May/June 2020

Fertilizer View

PROVIDE VALUABLE INFORMATION OF GLOBAL FERTILIZER INDUSTRY

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The Leading Fertilizer Platform

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Fertilizer View

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News in Brief

From January to April 2020, China's Fertilizer Imports and Exports Both Declined

According to the preliminary statistics of the Chinese customs, from January to April 2020, China exported 7.482 million tons of various elemental fertilizers (including ammonium chloride, potassium nitrate and animal and plant organic fertilizers, the same below), down 6.6% year on year. Exports totaled US $1.595 billion, down 28.4% from the same period last year.

Among them, in April, 2.079 million tons of fertilizer were exported, down 187,000 tons or 8.3% year on year. Fertilizer exports totaled $445 million for the month, down 29.8 percent from a year earlier.

In terms of import, from January to April 2020, China imported 3.05 million tons of various fertilizers, a year-on-year decrease of 1.14 million tons, or 24.7%. The cumulative import value was us $1.072 billion, a year-on-year decline of 27.3%.

Among them, 860,000 tons of fertilizer were imported in April, a year-on-year decrease of 330,000 tons, or 27.7%. Imports for the month totaled $254 million, down 32.9 percent from a year earlier. *(Source: FOHOTA)*

Fertilizer Body IFA Reschedules Annual Conference

The International Fertilizer Association (IFA) on Monday revealed the new dates for its postponed annual conference in India next year. The 88th edition of the popular industry event will now be held in New Delhi between 7 and 9 April 2021. The conference was originally due to take place in the same city in late April 2020, but this has been pushed back twice due to the coronavirus pandemic. Those dates were scrapped after the Paris-based body assessed feedback from members.

"We apologise for any inconvenience this date change may cause, yet believe the new timing will provide you with the most beneficial event experience and we want to ensure the highest level of participation for our members," IFA noted in an email.

The IFA's only remaining major conference this year is the Crossroads Asia-Pacific event in Singapore between 20 and 22 October, however a strategic forum is scheduled for the Rwandan capital Kigali in mid-November. *(By Richard Ewing)*

India's Domestic Fertilizer Sales at Record High in April Despite Lockdown

In India, fertilizer dealers purchased 1.6m tonnes of crop nutrients in 1-22 April, up 46% from 1.1m tonnes in the same period last year, according to the Department of Fertilizers (DOF) on Wednesday.

The record sales occurred despite the country having been in lockdown since 24 March. A favourable monsoon forecast ahead of the main kharif application season has helped demand.

Another import tender from India is expected shortly, for around 1m tonnes of urea, given the robust demand.

“The season is expected to be good", said a local source. "As good as last year.” Dealers and farmers are also building stocks to avoid any later logistical issues because of the coronavirus pandemic.

Sale of fertilizers to farmers was at 1.1m tonnes in the first 22 days of April, up 32% from around 800,000 tonnes in 1-22 April 2019, said the DOF.The DOF, railways and port authorities are working together to ensure the production and supply of fertilizers to farmers in the country ahead of the upcoming kharif application season.

State governments have sufficient stock of fertilizers, said Minister of Chemicals and Fertilizers, DV Sadananda Gowda. On 17 April, 41 rakes or wagons moved from plants and ports, the highest movement of fertilizers during lockdown.

Each rake carries 3,000 tonnes of fertilizers. The ministry also said that fertilizer production is running at full capacity. ***(By Deepika Thapliyal)***

COVID-19: Maintaining the Global Access to Fertilizers Is Essential for Food Security

While amidst the COVID situation, food is officially recognized worldwide as an “essential good” for international trade and supply chain measures, it bears emphasis that the production of most of our food is originated on the farm, according to the International Fertilizer Association (IFA).

Before impacting the end–consumption, supply chain disruptions affect farmers at the very beginning of the food production process: food availability starts at the farm level.

This means that current shortages in essential inputs, such as fertilizers, will have measurable consequences on planting, crop development, and the harvest later this year. They will also impact farmers’ income and hence their ability to invest in inputs for the subsequent planting and harvest season(s).

Governments, in cooperation with the fertilizer value chain and farmers, need to ensure that the current health crisis does not lead to a food crisis, by maintaining the adequate access to and affordability of fertilizer and other essential inputs.

This can only be achieved by prioritizing farm inputs as well as categorizing supply chain services as essential and indispensable.

Indispensable logistics include all activities that enable the flow of agriculture inputs, such as transportation, warehousing, procurement, packaging, inventory management and distribution and retail services as well as all necessary quality controls. ***(Source IFA)***

China Produced 12.894 Million Tons of Fertilizer In The First Quarter

According to statistics, in the first quarter of 2020, the national agricultural NPK fertilizer output was 12.894 million tons, down 1.5% year on year, with little fluctuation.

Affected by the covid-19 outbreak, there are widespread problems such as tight supply of raw materials, blocked transportation, low inventory in circulation and difficulty in terminal distribution. In the first two months of this year, China's fertilizer output was 7.709 million tons, down 4.1% year on year.

Since the start of spring ploughing, while doing their best to prevent and control covid-19, local governments have made intensive plans for the deployment of spring ploughing and preparations, and the utilization rate of chemical fertilizer enterprises in many areas has increased.

In March 2020, the national agricultural production of NPK chemical fertilizers was 5.069 million tons, a year-on-year growth of 5.1%. *(source: www.askci.com)*

China to Further Empower Rural Development with Digital Technologies

BEIJING — Chinese authorities released a guideline to promote digital technologies in rural areas as part of their efforts to advance agricultural and rural modernization.

The guideline, jointly issued by four government departments including the Ministry of Agriculture and Rural Affairs, detailed measures to support the use of information technology in epidemic control, as well as economic and social development in rural areas.

The guideline encouraged the use of technologies like big data, artificial intelligence, remote intelligent agricultural machinery and online services in areas such as spring farming, and vocational training and recruitment of migrant workers.

It also highlighted the construction of "new infrastructure" in rural areas, including expanding the coverage of the broadband and 4G network, improving internet access for schools, upgrading power grids and promoting smart water conservancy projects.

Meanwhile, the guideline pledged to bolster e-commerce in rural areas via ways including improving the urban-rural network to facilitate flows of agricultural produce to the cities and developing rural tourism.

