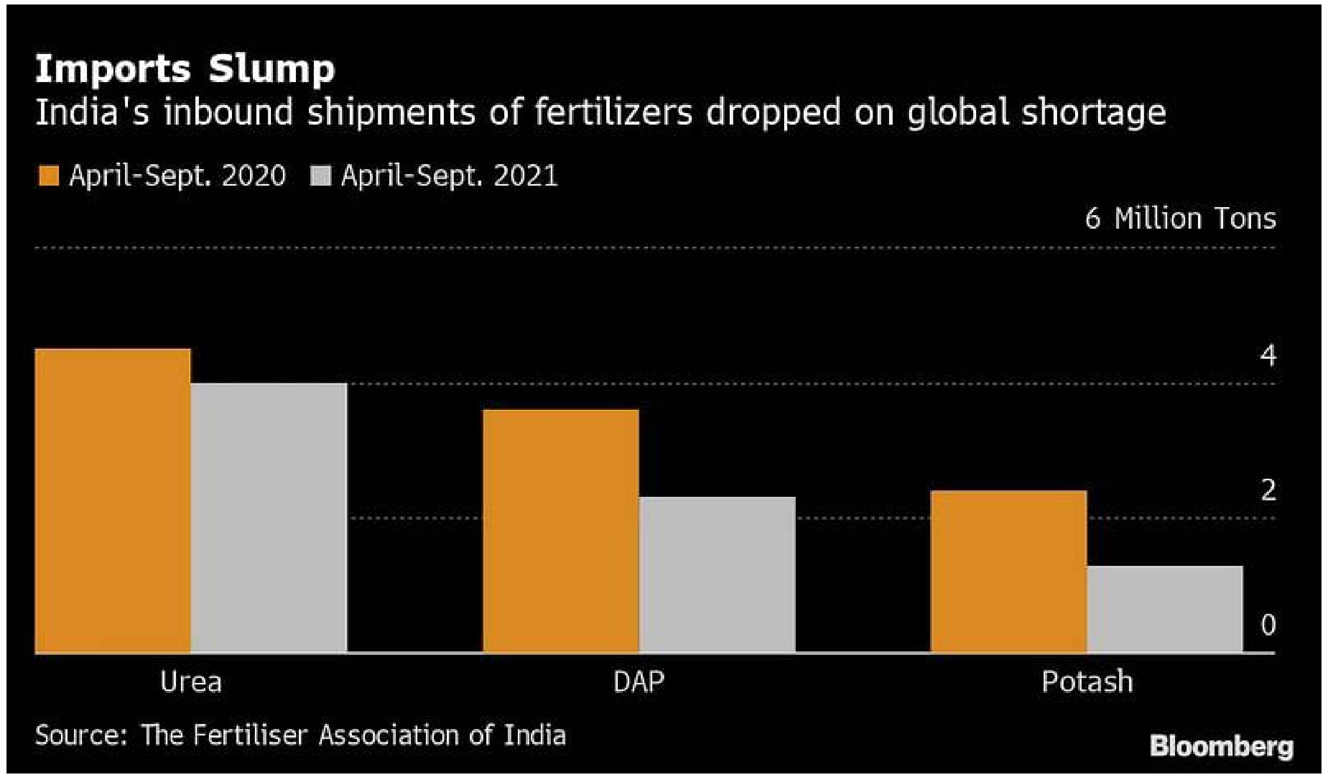
Corn prices have been rebounding over $5.50 a bushel, well over the five-year average around $4.34.

In Europe, France is the EU's largest food producer and exporter. Its fertilizer prices have more than tripled in the past year, which is equivalent to an increase in planting costs of 300 to 350 euros per hectare of crops. The planting cost is about 150 euros.

The crop office under the French Ministry of Agriculture said that due to the soaring fertilizer prices and tight market supply this year, the cost of French crop planting has increased, causing some farmers to stop planting corn next spring and instead plant some crops that do not rely on chemical fertilizers, such as spring wheat or sunflowers.



*BC Fertilizer Prices Are Getting More Expensive in Europe Adding to Food Inflation Concerns , **(Elizabeth Elkin and Megan Durisin)***



The export curbs by China, one of India's top suppliers, have left the South Asian nation with very few options for fertilizer supplies.

Asia

China controls about one third of the world's fertilizer market share, because of the world shortage, China has implemented a series of measures that either ban or further restrict exports to ensure that their domestic prices and supply remain stable for 2022.

India is one of the worst affected by worldwide fertilizer crisis.

India imports up to a third of its fertilizers and is the world's biggest buyer of urea and di-ammonium phosphate, known as DAP. The supply crunch will likely hurt production of staple crops such as wheat, rapeseed and pulses planted during the winter.

India is boosting its own fertilizer production and working on long-term deals with suppliers to curb price increases, according to people familiar with the matter.

The federal government has started making weekly allocation of fertilizers to districts based on demand to prevent hoarding by retailers and farmers amid low stockpiles. On the same time, talks are ongoing with countries such as Oman, Jordan, Morocco and Russia for long-term supplies.

Indian farmers squeezed by a massive shortage of fertilizers are turning to the black market and paying exorbitant prices for supplies.

On the black market, subsidized crop nutrients are sold illegally at prices much higher than levels set by the government. A 45-kilogram bag of di-ammonium phosphate is selling for 1,500 rupees ($20), above the maximum retail price of 1,200 rupees, farmer Patidar said. A bag of urea costs as much as 400 rupees compared with the usual price of 266 rupees.

Thailand must rely on imported fertilizers, including urea, diammonium phosphate and potassium, whose prices have risen sharply.

At present, the urea in the Thai market is only enough to be used until the end of October this year. Due to the high price, market purchases have almost disappeared.

According to the retail price data collected by the Ministry of Agriculture and Cooperatives of Thailand from fertilizer operators, the price of all formulated fertilizers this year is at the highest level in 12 years.

The use of chemical fertilizers in Thailand is expected to increase, especially for rice, rubber, cassava, oil palm, and Forage corn, these five crops, are included in the government's income guarantee program.

Africa

Food insecurity in the region - where several conflicts in the Horn of Africa, climate change and socio-economic conditions are already a cause for worry - is about to get worse as the global price of fertiliser soars.

Economists from the World Bank have warned that high fertiliser prices could exert inflationary pressures on food prices, compounding food security concerns at a time when the Covid-19 pandemic and drought induced by climate change are making access to food more difficult.

According to the World Bank's latest Commodity Markets Outlook released on Monday, skyrocketing fertiliser prices "will see more rationing, as farmers are forced to use less because it's too expensive", potentially disrupting food production and supply, especially for staples like maize.

Prices are being driven by surging energy costs, supply restrictions and trade policies.

Globally according to the analysis, the price of DAP (diammonium phosphate), the world's most widely used phosphorus fertiliser, has steadily gone up from a monthly average of $603.1 per metric tonne in August to $643.8 in September and $672.9 in October.

The price of TSP (triple superphosphate) jumped from $555 per metric tonne in August to $573.8 in September and $618 in October.

A spot check of prices in Kenya this week showed that a 50kg bag of fertiliser now costs between Ksh 4,000 ($35.67) and Ksh 5,000 ($44.58) up from Ksh 3,000 ($26.75) to Ksh 3,800 ($33.88) in May.

In Rwanda, the DAP 50kg bag of fertiliser retails for Rwf 31,650 ($31.04) from Rwf 30,750 ($30.16) three months ago. The price of a 50kg bag of urea fertiliser increased from Rwf 22,500 ($22.07) to Rwf 28,000 ($27.46) in the same period while NPK fertiliser prices increased from Rwf 32,500 ($31.87) to Rwf 35,900 ($35.21) per 50kg.

South America

Brazil is the world's fourth largest consumer of fertilizers (behind China, India, and the United States).

But Brazil produces only 2% of the world's fertilizers and thus is highly dependent on importing these products, usually imports about 80% of its fertilizer requirements.

Brazil imports 94% of its potassium, 76% of its nitrogen – used heavily on corn fields – and 55% of its phosphorus.

According to the National Association for the Diffusion of Fertilizers, around 32 of the 40 million tons of fertilizers delivered to Brazilian farmers in 2020 came from the international market.