Digital technologies should also be used to promote inclusive finance in rural areas, said the guideline. *(Source: XInhua News)*

ICL Agrees Potash Supply Contracts with Chinese Customers

ICL has announced that it has signed several contracts with its customers in China to supply an aggregate 910 000 t of potash, with mutual options for an additional 490 000 t, by the end of 2020.

The selling prices stipulated in the

contracts are US$70/t below the previous contracts and are in line with the recent contract prices in China. The contracts are part of the three-year framework agreement signed in 2018 between ICL and its Chinese customers. *(by Nicholas Woodroof)*

Nutrien Temporarily Shuts Down Trinidad Ammonia Plant

Nutrien has temporarily shut down one of the four ammonia plants at its Trinidad facility.

The temporary shutdown is in response to the current market price of ammonia. The plant has an annual ammonia capacity of 600 000 tpy.

The other three ammonia plants and one urea facility at the site will continue to operate at normal rates.

The company has said it expects the shutdown to last for a minimum of three months. *(Source: World Fertilizer)*

Fearca: Planting Using Airplanes in Argentina will Increase By 40%

According to the Argentine Federation of Cameras Agroaéreas (Fearca), during the current season, it expects the area planted using aircraft to increase by 40%, reaching a total of 500,000 hectares.

The practice is widely used in agricultural regions in the northern United States, where aircraft are used for planting in times of snowfall, when machines cannot do the job. In Argentina, airplanes have been used for planting for over thirty years, and this trend is expected to continue growing.

"Aerial sowing began in 1980 with the help of Direct Sowing in southern Santa Fe," said Virginia Zarantonello (Agricultural Engineer and Pilot), adding, "In my area, oats, rye, barley and raygrass are mainly planted.

Clovers and lately other seeds, such as triticale, vicia, villosa and sativa, are also being incorporated."

Sowing campaigns are carried out on both soy and corn just before the harvest, to ensure crop coverage on lots without crops for planting pastures.

Carlos Careaga (Pilot Applicator and Flight Instructor) said, "Aerial seeding is exciting, more so than the application of plant protection products.

Nowadays, sowing has become more focused and more precise, through performing this type of work with an airplane."

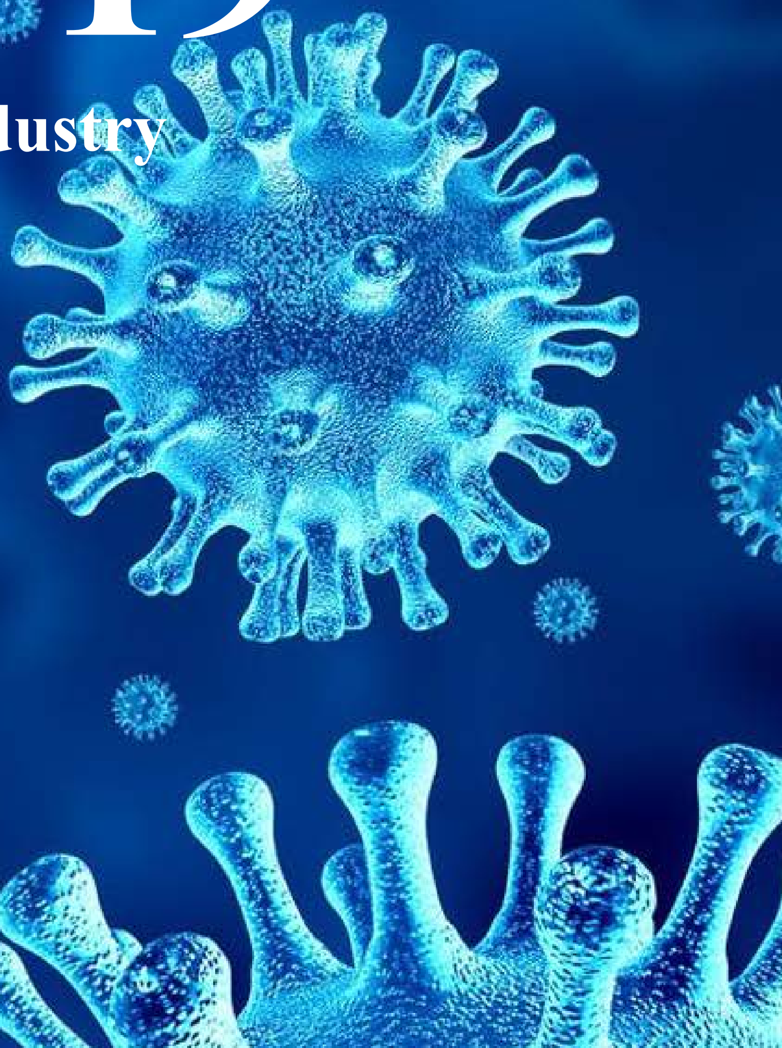
"Planting is being implemented far beyond the profit that subsequent crops generate.

There is talk of how to make a bed for the next crop, and, subsequently, using it as a fallow to control weeds that usually appear when the planting bed is left empty," Careaga added.

He stressed that "This practice makes the soil less eroded, in addition to the fact that the lot can be entered under any circumstances or conditions, enabling us to carry out our work when the producer needs it, arranges it or sees it convenient." *(Source from: infocampo.com.ar.)*

Influence of Covid-19

on Global Fertilizer Industry



By **Ethan Cui,** Managing Editor of Fertilizer View

Since the outbreak of the COVID-19 epidemic at the beginning of the year, the global economy and trade have been severely challenged, and the fertilizer industry is no exception.

In the post epidemic era, we need to sort out the impact of the fertilizer industry and the pressure it may face in the future, so as to help the industry and enterprises to do good preparation and solving the difficulties.

China

China is the largest fertilizer producer and consumer. The impact on the Chinese market will directly affect the global fertilizer market.

The Chinese market was the first one to be hit by the outbreak. In the early stage of the outbreak, for the purpose of epidemic prevention and control, factories were forced to shut down, logistics stagnated and trade was interrupted, which had an important impact on fertilizer production, transportation and trade in the first quarter in 2020.

Fortunately, the epidemic situation in China was quickly controlled. In mid February, 16 departments including the national development and Reform Commission jointly issued a document asking all provinces to secure the supply of fertilizer for spring agricultural production in 2020 on the basis of the prevention and control of the COVID-19 situation.

The fertilizer enterprises including Hubei Province overcame difficulties and resumed production in a variety of ways, effectively ensuring the use of fertilizer for spring planting.

At present, China's domestic fertilizer market is generally stable, with a slight increase in operating rate compared with the same period last year. However, considering the impact of the epidemic on the consumer market in the medium and long term, the demand side is still facing a lot uncertainty. Specifically reflected in the following aspects:

1. Farmers' general lack of confidence in prices of agricultural products will restrict their fertilizer input, resulting in a decline in fertilizer demand compared with previous years;

2. On the other hand, affected by the epidemic situation, the demand for fertilizer at the industrial field decreased;

3. At present, the trade exchange activities-exhibitions are basically stagnant, and the data of fertilizer import and export in the first quarter has declined;

4. the development of overseas epidemic has affected the agricultural labor force in some areas, forcing the main participants in the fertilizer field to make corresponding strategies and policies, developing products with advanced and innovative characteristics, such as slow and controlled release fertilizers that could increase nutritional efficiency, and saving artificial water-soluble fertilizers. It is promoting the growth of special fertilizer market.

Globally, the number of confirmed cases continues to grow in many countries. The COVID-19 epidemic has spread to more than 200 countries and regions in the world as of June 10th, and the number of confirmed cases has exceeded 7 million, according to WHO's daily epidemic report. Although in some countries the spread of the pandemic has slowed down and the number of cases has decreased, in others covid-19 is re-emerging or continues to spread rapidly. This is still a global problem and requires a global response.

India

In South Asia, the impact of the COVID-19 pandemic on India’s fertilizer production capacity is widespread, resulting in the complete closure of some factories or a decline in operating rates. Fertilizer factories across India are also under pressure from logistics restrictions, including road closures, insufficient truck drivers, and inability to the delivery of finished products leads to increased inventory and labor shortages at the production plant.

The COVID-19 pandemic has threatened more than 100 million hectares of crops in India. However, since the beginning of the outbreak coincides with the peak of the harvest season in India, there is no fertilizer shortage.

India is an important fertilizer exporter to China. Since India’s demand for fertilizers from China is more rigid, the impact of this epidemic on China’s fertilizer exports to India will be limited in the short term; in recent weeks, India’s purchases have been strong. Argus calculates that India’s total imports of DAP from June to July are about 1.7 million tons.

With the recent release of the blockade measures, the number of confirmed outbreaks in India has risen again. This is a bad sign. If the outbreak continues to develop, it will hit the already traumatized agriculture again. On the one hand, it will have an impact on agricultural product transactions. Due to the blockade of the market and the blocking of agricultural product trade, agricultural product prices have fallen; on the other hand, due to the impact of the international market transportation obstruction, it is expected that the fertilizer trade will continue to be affected; Reverse migration also causes a shortage of labor in the agricultural sector, which will cause damage to agricultural operations in many areas.

Africa

In Africa, about 650-670 million people already face food insecurity, accounting for about half of the population. Among them, more than 250 million people are considered serious food insecurity.

According to the epidemic data released by the African Centers for Disease Control and Prevention on June 10, a total of 203,899 confirmed cases of COVID-19 and a total of 5,530 deaths have been diagnosed in Africa. After the COVID-19 pandemic, the number of people facing severe hunger in Africa may double.

With the support of the United Nations, the Norwegian government and African institutions, Yara initiated the Africa Action Plan for "Prospering Farms, Prospering the Future". It is intended to provide local agricultural producers with mineral fertilizers and related digital solutions, as well as information and pesticide support to ensure food security after the global economic crisis caused by the COVID-19 pandemic.

Yara is taking action, promising to provide $25 million to provide food for more than 1 million people in southern and eastern Africa. Uralkali, a Ural potash company, also joined the plan.

Europe

At present, as the European epidemic continues to slow down, many European countries have successively adjusted their national epidemic prevention regulations and further relaxed restrictions. Madrid, Spain has entered a second stage of emergency downgrade; the British government announced measures to "unblock" large-scale outbreaks; France will open its border to the EU on June 15.

In terms of fertilizers, the strict regulations on the use of synthetic fertilizers by European governments and the increasing popularity of organic fertilizers have driven the growth of the European organic fertilizer market.

However, during the outbreak of the COVID-19 pandemic, the delays and interruptions in the borders of countries during the blockade affected the transportation and delivery of organic fertilizers in the European market. The European Union's goal is to increase food production to ensure food security for the next season in the region, This will increase the demand for fertilizers.

Potash Market Shocked:

by Chinese MOP Contract's $70/tonne Drop

The global muriate of potash (MOP) fertilizer market was left stunned this week by news that Belarus Potash Company (BPC) was first to settle a 2020 long-term supply contract with a consortium of Chinese buyers, at a $70/tonne decrease from the 2018-2019 benchmark.

Although the precise tonnage BPC is to supply under the agreement is as-yet undefined, the $70/tonne decrease to $220/tonne CFR (cost & freight) China caught many players by surprise.