Soaring fertilizer prices will impact Brazil's largest corn crop, which will be planted starting in January 2022, after the soybean harvest. Many farmers haven't guaranteed their fertilizer needs yet for the second crop corn, known as "safrinha".

In Brazil, fertilizer prices are rising to near historical levels, causing uncertainties relative to the 2021/2022 crop. For example, from January to September 2021, the exchange ratio of a 60 kilogram (kg) bag of safrinha corn to NPK (nitrogen, phosphorus, and potassium) and urea for one hectare increased 92% and 60%.

About 70% of farmers' fertilizer needs for planting the safrinha corn next year have been negotiated as of the end of October. In Mato Grosso, Brazil's largest corn-producing state, the percentage is 90%.

Despite the increase in fertilizer imports, with planting starting in January 2022, there is a risk of farmers not receiving the product on time.

Even so, this should not affect the projected planting area for the safrinha in 2022. Planting is expected to total a record of 39.20 million acres, an increase of 5.8% in relation to the last harvest.

If fertilizer is not available, Brazilian farmers will likely reduce, even forgo, fertilizer. Failure to apply fertilizer at the right time for corn planting can reduce the volume and quality of the country's grain harvest.

However, lower yields can be offset by the lower cost, balancing the producer's profit.

Nutrien Ltd., one of the world's biggest fertilizer suppliers, will build four blending facilities in Brazil that will more than double its capacity in the nation.

Nutrien delivered a record 1 million tons of fertilizer in Latin America so far this year, heading for 1.2 million tons total in 2021.

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How Some Crops Replenish

Their Own Fertilizer Through Bacteria in Their Roots – A Surprisingly Complex Interaction

Plants need nitrogen in the form of ammonium if they are to grow. In the case of a great many cultivated plants, farmers are obliged to spread this ammonium on their fields as fertilizer. Manufacturing ammonium is an energy-intensive and costly process — and today's production methods also release large amounts of CO_2.

However, a handful of crops replenish their own supply of ammonium. The roots of beans, peas, clover, and other legumes harbor bacteria (rhizobia) that can convert nitrogen from the air into ammonium. This symbiosis benefits both the plants and the rhizobia in an interaction that scientists had until now seen as relatively straightforward: the bacteria supply the plant with ammonium; in return, the plant provides them with carbonaceous carboxylic acid molecules.

A surprisingly complex interaction

Under the leadership of Beat Christen, Professor of Experimental Systems Biology, and Matthias Christen, a scientist at the Institute for Molecular Systems Biology, ETH researchers have now succeeded in demonstrating that the plant-bacteria interaction is in fact surprisingly complex. Along with carbon, the plant gives the bacteria the nitrogen-rich amino acid arginine.

"Although nitrogen fixation in rhizobia has been studied for many years, there were still gaps in our knowledge," Beat Christen says. "Our new findings will make it possible to reduce farmers' dependence on ammonium fertilizer, thereby making agriculture more sustainable."

Using systems biology methods, the researchers investigated and unraveled the metabolic pathways of rhizobia that cohabit with clover and soya. Joining forces with ETH Professor Uwe Sauer, they verified the results in growth experiments with plants and the bacteria in the lab. The scientists suspect that their new findings will apply not just to clover and soya, and that the metabolic pathways of other legumes are regulated in similar fashion.

A battle royal, not a voluntary symbiosis

The findings shed new light on the coexistence of plants and rhizobia. "This symbiosis is often misrepresented as a voluntary give and take. In fact, the two partners do their utmost to exploit each other," Matthias Christen says.

As the scientists were able to demonstrate, soya and clover do not exactly roll out the red carpet for their rhizobia, but rather regard them as pathogens. The plants try to cut off the bacteria's oxygen supply and expose them to acidic conditions. Meanwhile, the bacteria toil ceaselessly to survive in this hostile environment. They use the arginine present in the plants because it enables them to switch to a metabolism that does not require much oxygen.

To neutralize the acidic environment, the microbes transfer acidifying protons to nitrogen molecules taken from the air. This produces ammonium, which they get rid of by conducting it out of the bacterial cell and passing it on to the plant. “The ammonium that is so crucial for the plant is thus merely a waste product in the bacteria’s struggle for survival,” Beat Christen says.

Converting molecular nitrogen into ammonium is an energy-intensive process not only for industry but also for rhizobia. The newly characterized mechanism explains why the bacteria expend so much energy on the process: it ensures their survival.

Biotechnology: paving the way to sustainable agriculture

Agriculture and biotechnology will be able to use this new insight to transfer the process of bacterial nitrogen fixation to non-leguminous crops, such as wheat, maize, or rice. Scientists have made many attempts to achieve this transfer, but have always met with limited success because an important piece of the metabolic puzzle was missing. “Now that we’ve mapped the mechanism down to the last detail, this is likely to improve our chances of achieving a favorable result,” Beat Christen says.

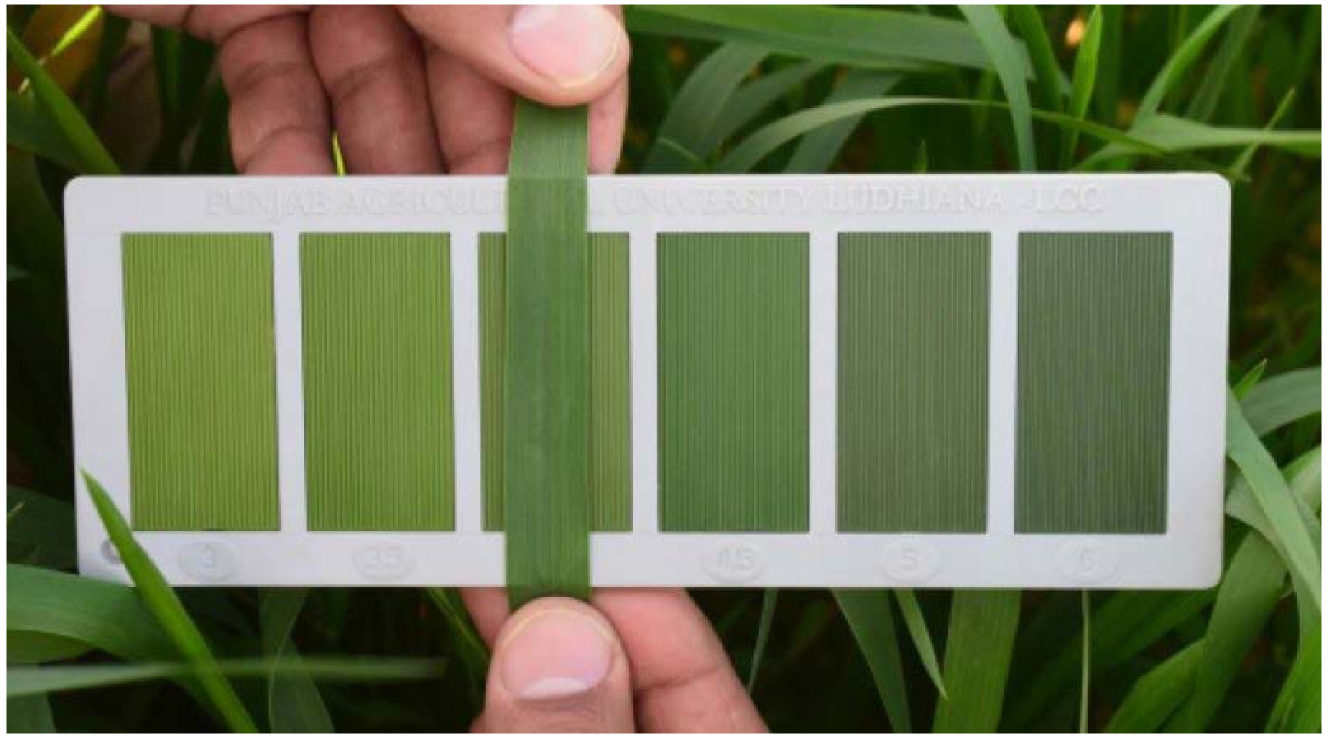
One possible approach is to use biotechnological methods to insert all genes necessary for the metabolic pathway directly into the crops. Another line of action would be to transfer these genes into bacteria interacting with the roots of wheat or maize. These bacteria do not currently convert nitrogen in the air to ammonium, but biotechnology has the means to make it happen — and the ETH researchers will now pursue this approach. *(Source: SciTechDaily, By ETH Zurich)*

Reference: “Co-catabolism of arginine and succinate drives symbiotic nitrogen fixation” by Carlos Eduardo Flores-Tinoco, Flavia Tschan, Tobias Fuhrer, Céline Margot, Uwe Sauer, Matthias Christen and Beat Christen, 3 June 2020, Molecular Systems Biology.