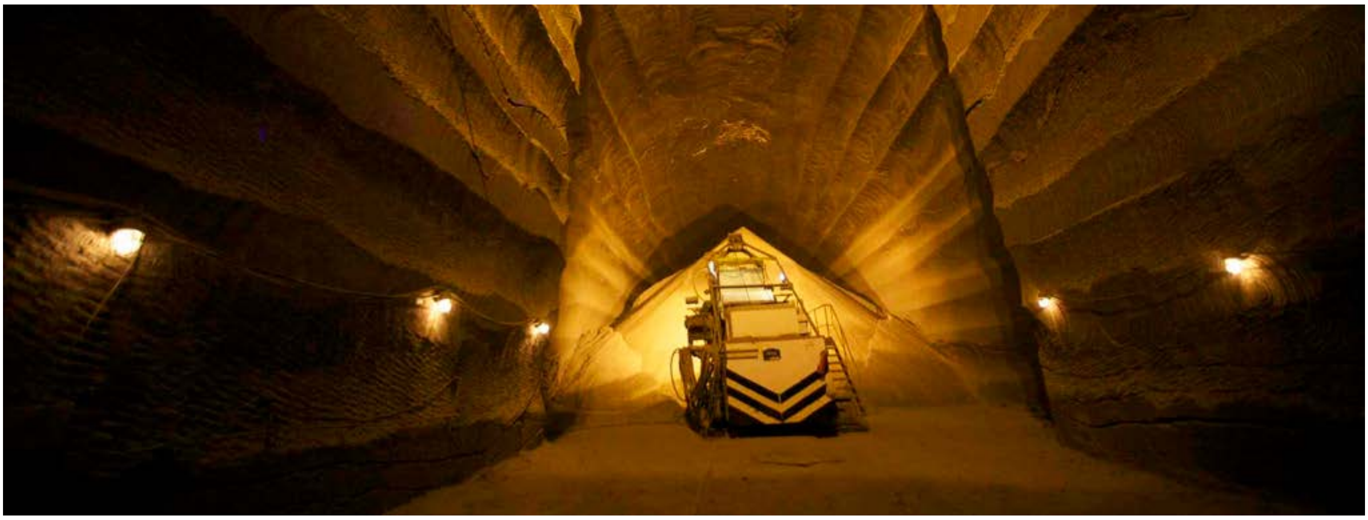
In recent weeks, potential decreases of $30-50/tonne were heard on the table – and are now proven to be conservative.

That said, the news did leave some players viewing the lower price point as a reasonable compromise amid a tumultuous market, and one producers can build on if demand improves throughout the year.

In a press release on Thursday, BPC said it reached the agreement with Chinese buyers Sinochem, China National Agricultural Means of Production Group (CNAMPGC), and China National Offshore Oil Corporation (CNOOC).

In the case of long-term contract talks with key importers China and India, once one of the largest MOP producers announces an agreement with its own buyers, other producers traditionally settle at a similar price point in their own, separate negotiations.

In its announcement, BPC said:



"Quarantine measures made both governments and people realise more clearly how important [the] agricultural sector is for normal life. Food security is once again at the top of the list, and regularity of food production and related distribution chains must be prioritised."

Describing the agreement as "a vital step", BPC added: "The price of the new China contract builds a firm foundation for the stabilisation, recovery and further incremental development of the global potash market."

Another source at a rival European fertilizer major agreed, adding "this milestone should reactivate the market".

This settlement will act as a bellwether for the remainder of the year's potash trade, with repercussions into 2021 and beyond.

Many smaller buyers in regions including southeast Asia have withdrawn from the market in recent weeks, awaiting news from China.

The new China benchmark at $220/tonne CFR may put some bearish pressure on offers into southeast Asia - although it may take some time before talks begin in earnest.

In Malaysia, standard-grade MOP was heard on offer at $250-255/tonne CFR, with Indonesia priced $5-10/tonne above this.

Standard-grade MOP in Vietnam and Thailand was heard at $260-265/tonne CFR.

For granular material, Malaysian offers are around $265-270/tonne CFR, with Indonesia around $5-10/tonne higher.

Demand is notably stronger in Vietnam and Thailand, where granular MOP was priced at $275-280/tonne CFR.

Finally, in the other key bellwether MOP import market – India – there is little news from similar ongoing long-term import contract talks; although the settlement of the Chinese benchmark may soon spur movement.

Market speculation indicates Indian buyers may have to pay slightly more than China's new $220/tonne CFR China benchmark for the second half of their 2020-2021 requirements.

Offers were previously heard priced at a benchmark of $280/tonne CFR India, which was settled for a six-month contract late last year, and expired in March. ***(Source: ICIS, author: Andy Hemphill)***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Production and Application in Vietnam

Vietnam is one of the most biodiversity countries with 13,200 terrestrial plant species, around 10,000 animal species and 3000 aquatic species. The country also has an extremely long coastline extending over 3260 km, but Vietnam is the country most vulnerable to climate change and frequent natural disasters in Southeast Asia. Agriculture is the most important economic sector in the country and more than 70% of Vietnam's population is dependent on it. In the period 2000–2018, the output value of agriculture, forestry and fisheries continued to increase with the average rate of more than 4%/year. In terms of value-added of agriculture, the average growth rate of 3.7%/year of GDP in that period is relatively high and stable. The structure of agricultural production has gradually shifted to the higher efficient sector which is associated with market demand. Agricultural production has gradually improved to meet domestic needs. Despite market fluctuations, natural disasters, complicated epidemics, food production continues to grow in absolute value. Agriculture, forestry and fisheries are the only sectors of Vietnam to have consecutive trade surplus, even in the phase of difficult economic state. It shows the evident comparative advantages of Vietnam's agriculture demonstrating the important role of agriculture in the balance of payments of Vietnam's economy.

Fertilizer consumption

Together with the trend of agricultural intensification, the use of inputs, especially fertilizers for crops, also increased very quickly in the past two decades. The country has imported between 3.5 million and 4.5 million tons inorganic fertilizers per year since 2000. Urea imports reached a peak in 2000–2004, before declining but amounts of imported ammonium sulfate and potassium have tended to increase since. From 1985 to 2005, the rate of fertilizer consumption of nitrogen, phosphorous, and potassium increased by about 10% per year, peaking at 25 million tons in 2005. Fertilizer use for crops has varied among and within provinces, but generally increased in volume over time. Fertilizer application rates vary greatly, depending on the types of crops, varieties, cropping seasons, locations, soil types, and forms of application. Overall, fertilizer use in crop cultivation has been increasing. In general, crop requiring the most fertilizer application is rice, accounts for approximately 65% of total fertilizer demand, followed by corn crop with 9%. Short duration growing crop such as sugarcane, peanuts, soybeans, cotton, vegetables etc. use 6% of fertilizer; the other plants including rubber, coffee, tea, pepper, cashew, fruit, etc. account for 20% (Figure 4).

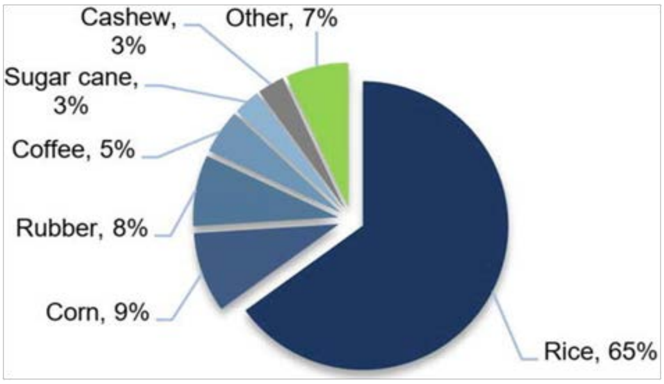


Figure 4. The fertilizer use by crop in Vietnam.