Rhizobia (in blue) in the roots of a plant. The brown structures are plant proteins (colored electron microscope image). Credit: ETH Zurich / Anne-Greet Bittermann

Could Genetically

Engineered, Nitrogen-Fixing Crops Replace Polluting Synthetic Fertilizers?

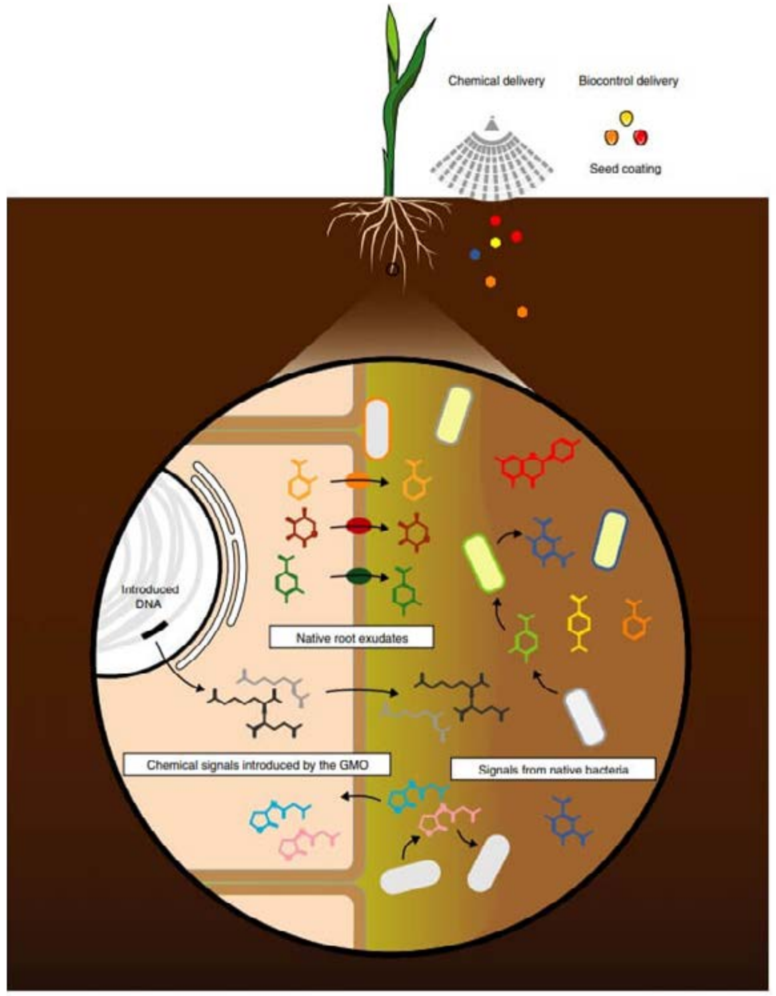


Credit: Trends in Plant Science

To keep food affordable and protect the environment, crop plants need just the right amount of nitrogen, but this is a challenge for both farmers and scientists. Too much nitrogen fertilizer on crops pollutes rivers and well water and its cost makes food more expensive. With too little nitrogen, yields decrease and the imbalance between supply and demand makes food more expensive. Higher grain prices can also make it more profitable to clear tropical forests for agriculture.

Biological nitrogen fixation is a potential solution to these problems. Legume crops like beans, peanuts, soybeans, and alfalfa get much of their nitrogen from symbiotic bacteria, known as rhizobia, which take nitrogen gas from the air and convert it into forms plants can use.

The carbon compounds the rhizobia need come from their plant hosts. These resources could otherwise have been used to make more seeds, so legumes have evolved sophisticated mechanisms to support no more nitrogen fixation than they need. When less-expensive nitrogen sources like ammonia or nitrate are available in the soil, legumes make fewer of the root nodules that house the bacteria and may even shut down existing nodules.



Credit: Ryu et al.

Biological nitrogen fixation: Environmental benefits and lower cost?

Could non-legumes also use nitrogen fixation somehow, with similar environmental benefits? If so, would farmers save enough money on fertilizer costs to balance the yield decrease from diverting resources from seed production to nitrogen fixation? Or might a more-reliable nitrogen supply actually increase yields, despite the energy cost?

Corn, wheat, and rice do not make root nodules, but some bacteria that live on or near their roots can fix small amounts of nitrogen. In Nature Microbiology, Ryu et al. discuss genetic improvement of these bacteria. They normally fix little or no nitrogen if exposed to oxygen, which destroys the key enzyme, nitrogenase, or if ammonia is available. Ryu et al. were able to change these traits, but practical applications of their work are far from certain, even in the long term.

Knocking out repression of nitrogen fixation by ammonia may seem like a step backwards, from an environmental point of view. After all, the ability of legume crops to fix no more nitrogen than they need is key to limiting nitrate pollution of our water supplies. But we want nitrogen fixation rate to depend on overall plant needs, not just on ammonia levels around the bacteria. So Ryu et al. engineered bacteria to adjust nitrogen-fixation rates in response to signals from plants. Energy would still have to come from the plants, however. Would the benefits of nitrogen fixation justify this cost? Let's be optimistic and assume they would, initially.

But bacteria evolve. Even if they provided nitrogen at a reasonable cost at first, benefits could decrease in only a few days. The paper mentions the "fitness burden" of nitrogen fixation, causing rhizobia that fix more to die out. A "cheating" mutant that fixed only as much nitrogen as it needed itself, with nothing extra for the plant, would free up resources for its own reproduction and take over.

Yet, nitrogen fixation by rhizobia in legume root nodules has persisted for millions of years. What has limited the spread of rhizobial "cheaters"? Legumes shut off the oxygen supply to nodules that fail to fix enough nitrogen, saving resources for the plant and limiting reproduction by rhizobial "cheaters." If we want corn, wheat, or rice to get much of their nitrogen from bacteria, they will need some such mechanism to shut down nodules that cost more than they are worth.

It may be more feasible to add nitrogen-fixation genes to new crops themselves, rather than relying on bacteria. The crops would still have to pay nitrogen-fixation's high energy cost, but it might be worth it in at least some cases.

Oxygen would still be a problem. Even moderate concentrations of oxygen can destroy nitrogenase, yet oxygen-based respiration is needed to meet nitrogen-fixation's energy needs. In legumes, regulation of oxygen supply to the nodule interior helps solve this problem. But some of the bacteria described in the Nature Microbiology paper fixed nitrogen in oxygen concentrations above 1%.

If this work points the way to oxygen-tolerant nitrogen fixation by plants, we might someday be able to grow corn, wheat, and rice without nitrogen fertilizer. ***(Source: Science 2.0/GLP, by R. Ford Denison)***

Sap pH as a Susceptibility

Indicator for Disease and Insect Susceptibility

Sap pH as a susceptibility indicator:

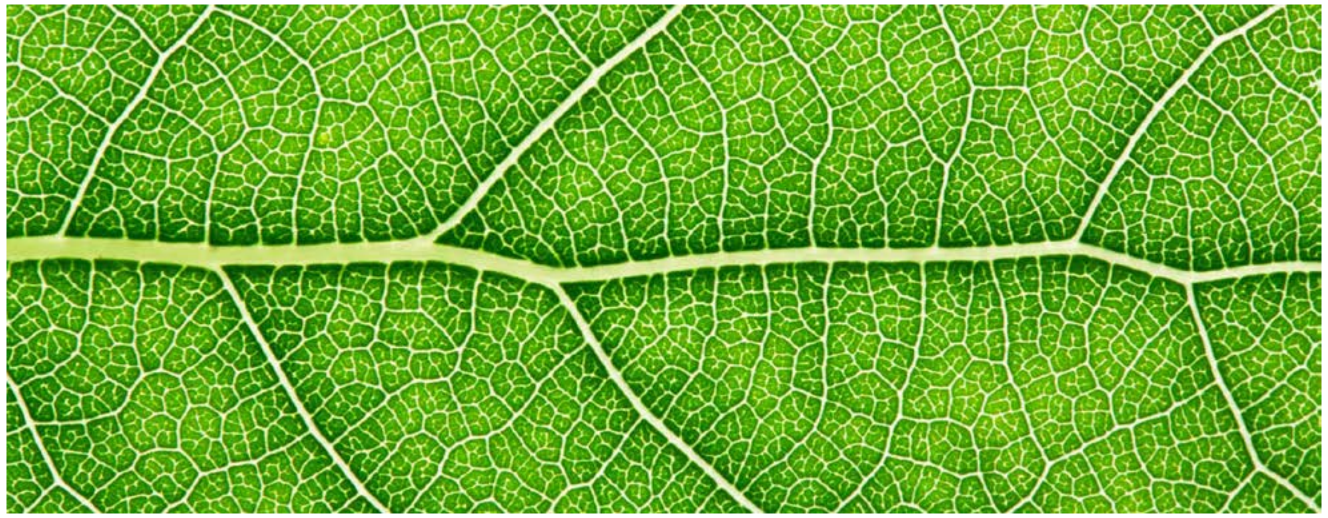
Bruce Tainio pioneered the use of plant sap pH as an indicator for disease and insect susceptibility in 1988. We have used this tool in our consulting work since the beginning, and have found it invaluable. Today, pH is included in lab sap analysis because of Bruce's work.

More recently, we have learned from Olivier Husson's work, that measuring pH by itself is incomplete, since the environmental parameters organisms require to become virulent are at least two dimensional, as they are determined by both Eh and pH, not by pH alone.

Plant Tissue pH = Energy

While laboratory soil and tissue tests are good tools, we often don't receive the results for several days, or even up to two weeks in some cases. On a growing crop, that can be too late.

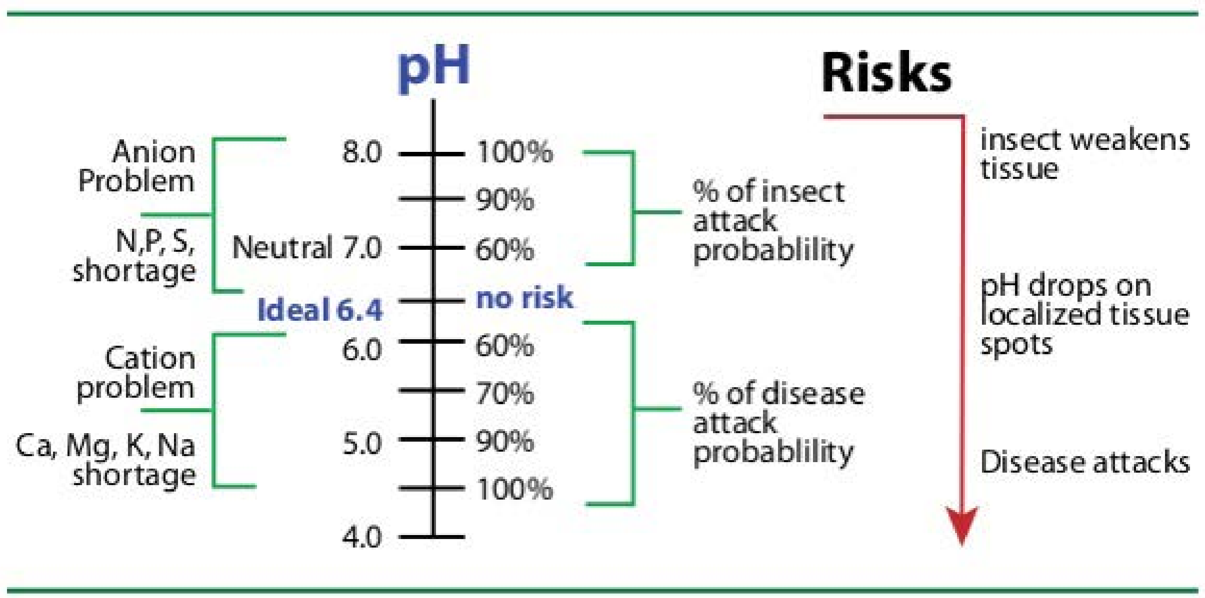
With this in mind, we developed a diagnosis of plant health based on liquid pH values of plant tissue sap, which has been used in our biological program at Tainio Technology & Technique since 1989.



Simple to use and 100 percent accurate, a quick plant tissue pH test is an instant snapshot of the state of health of any plant and can tell us the following information:

1. Enzymatic breakdown of carbohydrates (sugars) for proper growth and vitality of the plant.
2. Risk potential for insect damage.
3. Risk potential for foliage disease attack.
4. Nutritional balance in the growing crop.
5. Quality of nutrition in the fresh fruit or vegetable crop to be harvested.
6. Shelf storage potential of fresh fruits and vegetables.

The table below is a general guideline to determine what tissue pH means. With this scale we can predict the probability of insect and disease resistance or susceptibility.



The dictionary defines pH as "a number equal to the logarithm of the reciprocal of hydrogen ion concentration within a solution." That's a mouthful, but more simply put, pH represents the percentage of hydrogen ions in a solution. In our case, the solution is the liquid of the plant cell, or the sap.

It is important to know that a change in the pH level of a solution of just one unit equals a tenfold change in the hydrogen ion concentration. If the pH is increased or decreased by two units, the hydrogen ion concentration changes by a hundredfold! Thus we can see why what appears to be only a slight shift in pH can spell disaster for the farmer.

A neutral pH of 7 within the cell fluid means it contains 100 percent saturation of cations other than hydrogen (in other words, the sap contains no free hydrogen ions). At a plant's ideal cellular fluid pH of 6.4, the saturation of cations other than hydrogen is about 88 percent. At 88 percent saturation – principally of calcium, magnesium, potassium and sodium – the ionization and activity of these elements generates an electrical frequency of between 7.5 and 32 Hertz, which is one of the "healthy" frequency ranges of all living cells.

To decrease cellular pH to 6.0 is to lower the saturation of the above four principle elements to 80 percent, thus lowering the plant's frequency to a level of lower resistance to bacterial, fungal and viral plant pathogens.

Studies have shown that insects are attracted to a tree or plant by the tree or plant's frequency. If the saturation of Ca, Mg, K and Na increases to over 88 percent saturation, the frequency from these ions in the cell are increased, and consequently, insects are attracted to the higher-than-normal cell frequency.

The same process occurs in animal and human cells. Hydrogen accumulation in the cell tissue means the saturation of Ca, Mg, K and Na is decreasing, thus causing the frequency to decline. This low frequency leaves the cell an easy target for disease.

Oftentimes we see both insect and disease problems occurring at the same time. This can happen when insects attack due to a high plant tissue pH, and the tissue becomes weakened in the localized areas of attack. Next, localized, rapid energy loss (a drop in pH) occurs at the insect-damaged spots, resulting in tissue disease attack of those areas on the plant.

When a pH shift of a half point (0.5) or more from the ideal 6.4 occurs in the cellular liquid, a laboratory tissue test should be taken to determine exact imbalances and which materials should be applied.

Tissue pH Rule of Thumb

Low pH + Moderate Brix = Calcium Deficiency

Low pH + Low Brix = Potassium Deficiency

6.4 pH + High Brix = Balance

In the interim, for a quick adjustment to bring up the pH, calcium can be foliar applied in small amounts per acre. To quickly bring down a pH that is too high, on the other hand, small amounts of phosphate can be applied to the foliage. These types of quick fixes are usually only temporary, however, and should only be used while awaiting a complete tissue test analysis.

Like most busy people, we have neither the time nor the patience to puree the two pounds of plant tissue it takes to get enough for a conventional pH meter readings; so we use the Cardy Twin drop pH tester, made by Horiba. With this pH meter, a reading can be taken out in the field in less than one minute. We just take a few leaves, roll them up into a tight ball, and squeeze out a few drops of sap using a garlic press. Be sure and use a good quality stainless-steel press, as a cheaply made garlic press will break.