There are three main cropping seasons in Vietnam: Winter-Spring from late November to March of the following year, Summer-Autumn from April to August and Autumn-Winter from late August to late November. Agricultural production mainly concentrates in the Winter-Spring season. The demand in Winter-Spring crop accounts for 49% of total fertilizer demand per year, the other two seasons have relatively equal demand of about 25% of total demand. Fertilizer demand in Northern Vietnam is clearly separated by different time of a year. While Summer-Autumn season takes up only 6% of total demand that of Winter-Spring season is up to 58% of fertilizer demand. Fertilizer demand in Central Vietnam and Southern Vietnam don't have that difference and f is relatively stable throughout the year. Briefly, Winter-Spring has seasonally highest fertilizer demand (Figure 5) [4].

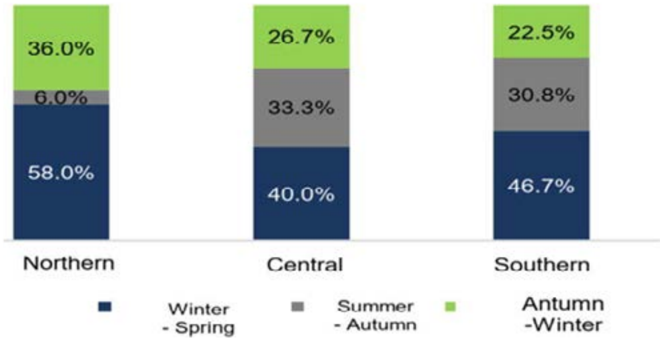


Figure 5. Fertilizer demand by season and region (source: Tin [4])

Annually, Vietnamese farmers spend about VND 110.000 billion (about USD 5 billion) on fertilizers. Compared with nearby countries, Vietnam fertilizer consumption is only lower than China in terms of fertilizer use dosage. Vietnam farmer apply NPK fertilizer of dosage 297 kg/ha. The Vietnam fertilizer market was estimated at USD 228.1 million in 2017 and is expected to reach to USD 280.9 million by 2023, growing at a CAGR of 4%. Currently, the market is less regulated, less technologically, highly competitive, and has good opportunities for growth [5].

Vietnam, as previously noted, has achieved high rates of growth in agricultural output over the past decades, but this accomplishment has been at a heavy cost to the environment. The sector's increasing use of land and synthetic inputs has accelerated deforestation, biodiversity loss, land degradation, water pollution, and greenhouse gas emissions. Saddled as it is with high expectations, Vietnamese agriculture will need to produce more from less going forward. Maintaining high output growth under changing climate and economic conditions may require a strategy of intensification, sparing not only time and labor, but also land and water, pesticides and fertilizer.

Recently, the Vietnamese government has policies to shift away from production to focus more on quality, value addition and sustainability. This strategic shift was highlighted in Decision no. 899/QD-TTg dated 10th June, 2013 on approving the plan of restructuring the agricultural sector towards improving added value and sustainable development. The agricultural restructuring plan (ARP) defines sector goals in terms of the triple bottom line of economically, socially, and environmentally sustainable development. It lays out expected changes in the roles and spending patterns of the government in the sector and discusses the need to work with other stakeholders, including in the private sector. There are currently many initiatives aiming in these directions. Yet achieving the shift these represent on a large, sector-wide scale, will require important changes in certain economy-wide and sector-specific policies and, over time, major changes and additions to the core institutions servicing agriculture. It calls for an ambitious and ongoing process of learning and experimentation, and several potential directions are offered below for consideration. Various programs have been initiated in Vietnam to promote sustainable production and natural resource management practices.

Vietnam is a tropical country and has enormous progress and remarkable growth in agriculture contributing actively in poverty reduction, national food security, and social stability in last 30 year. Vietnam faces bright opportunities in both domestic and international markets; yet effectively competing in these will depend upon the ability of farmers and firms to deliver products with reliability, and with assurances relating to quality, safety, and sustainability. Organic agriculture using organic fertilizer is one of Vietnam government priority. Vietnam has good condition for organic fertilizer production and application, but the production capacity is small not meet the demand for organic agriculture. Vietnam government promotes the organic fertilizer production and application and has the policy to develop the organic fertilizer in Vietnam. ***(By Pham Van Toan, Ngo Duc Minh and Dao Van Thong)***

Govt of India

to Roll Out Regulatory Guidelines for Biostimulants

By **Rituraj Tiwari , ET Bureau,** Editor, The Economic Times

A senior agriculture ministry official:

"Framing of rules is in final stages. As per the proposed guidelines, biostimulants will have to be first registered with government and have to prove efficacy before hitting in the market. Proper labelling will have to be done including name of manufacturers, ingredients and expiry date."

New Delhi: The government will announce guidelines to regulate the Rs 1,500 crore market of biostimulants that promise farmers higher yields, quality and other benefits from the use of various compounds and micro organisms.

Unlike fertilizers and pesticides, these products are not regulated and are sold without a certification of their efficacy, officials said. The government will set up a regulatory body for such products, officials said.

“Framing of rules is in final stages. As per the proposed guidelines, biostimulants will have to be first registered with government and have to prove efficacy before hitting in the market. Proper labelling will have to be done including name of manufacturers, ingredients and expiry date,” said a senior agriculture ministry official.

He said the need for a regulatory body has arisen as many companies have started manufacturing biostimulants without any authentic formulation.

“Farmers are getting cheated as there is no authority to authenticate the efficacy of the growth stimulants. The regulatory body will ensure farmers get genuine products which help in improving yield per hectare,” he said.

The biostimulant industry is highly unorganised with small players crowding the space. With rising demand for organic food products, the demand for organic farming will increase, which in turn will boost demand for biostimulants.