Generally, the more mature leaves on the plant will give the most accurate picture of the plant's health, level of resistance or susceptibility to problems. Since the plant spends most of its energy supporting new growth, the pH of new leaves will not reflect the pH of the rest of the plant as a whole.

pH & SUGAR

An indirect method of determining the energy levels of a plant is to measure the carbohydrate (sugar) levels in the cell liquid. For this test, a refractometer is used to determine the level of sucrose in the cellular fluid. This reading is referred to as the brix scale.

Within a given species of plant, the crop with the higher refractive index will have a higher sugar content, a higher mineral content, a higher protein content and a greater density. This adds up to sweeter-tasting, more nutritious food with a lower nitrate and water content and better storage characteristics. Such produce will generate more alcohol from fermented sugars and be more resistant to insects, reducing the need for insecticides. Crops with higher sugar contents will also have a lower freezing point and therefore be less prone to frost damage. Soil fertility needs can also be ascertained from this reading.

The brix levels should not be taken as an exact measurement of a plant's vitality, but rather as a guideline. Stored sugar is not a cellular energy source until its carbon-hydrogen-oxygen molecular links are enzymatically broken apart. If this line breaks or energy release occurs faster than the cell can use it, then that energy is lost into the air. This condition usually occurs when the liquid pH of the cell is below 6.4 and most often indicates low Ca and high K.

The reverse can also occur – if the links between the carbon, hydrogen and oxygen molecules of a sugar are broken too slowly due to low enzyme activity, the plant becomes starved for the energy it needs for growth. This is usually caused by low manganese or zinc, or from high nitrogen/high tissue pH levels, coupled with drought stress.

As a general rule, we can say that when a plant has a low tissue pH and a moderate brix level, there is usually a calcium deficiency involved. On the other hand, a low pH with a low brix level usually indicates a potassium deficiency. The ultimate goal is to achieve a pH of 6.4 with a high brix level.

Plant tissue pH management is a relatively small but invaluable investment of your time and budget, which cannot only help you prevent disease or insect attacks, it can stop them in their tracks even once they have gotten started. This means better yields, bigger profits and most importantly, less need for chemicals. ***(Source: John Kempf Blog, by Bruce Tainio)***

Frontier of Science & Technology

A New Way to Genetically

Tweak Photosynthesis Boosts Plant Growth

FIELD TEST Field tests with plants under real-world farming conditions have revealed how tweaking plants' genetic instructions for a process called photorespiration increases crop yield. **(BRIAN STAUFFER/UNIV. OF ILLINOIS)**

A genetic hack to make photosynthesis more efficient could be a boon for agricultural production.

This feat of genetic engineering simplifies a complex, energy-expensive operation that many plants must perform during photosynthesis known as photorespiration. In field tests, genetically modifying tobacco in this way increased plant growth by over 40 percent. If it produces similar results in other crops, that could help farmers meet the food demands of a growing global population, researchers report in the Science.

Streamlining photorespiration is "a great step forward in efforts to enhance photosynthesis," says Spencer Whitney, a plant biochemist at Australian National University in Canberra not involved in the work.

Now that the agricultural industry has mostly optimized the use of yield-boosting tools like pesticides, fertilizers and irrigation, researchers are trying to micromanage and improve plant growth by designing ways to make photosynthesis more efficient.

Photorespiration is a major roadblock to achieving such efficiency. It occurs in many plants, such as soybeans, rice and wheat, when an enzyme called Rubisco - whose main job is to help transform carbon dioxide from the atmosphere into sugars that fuel plant growth - accidentally snatches an oxygen molecule out of the atmosphere instead.

That Rubisco-oxygen interaction, which happens about 20 percent of the time, generates the toxic compound glycolate, which a plant must recycle into useful molecules through photorespiration. This process comprises a long chain of chemical reactions that span four compartments in a plant cell. That waste of energy can cut crop yields by 20 to 50 percent, depending on plant species and environmental conditions.

Using genetic engineering, researchers have now designed a more direct chemical pathway for photorespiration that is confined to a single cell compartment — the cellular equivalent of a Maine-to-Florida road trip straight down the East Coast.

Paul South, a molecular biologist with the U.S. Department of Agriculture in Urbana, Ill., and colleagues embedded genetic directions for this shortcut, written on pieces of algae and pumpkin DNA, in tobacco plant cells. The researchers also genetically engineered the cells to not produce a chemical that allows glycolate to travel between cell compartments to prevent the glycolate from taking its normal route through the cell.

Unlike previous experiments with human-designed photorespiration pathways, South's team tested its photorespiration detour in plants grown in fields under real-world farming conditions. Genetically altered tobacco produced 41 percent more biomass than tobacco that hadn't been modified.

"It's very exciting" to see how well this genetic tweak worked in tobacco, says Veronica Maurino, a plant physiologist at Heinrich Heine University Düsseldorf in Germany not involved in the research, but "you can't say, 'It's functioning. Now it will function everywhere.'"

Experiments with different types of plants will reveal whether this photorespiration fix creates the same benefits for other crops as it does for tobacco. South's team is currently running greenhouse experiments on potatoes with the new set of genetic modifications, and plans to do similar tests with soybeans, black-eyed peas and rice.

The vetting process for such genetic modifications to be approved for use on commercial farms, including more field testing, will probably take at least another five to 10 years, says Andreas Weber, a plant biochemist also at Heinrich Heine University Düsseldorf who coauthored a commentary on the study that appears in the same issue of Science. In the meantime, he expects that researchers will continue trying to design even more efficient photorespiration shortcuts, but South's team "has now set a pretty high bar." ***(Source: Science News, by Maria Temming)***

NEW AND IMPROVED Modifying tobacco plants' genetic instructions for photosynthesis increased the growth of tobacco plants by about 40 percent (one at left) compared with unmodified plants (one at right). **CLAIRE BENJAMIN/RIPE PROJECT**

9th CAC AWARDS UNVEIL

CAC has worked with perseverance for 22 years, devoting to serving industry as its original aspiration.It has effectively promoted the rapid growth and international development of China's agrochemical industry.

9th CAC Awards set up six awards including, "2020 TOP 20 Chinese Pesticide Exporters", "Excellent Fertilizer Exporters", "CAC.Fertilizer Enterprises With International Influential Brands", "2020 Overseas Market Expansion Awards", "2020 Promising Company Awards", and "CAC Recommended Suppliers 2021", with 46 fertilizer enterprises won the prize. Here is the list of fertilizer enterprises:

CAC FERTILIZER ENTERPRISES WITH INTERNATIONAL INFLUENTIAL BRANDS

Hebei Zhongchang Fertilizer Co., Ltd. was built in 1996, as a professional manufacturer and trader of Ammonium Sulphate Granular, Compound Fertilizer, Slow Controlled release fertilizer (SCRF) and Water solube fertilizer(WSF). We have the production ability of 300,000 tons each year, including 150,000 tons of slow controller release fertilizer and NPK compound fertilizer, 100,000 tons of ammonium sulphate granular, 50,000 tons of water soluber fertilzer (WSF). The business spread all over the world, more than 30 countries and districts. We will sincerely providing the best products for every customer.

E-mail: dekay01@zchf.net
Web: www.en.zchf.net

SHANXI KNLAN Chemical CO., LTD. is the leading professtional producer in China for high efficient straight & NPK fertilizers.Our main products are Calcium nitrate Granular/Crystal, Calcium Ammonium Nitrate, Magnesium Nitrate Prill/Crystal, Potassium Nitrate, Sodium Nitrate, Ammonium Sulfate/Chloride & NPK compound fertilizers, Magnesium chloride. As ISO9001:2008 approved company and Member of the International Fertilizer Industry Association (IFA), We have obtained REACH's full registration certificate, and our products are well sold in China and over 80 counties and areas on the world.

E-mail: info@knlanchem.com
Web: www.knlanchem.com

Qingdao HaiJingling Seaweed Biotechnology Group CO., LTD. is an Qingdao based group enterprise integrating R&D, manufacturing and marketing, with main products as seaweed extract, seaweed liquid fertilizer (OEM available), chitosan etc. We have strong capability of research and extensive market both in China domestic in decades of privinces and cities and also oversea countries. Over a decade of years Haijingling has built its name in China and abroad. Welcome friends and business partners all over the world to visit our company and build longterm partnership.

E-mail: sam@jlfert.com
Web: www.jlfert.net

Chengdu Wintrue Holding Co., Ltd., was established in 1995 and is headquartered in Chengdu.On 18. Jan. 2011, the company was listed on the Shenzhen Stock Exchange. The company has five business divisions, more than 100 molecular companies, including five overseas subsidiaries, with total assets exceeding 10 billion yuan, the capacity of compound fertilizer is 5.1 million tons. Wintrue has market expansion along the compound fertilizer industry chain for many years, and now formed an industrial pattern of coordinated development of compound fertilizer business and condiment business.

E-mail: web@wintrueholding.com
Web: www.wintrueholding.com

Citymax is engaged in developing visual organic farming chains.Thanks to the experience acquired in years' innovating and researching activity, Citymax offers a complete portfolio of biostimulants and organic formula fertilizer under the brand of CITYMAX;2 high-tech production base has made the yearly capacity more than 10,000MT;we are active in more than 30 countries, with agents and exclusive agents;With ISO 9001 CITYMAX is the only Chinese company in the field with full series products that listed in USA OMRI. In 2018, CITYMAX will pass REACH and ECOCERT.

E-mail: infor@citymax-agro.com
Web: www.citymax-agro.com

QINGDAO BRIGHT MOON BLUE OCEAN is a wholly owned subsidiary of QINGDAO BRIGHT MOON SEAWEED GROUP, relys on State Key Laboratory of Bioactive Seaweed Substances and Ministry of Agriculture Key Laboratory of Seaweed Fertilizers, products include more than 100 varieties in six series, including Seaweed Organic Fertilizer, Seaweed Organic-Inorganic Compound Fertilizer, Seaweed Blending Fertilizer, Seaweed Foliar Spray Fertilizer, Seaweed Water Flush Fertilizer, Seaweed Microbial Agent Fertilizer, exported to more than 80 countries and regions around the world, praised as "Pure Seaweed Fertilizers"

E-mail: lch@bmsg.com
Web: e.myhzf.com

The leader of granular-water soluble fertilizer.

E-mail: anny@cocoly.com.cn
Web: www.cocoly.cn

TBIO CROP SCIENCE endeavors to produce the natural environmental friendly substance for modern agriculture. TBIO focus on adding value through the edging technology and the continuous innovation. TBIO work with our partners from more than 20 countries.

E-mail: info@tbio.cn
Web: www.tbio.cn

Rural Liquid Fertilisers RLF is a world class fertiliser company that develops highly advanced crop nutrition products for global agriculture. It is the manufacturer and global distributor of these products.RLF supports a diverse range of products, customers and markets. It has an outstanding technical capacity. RLF's talented team are passionate about delivering real value and genuine on-farm crop and economic returns.RLF is a dynamic, committed and customer focused organization.

E-mail: wuying@rlfchina.com.cn
Web: www.ruralliquidfertilisers.com

Laizhou Laiyu Chemical Co., Ltd. was established in 1984,mainly engaged in the R&D, produce and sale of magnesium salt products. we passed national security standardization, ISO9001/14001/22000 certificate, OHSAS18001 and REACH. Obtained food/feed additive production license,passed FAMI QS certificate .We are the only factory gained national green factory.
Our main product are magnesium salts, new military materials, environmental dust suppressants and agricultural soil conditioning agents. We were approved as one of the 4th batch national grade green factory companies in 2019.

E-mail: lyhg@laiyu.com
Web: www.laiyu.com

Jiangsu Hanling Fertilizer Co.,Ltd founded in 2002, is a leading manufacturer of Amino acid series organic fertilizer and feed additive in China .Our plant covers an area of 180,000.00 square kilometers with more than 400 employees . We have established branch office in Shanghai in 2016.

- Chinese Largest Amino Acid Chelate Manufacturer

- China's Second Largest Production Base Of Hydrolyzed Amino Acid .

- Chinese Only One Amino Acid Granular Manufacture

E-mail: jacky@hanling-fertilizer.com
Web: www.hanling-fertilizer.com

Bohigh Zinc Product Co., Ltd. (Stock Code:835723) the largest zinc sulfate manufacturer in Asia, was established in 2007, with wholly owned and holding real estate enterprises in Jiangxi, Hunan Province and Inner Mongolia.

Bohigh is such a company which intergrates solid waste treatment, renewable resources and zinc nutrition, and has become the largest trace mineral elements (zinc sulfate) production enterprise in China, and the only Zinc Brand designated both by International Zinc Association and Ministry of Agriculture in China.Bohigh zinc sulphate has been exported to more than 55 countries.

E-mail: miller.zou@chinabohigh.com;
sales@chinabohigh.com
Web: www.chinabohigh.com

LZZD CHEM is a leading Magnesium Sulphate Heptahydrate(95%,98%,99.5%) and Sulfamic Acid(99.5%,99.8%) Chinese manufacturer, with 12 years' experience of manufacturing and exporting. ISO 9001, ISO14001, ISO45001, REACH, KOSHER, HALAL and FDA certificate approved. The capicity of Sulfamic acid is 60000 t/year, Magnesium sulphate is 180000t/year. Products grade are agriculture/feed/industry degree currently.

E-mail: sales@lzzdchem.com
Web: www.lzzdchem.com

Haicheng Magnesium Fertilizer Industrial is a magnesium production company specializing in customized chemical fertilizers.With 200,000 tonnes of production annually. Our main products include MgSO4.H2O, MgSO4.7H2O, MgO and Palm Trees Special Purpose Fertilizer etc.

E-mail: myangmeihua@126.com
Web: www.cleanmg.com

Yigeda Bio-technology Co., Ltd. is subsidiary of leading bio-agricultural Co., Ltd. founded in Beijing in 1999. It locates at the core area of Zhongguancun Street in Haidian, Beijing. We focus on development and utilization of marine biological resources and corresponding research and development, production and sales of seaweed extracts, chitosans and chitosan oligosaccharide. Now all products are exported to more than 40 countries and regions in the world.

E-mail: overseas@yigeda.com
Web: www.yigeda.com

Located in Yantai city of East China, Wuzhoufeng Agricultural Science and Technology Co., Ltd, as a subsidiary company of SinoAgri Holding Corporation, is a large company engaged in develop, produce and marketing of compacted granulation, compound/complex and slow/control released fertilizers. The company currently owns eight production facilities in Northeast China, North China and Central China with a combined annual capacity of 5 million tons.

E-mail: xiaomeiyu@163.com
Web: www.wuzhoufeng.com

HUNAN WORLDFUL AGROTECH CO., LTD. located in Changsha city, Hunan province. Started our business from 2006, we are focus on organic fertilizers and chemicals related to agriculture, and animal feed more than 13 years. As a result of our hard working, we have become the top and the best supplier for camellia saponin products, amino acid organic granule fertilizers and humic acid series products in China, and also make huge progress to supply the best nutrients and solutions for plants & animals.

E-mail: calvin.ren@cnworldful.com
Web: www.cnworldful.com

Shanxi Jiaocheng Hongxing Chemicals CO., LTD., recognized as the largest domestic manufacturer of Nitrogen, Calcium and Magnesium fertilizers, is a massive private corporation aims to produce Nitrate Nitrogen, potassium, calcium, magnesium fertilizers and chemical compound fertilizers relying on coal as the fundamental material. It is the first chemical company authorized to operate foreign trade, and the leading exporter in fertilizer business which has been qualified as a member of China Chamber of Commerce for Import & Export of metals, minerals and chemicals since 2002.

E-mail: hxchem@china-hxchemical.com
Web: www.china-hxchemical.com

Humate (Tianjin) International Limited focus on R&D, production and marketing of X-humate and OK brand Humic acid series products since 2002, in China. The main products including Water soluble Humic acid, Fulvic Acid, Seaweed Extract, Amino Acid, series Organc Fertilizer products. They're exported to more than 60 countries in Europe, North & South Amercia, Asia, Africa, and enjoy a high reputation both at home and abroad. X-humate Brand Potassium Humate has been registered REACH in EU, and listed in OMRI and CERES Products.