“Once the industry gets regulated, all non-descript players will vanish and only those with authentic formulations will remain in the market. No biostimulant shall contain any pesticides beyond a permissible limit of 0.01ppm,” he said.

Recently, the government tabled Pesticide Management Bill in Lok Sabha with an aim to regulate the manufacture, import, sale, storage, distribution, use and disposal of pesticides to ensure the availability of safe pesticides and minimise the risk to humans, animals and environment. ***(Source from The Economic Times)***

China's Agriculture

Upgrade to Accelerate in Next Decade

The transformation and upgrading of agriculture in China will significantly accelerate in the next 10 years, and the level of agricultural modernization will steadily improve, according to a report released on Monday.

The China Agricultural Outlook (2020-2029) released by the China Agricultural Outlook Conference 2020 summarized and reviewed the market situation of 18 major agricultural products in 2019, made projections on production, consumption, trade and price in the next 10 years, and analyzed existing uncertainties.

The focus of China's agriculture development will shift from increasing production to improving quality. The production and supply of green, ecological, high-quality and safe products will increase significantly, the report said.

The structure of food grain varieties will continue to be optimized, with the planting area steadily declining. Unit yield increases will promote the steady growth of rice and wheat output, with an average annual growth rate of less than 1 percent in the next 10 years, said the report.

Soybean and milk output will grow at an average annual rate of 3 percent, and corn, fruit and poultry meat 2 percent to 3 percent, while pork, beef and mutton, sugar, vegetables and potatoes grow 1 percent to 2 percent.

The report said China's population growth will lead the continued growth of food consumption. In the next 10 years, total domestic consumption of rice and wheat is expected to increase by 2.4 percent and 11.8 percent respectively.

The scaling up of livestock production will drive the expansion of feed use consumption of coarse grains and soybeans. The total domestic consumption of corn and soybeans is expected to grow by 18.7 percent and 14.5 percent respectively.

The changing pattern of China's food consumption will stimulate demand for animal products. The total domestic consumption of meat, poultry eggs, dairy products and aquatic products is expected to increase by 20.7 percent, 8.9 percent, 39.5 percent and 9.8 percent respectively.

China's agricultural sector will be further opened up to the outside world. International trade in agricultural products will become increasingly active, and China will remain the world's largest importer of agricultural products, the report said.

China's trade partnerships with the United States, Brazil, ASEAN, the European Union, Australia and countries participating in the Belt and Road Initiate will strengthen. Agricultural imports will continue to grow and import sources will be more diverse.

Imports of wheat and corn are expected to increase by 67.1 percent and 74.6 percent respectively. Imports of soybeans are expected to reach 99.52 million tonnes, up 7.5 percent, and sugar imports will continue to increase, with an expected growth of 142.7 percent, according to the report.

China's pork imports are expected to increase significantly in the early period of next 10 years and fall rapidly in the later period due to production recovery, and beef and mutton imports will continue to increase, the report said.

Imports of dairy and aquatic products are expected to increase by 46.8 percent and 37.5 percent respectively in the next 10 years. Exports of traditionally competitive products, including fruits, vegetables and aquatic products, will maintain growth, with average annual growth rates of 5.9 percent, 3.2 percent and 1.3 percent respectively.

The price formation mechanism for agricultural products in China will continue to improve, with both nominal and real prices of agricultural products on an upward trend.

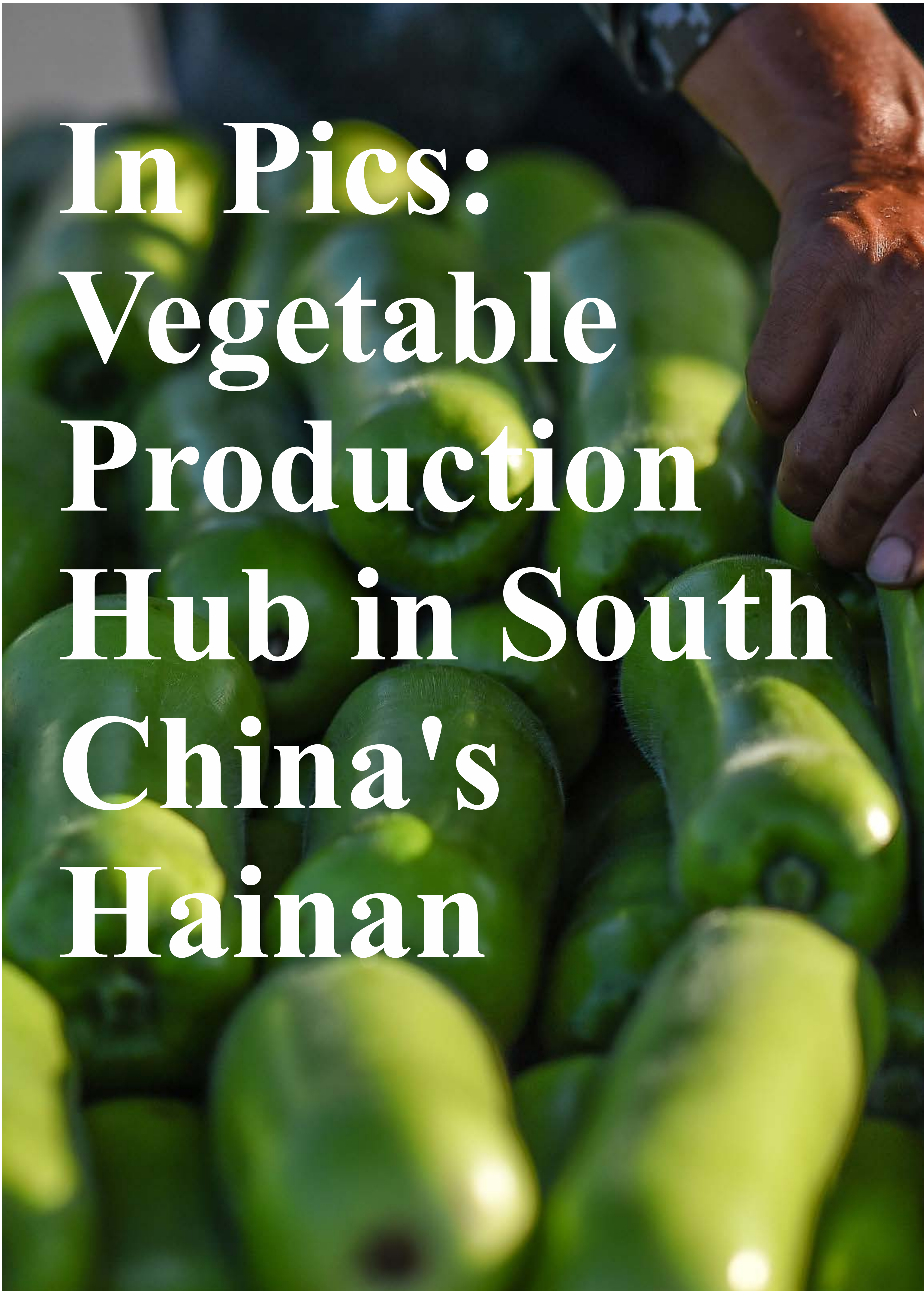
The supply of food grains will be ample in China, and the trend of market-based pricing of rice and wheat will be more obvious. Feed grain supply will be tight, and corn prices are expected to rise moderately.