E-mail: info@x-humate.com
Web: www.x-humate.com

Shanxi Huaxin Group is located in Jiaocheng, Shanxi, China. It was founded in 1998 with total assets of RMB10 billion, collected by coal mining, coal washing, coke chemical, fertilizer, real estate, tourism, liquor and other related industries. It can produce 200 thousand tons of Ammonia, 300 thousand tons of Nitric Acid, 400 thousand tons of Ammonium Ntrate, 200 thousand tons of Calcium Ammonium Nitrate, 100 thousand tons of Megnesium Nitrate and 600 thousand tons of Nitrated-based NPK Fertilizer per year, which made Shanxi Huaxin become the biggest resources supplier in Jiaocheng.

E-mail: sxhx888@sxhuaxin.cn
Web: www.sxhuaxin.cn

Established in 2003, Lardmee has an advantage in tower prilled potassium humate complex fertilizers. The Southern and Northern factories, with four high towers, produces over 835,000 tons fertilizer per year.

Lardmee have received numerous patents in fertilizer production technologies and equipment. With that, Lardmee produces a wide range of products for various crop growers across China and over the world.

E-mail: overseas@lardmee.cn
Web: www.lardmeefertilizer.com

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Xiamen Topusing Chemical Co.,Ltd. is a professional agrochemicals company which is focus on agricultural chemicals research, production and export especially on special fertilizer formulas. From the year 1998 Topusing Chem. makes all their efforts in supplying the plants every kind of fertilizers for most crops stage. Base on four production bases in Fujian, Sichuan, Jiangsu and Taiwan, strict quality control and sincere services, our products have been exporting to more than 80 countries. To guarantee all products and services, Topusing has been certified by ISO9001: 2008, CQC. etc.

E-mail: info@topusing.com
Web: www.topusing.com

Linker agritec is a new fertilizer R & D, manufacturing, marketing integration of producers and service providers, set high-quality product supply and LINKER service mode in one. Linker agritec is the pioneer of carbon enzyme special fertilizer category. Linker ® trademark has been successfully registered in many countries, opening the international cooperation strategy and making global agriculture obtain better harvest.Master the core production technology of CTC micro-carbon and growth promotion, and the core production technology of three choices and three chelates.

E-mail: alice@linkeragritec.com
Web: en.linkeragritec.com

Mata Ecology, with the mission of building a new business form of the oyster industry, takes oyster shell recycling as a breakthrough, is committed to opening up the oyster industry chain's seedling, breeding, processing, and processing links, and exploring the marine industry cycle. Oyster calcium products have been successfully used in plantation, aquaculture, environmental protection, food, home building materials and exported to Japan, the United Kingdom and Malaysia.

E-mail: 615851766@qq.com
Web: www.fjmata.com

Crown Champion was established in 2000, mainly devotes to ammonium sulphate granular and magnesium sulphate, as well as other fertilizers including potassium sulphate, zinc sulphate, ferrous sulphate, calcium ammonium nitrate, magnesium nitrate NPKS ect.
Our factory Tianjin Topfert Agrochemical Co., Limited, invested and established in 2002, mainly manufactures ammonium sulphate granular with yield of 100,000mts per year and 100,000mts magnesium sulphate per year.

E-mail: amy@crownchampion.com
Web: www.crownchampion.com

Professional marine BioTech R&D and manufacturer, by using advanced technology of cold enzymatic, membrane separation and low temperature drying, we produce the PUREST and TOP 1 Fish Protein and Seaweed Extract powder products in the world. These two products are listed both in the USDA, OMRI and China as "Organic Fertilizer" and have been exported to the USA for 9 years, since 2014 our fish protein has been ranked first share in the USA fish fertilizer market. The special advantages of our fish and seaweed are: subsalt, no additives, small molecular, perfect pH, soluble and compatibility.

E-mail: hongdebio@163.com; 1649146119@qq.com
Web: www.hongdebio.com

Laizhou Guangcheng Chemical Co., Ltd. is located in the west of Qiansu Village, Chengguo Town, Laizhou City, Shandong Province, founded in 2008, covers an area of 45,400 square meters (60 mu), with an annual output of 10,000 tons of sulfamic acid and 150,000 tons of magnesium sulfate.In 2014, we settled in Laizhou Advanced Manufacturing Industrial Park, and added a new production line to produce high-quality anhydrous ,monohydrate magnesium sulfate, trihydrate magnesium sulfate. We have REACH registration, FDA certification, ISO9001 and ISO 14001. Products are exported to overseas.

E-mail: sales@guangchengchem.com
Web: www.guangchengchem.com

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Chengdu Beluckey Technology CO., LTD. (as Beluckey), is also ISO9001:2008 certificated and EU REACH registered.

We focus on water soluble fertilizers which are widely used in drip-spray irrigation system. Its major products include: Urea Phosphate (UP 17-44-0), MKP, MAP, Potassium Nitrate (NOP), Magnesium Nitrate (Crystal&flake), Monopotassium Phosphite (0-58-38), Phosphoric Acid, LIQUID APP 11-37-0, CALCIUM NITRATE AND NPK + T.E. FERTILIZER.

E-mail: info@beluckey.com
Web: www.beluckey.com

Xinjiang Heise Eco-Tech CO., LTD. is a new company founded by Double Dragons Humic Acid CO., LTD.

Xinjiang and Xinxiang Shenlen New Energy Investment CO., LTD. Our new company inherited more than 20 years experiences for humic acid based products production, research and technical services of DOUBLE DRAGONS. Now we are focus on various high quality Humic acid products such as Humic Acid, Sodium Humate, Potassium Humate, Fulvic Acid, and Potassium Fulvate. We highly hope to establish business relations with your esteemed company on the basis of mutual benefit in an earlier date.

E-mail: wxl@ddha1997.com
Web: www.ddha1997.com

Guangdong Ruifeng Ecological Environment Technology Co., Ltd. is a national high-tech enterprise integrating scientific research, production and sales. High-tech new-type fertilizer company mainly produces products with high tower nitro water-soluble microbial fertilizer, fully water-soluble nitrosulfur-based compound fertilizer, multi-element water-soluble carbon-based bacterial fertilizer, and liquid bacterial fertilizer.

Ruifeng Ecology regards China's soil solutions as its mission, specializes in bacterial fertilizer, repairs soil, promotes green, high-quality and high-yield agriculture.

E-mail: 28931413@qq.com
Web: www.rfstgroup.com

Weifang Huakang Magnesium Sulphate Co., Ltd. is the largest manufacturer of magnesium sulphate anhydrous and magnesiumsulphate monohydrate in China. It is established in August 2007 and gradually developed from annual production of 20,000 tons magnesium sulphate to 50,000 tons one year.

In order to meet the market demand, we have invested more than RMB 10 million for purchasing German huge producton line to produce magnesium sulphate anhydrous and magnesium sulphate monohydrate , with annual quantity capability of over 12,000 tons.

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E-mail: 969796276@qq.com
Web: www.mgso4.com.cn

Shandong Aifudi biological Co., Ltd. was founded in 2010, mainly engaged in the research and development, production and sales of enzyme fertilizer, which is the largest enzyme fertilizer production base in the industry.

The company leads the corporate culture with "the way of Confucius and Mencius", adheres to the concept of "being a man first, then doing things" and deeply cooperates with customers all over the country to create brilliance!

E-mail: 578999617@qq.com
Web: www.afdgs.com

Ginyung Glycolipid Industry (Xi'an) Co., Ltd., as a technical and market-driven enterprise, is mainly engaged in the research, production, sales and marketing of biological glycolipid. In the aspect of soil amendment and plant nutrition, we have intensively studied for the past years. We deeply analyze the current situation of agricultural development, study the problems relating to the status of soil, physiological growth theory of the crops, environmental stress, etc., and commit to the improvement of soil quality, efficient absorption, transmission and utilization of the plant nutrition.

E-mail: 13772487851@163.com
Web: en.ginyung.com

Our company as established in 2016. We have our own humic acid product manufacturing facility in Shanxi province. Now we are mainly supplying humic acid products to both the domestic market and the overseas market. The main products we supply include potassium humate, sodium humate, potassium fulvate, bio fulvic acid, humic acid granule products, etc. The main export market of our company is Asia. We have lotsof strategic partners in the market of Asia.

E-mail: vanhuai2015@126.com
Web: www.vhhumate.com

Shandong Jinboer Fertilizer CO., LTD. is a designated manufacturer of fertilizers produced by the Ministry of Agriculture of China. It has strong technical force to take the lead in overcoming the world difficult problem of crystallization of 200-200-200 clear water-soluble fertilizers at room temperature. Product bare - 19 C refrigerator clear transparent non-crystalline quality is stable! 65 Break through the latest solution of potassium phosphite combined with fertilizer for ulcer disease.

E-mail: sdjinboer@163.com
Web: www.sdjinboer.com

Shandong Pengbo Biotechnology Co., Ltd. is a high-tech enterprise jointly established by overseas returnees in 2014. Some key research and development plans undertaken by Pengbo are listed into the national 13th Five-Year Plan. ZNC, Pengbo's new R&D product, is an ultra-active plant immune inducer (extract from endophytic fungus of wild plants) derived from the natural eco-system. The main functions of ZNC are: promoting plant growth; resisting diseases; resisting stress; promoting plant reproduction and development; improving fertilizers' effect.

E-mail: pbswkj@163.com
Web: www.pbbiotech.cn

Shanxi linhai humic acid science and technology co., ltd. is a set of research and development, production, sales, service in one of the humic acid science and technology of well-known enterprises. The series of mineral source potassium humate products launched in recent years have the remarkable characteristics of high water solubility, high activity, resistance to hard water and strong compatibility, which can help the transformation of chemical fertilizer enterprises and is the most ideal carrier of various high-end water soluble fertilizers.

E-mail: linhai@humicacid.cn; 245154088@qq.com
Web: www.lhfzs.com

QINGDAO FUTURE GROUP is a new biotechnology international company dedicated to crop organic nutrition solutions. The company is mainly engaged in the research and development, production, compounding, sales and agricultural consulting services of all kinds of biostimulants. The main prilducts are humic acid, fulvic acid, amino acids and seaweed fertilizer. Qingdao future group provides farmers, fertilizer manufacturers and distributors all over the world with organic and sustainable agricultural input products and biostimulant products.

E-mail: info@cnfuture.com.cn
Web: www.cnfuture.com.cn

HAITOR is an innovative silicon fertilizer company headquartered in Qingdao, China. Mainly engaged in technology R & D, manufacturing, import and export of silicon fertilizer. Business form is to provide global agrochemical enterprises with technical support, silicon fertilizer raw materials and mature formula OEM services. HAITOR has a silicon fertilizer institute, factory and an imp& exp company. HAITOR R&D centers are located in China, Germany and Japan. HAITOR established the branches in South Korea and Pakistan, and sales and service networks in various countries around the world.

E-mail: 001@haitor.cn
Web: www.haitorgroup.com

Naturland Solutions (SL) has been committed to the development and production of eco-horticultural nutritional products since the early 19th century. It has more than 100 years of R&D and production management experience, especially in the field of marine bio-fermentation. A number of invention patents.

E-mail: 54521913@qq.com
Web: www.naturland-china.com

Shanghai Dajing Bio-Engineering Co., LTD was founded in 2002, registered in Shanghai Zizhu National Science park.Relying on the multi-disciplinary talents and scientific and technological achievements of Shanghai Jiao Tong University, the company has jointly established a joint laboratory with Shanghai Jiao Tong University, focusing on the technical research and development and product creation for the sustainable development of agricultural ecological resources is an international professional production of trichoderma liquid biological fermentation field leading enterprises.

E-mail: info@dajingbio.com
Web: www.dajingbio.com

Shenzhen Eagle Brother UAV Innovation Co., Ltd. is found in 2015. It is an Innovation, creative enterprise that has both multi-rotor drone and single rotor drone technologies. Since the company been established, Eagle brother setup '5 centres': operational centre, training centre, agricultural service centre, UAV education institute. Eagle Brother is becoming a large-scale, standardized enterprise. Eagle Brother focuses on UAV technologies and creative solutions to empower modern agriculture. Our global clients will be able to invest less but gaining more, creating sustainable value.

E-mail: yan.xiao@111uav.com
Web: www.ebuav.com

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The Xinyang Group,approved by the Ministry of Foreign Trade & Economic Cooperation,is a comprehensive group that specializes in mine opening,mineral processing,medium and trace mineral fertilizer production,flame retardant production,environmental pollution treatment,import & export trade and scientific research.The group owns numerous nonmetallic mines,including brucite mines,magnesite mines,potash feldspar mines,dolomite mines,wollastonite mines and so on,with total reserves over 100 million tons.Among these mines,NUANHE brucite mine is one of the largest brucite mines with premium quality.

E-mail: info@xymining.com.cn
song_li@xinyangmg.com
Web: www.xinyangmg.com

Jiangxi Green Top Biological Technology Co., Ltd is one of the professional manufacturer and supplier of organic fertilizers to the world clients. Our current product is humic acid, potassium humate, sodium humate, fulvic acid, potassium fulvate, amino acid, seaweed extract and other organic fertilizer formulations.
We continuously invest in new products and innovative technologies to provide our customer high-quality products with a wild range of application.

E-mail: tony@gzgreentop.com
Web: www.gthumic.com

Forbon is a listed company, stock code 300387. In the traditional fertilizer additives, Forbon became the leading company in the fertilizer additives all over the world. In the agriculture big data and intelligent agriculture, Forbon holding the SoilOptix company in Canada with the rapid soil detection technology which is similar to soil CT scanning technology; ,Forbon invested Wuhan Heda science and technology limited company which is a agricultural intelligent platform.

E-mail: xjkun@forbon.com
Web: www.forbon.com

Guizhou Chanfert Enterprise Co., Ltd, founded in 2009, is the wholly owned subsidiary of Guizhou Chanhen Chemical Corporation (Stock code :002895).
Its main operational products and services: MAP, DAP, Ammonium Polyphosphate, MKP, SSP, TSP, Acidic Triple Superphosphate, Acidic Potassium Phosphate, Double Superphospahte, CAN, Urea Phosphate, Phosphoric Acid, Ammonium Sulfate, Ammonium Chloride, Potassium Sulfate, Potassium Chloride, Macro-nutrient Water-soluble Fertilizer, Bulk Blending Fertilizer, Compound Fertilizer, Soil Conditioner, Phosphogypsum and its products, and etc.

E-mail: mendy@chanhen.com
Web: www.chanphos.com

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- **Efficiency:** 14ha/Hour **Spray Width:** 5-8M

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  Compared with ground machinery, 25-30% of pesticide
- **50-100**
  A drone can replace 50-100 manual operations
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- **Easy to use**
  Smart operation with mobile APP

5

SHENZHEN EAGLE BROTHER UAV INNOVATION CO., LTD.
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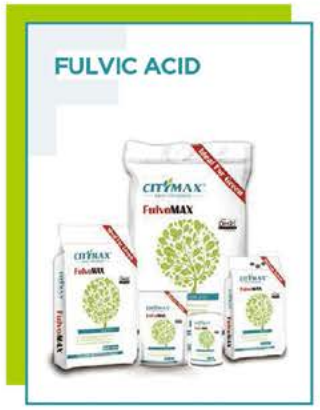
Citymax group is a member of EBIC, with 5 international certificates: OMRI, Ecocert, REACH, ISO9001,BC etc.the group includes: Ctiyamx AgroChemical;Greenfert Crop Science; Citymax Agrotech ;Super Bio Crop Nutrients Science; Citymax(Hong Kong) CropScience ; Croptech(Turkey) Ltd.;
The company's main products are humic acid, bio-fulvic acid, seaweed extract and amino acid, and many different kinds of formular liquid fertilizer products right now products from Citymax has successfully opened the market of Asia, Middle East, Australia, North America, Latin America and Africa and so on more than 40 countries in which there are more than 25 countries has distributed Citymax Brand products.



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Oct/Dec 2021

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