Land-intensive products such as soybeans, cotton, sugar and vegetable oil will be in short supply, with a high import dependency and close price linkage at home and abroad, the report said.

The China Agricultural Outlook Conference, organized by the Agricultural Information Institute of the Chinese Academy of Agricultural Sciences, has issued the China Agricultural Outlook report for six consecutive years.

The report updates agricultural monitoring information, and guides agricultural production and market adjustment of agricultural products.

In Pics: Vegetable Production Hub in South China's Hainan



A farmer arranges vegetables in Yazhou District in Sanya, south China's Hainan Province, Jan. 5, 2020. Yazhou District is an importance hub of vegetable production in Hainan Province.
Photo by Pu Xiaoxu/Xinhua

General Introduction

of Agriculture in Hainan

Brief Introduction:

Hainan province, located in the southernmost point of China, is evergreen all year round and thus usually known as "the natural greenhouse".

As the most important production base of natural rubber breeding base of crop seed in southern China, Specific Animal Disease Free Zone and tropical agricultural base, Hainan considers agriculture as the fundamental, pillar and competitive industry in its economy.

General introduction of agriculture in Hainan

Located in the southernmost point of China, Hainan boasts a tropical marine monsoon climate with abundant sunlight and temperature which are suitable for the photosynthesis of plants. Therefore, Hainan is rich in resources of species and vegetations and is considered as the golden place for developing tropical high-efficiency agriculture with its own characteristics. Hainan covers a land area of 3.5354 million hectares, 42.5% of the tropical and subtropical land in China. The arable land is 769,000 hectares, which is 21.8% of the province's total land area. Hainan has a population of 8.178 million, among which the agrarian population is 5.6 million, accounting for 68.5% of the total population.

In recent years, Hainan has carried out the development strategy of "a province with one base and one resort" (i.e. building Hainan into a newly industrialized province with a tropical high-efficiency agricultural base and a tourist resort.), continuously consolidated the fundamental and pillar position of agriculture, actively pushed forward the strategic adjustment of agriculture and rural economic structure with the market demand

Dozens of heavy trucks are parked in the field at the watermelon planting base in the US village, Longlou Town, Wenchang, Hainan Province. Thousands of boxes of watermelon will be transported away. The picture is from @ VCG

as the orientation and resources as the basis, intensified the effort in developing market agriculture, green agriculture and technological agriculture, promoted the industrialized operation of agriculture and the overall quality of agriculture so as to accelerate the development of agricultural economy. In 2006, the added value of agriculture in Hainan reached 34.42 billion yuan, increased by 9.1% compared with the same period of last year; the per capita net income of farmers is 3,256 yuan, increased by 8.4% compared with the same period of last year, which exceeds the goal stipulated by the Eleventh Five-Year Plan of a year-on-year growth rate of 6%The added value of agriculture still accounts for 32.73% of the total GDP of Hainan.

Development of competitive industries of Hainan's agriculture

Unique natural resource and sound ecological environment contribute to the diversified structures and distinctive features of Hainan's agriculture. Compared to other provinces nationwide, the competitive industries and industries with special characteristics of Hainan's agriculture can be classified in six groups:

(1) Out-of-season vegetables. In winter, thanks to its abundant sunlight and suitable temperature, Hainan has incomparable advantages in cultivating vegetables with their low cost and outstanding quality. The annual vegetable acreage in Hainan is 3.2158 million acres with a total output of 4.487 million tons. This has become one of the major sources of farmers' income. 80% of the out-of-season vegetables are sold to 50 large- and medium-size cities in mainland China, while the rest are exported to Japan, South Korea, and Hong Kong, etc.

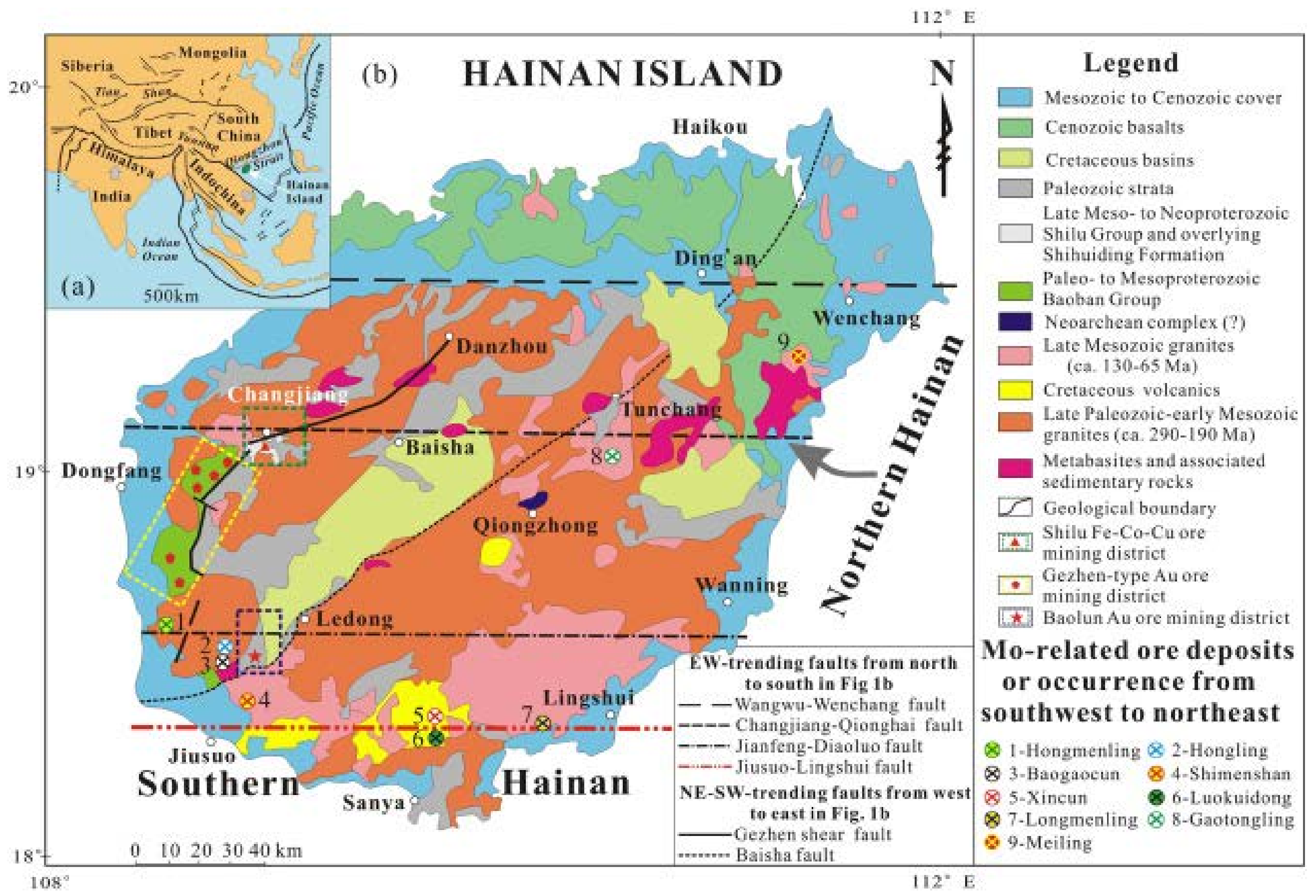
(2) Tropical fruits. In recent years, tropical fruit industry has witnessed a rapid growth and ranked one of the competitive industries with great potential. Hainan boasts a great variety of fruits, such as banana, mango, pineapple, jackfruit, litchi, longan, carambola, green orange, wax-apple. The total fruit acreage in Hainan reaches 2.5461 million acres with a total output of 1.8785 million tons, among which banana acreage is 690,000 acres with an output of 1.0863 million tons, mango 692,500 acres with an output of 262,400 tons, ranking the first in China, pineapple 192,500 acres with an output of 211,400 tons, litchi and longan 633,800 acres with an output of 109,100 tons.

(3) Tropical cash crops. The tropical crop is a distinctive feature of Hainan's agriculture, which includes rubber, coconut, betel palm, pepper, coffee bean, etc. The annual total tropical crop acreage of Hainan stands at 7.8923 million acres, among which natural rubber acreage is 6.0323 million acres with the dry glue output of 247,500 tons, accounting for 46.9% of the national total output, coconut 646,100 acres with an output of 214 million tons, 98.7% of the national total output, betel palm 796,000 acres with an output of 74,800 tons, 100% of the national total output, pepper 343,900 acres with an output of 31,400 tons, 98.7% of the national total output.

(4) Husbandry. Surrounded by sea, which provides a natural protection against epidemics, Hainan island has prominent advantages and distinct features in developing husbandry. Wenchang Chicken, Jiaji Duck, Dongshan Mutton, Lingao Roast Pig enjoy high reputation inside and outside the Island. In particular, as the construction of the Specific Animal Disease Free Zone and the epidemic prevention monitoring system continuously improve, Hainan has not only successfully controlled the occurring and spreading of the major animal epidemics such as Highly Pathogenic Avian Influenza and safeguarded its brand name as the epidemic-free and healthy island, but also effectively promoted the rapid development of husbandry of the whole province. The meat products have been sold to the mainland market, which lays a solid foundation for the construction of the National Livestock and Poultry Product Export Base.

(5) Seed breeding industry. As the seed breeding base in southern China, every year Hainan receives 5,000 experts and researchers specializing in seed breeding from all over the country. They have come to Hainan to launch research and production in breeding seeds, adding generations and testing and made a great contribution to seed improvement and upgrading by breeding seeds of 150,000 acres with the output of 28,000 tons;

(6) Processing industry for agricultural products. Hainan has a wide range of agriculture specialties with considerable production capacity. But the scale of the processing industry is not large enough and still has room for improvement. There are more than 3,500 processing enterprises in Hainan, among which only 360 have realized economy of scale. Though the added value of the processing industry reaches 3 billion, the conversion rate is only 35% lower than the national average. Given the above factors, the processing industry of tropical agricultural products promises a vast market and immense potential. *(Source: www.ta.net.cn)*



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Seaweed Extracts:

What Makes Them Work?

Russell Sharp:

In many coastal regions, raw seaweed has been used for millennia to improve the productivity of farming systems. Then, in the latter half of the 20th century the use of liquid seaweed extracts on crops became widespread globally. Farmers using these extracts repeatedly reported positive results on crop yield and quality.

As these results could not simply be correlated to the seaweed extract's elemental nutrient content, it took time for a scientific explanation for these effects to catch up. As we have gained a clearer understanding of algal biochemistry and the associated modes of action, we no longer considered seaweed extracts to be fertilizers, and instead classify them as one of the key product classes in the rapidly developing sector of biostimulants.

Below I have linked the positive effects observed when using seaweed extracts to the latest scientific knowledge of the compounds present in seaweeds to further our understanding of how and when to use seaweed extract products to maximize their efficacy.

Most of the seaweed extracts used in agriculture as biostimulants are extracted from species of brown algae (Phaeophyceae); most notably the species Ascophyllum nodosum (knotted wrack). As Ascophyllum nodosum grows in the intertidal zone of the Northern Hemisphere it has been proposed that the stressful conditions of repeated exposure to desiccation, ultraviolet light, and temperature fluctuations experienced by the seaweed in this habitat, combined with a slower growth rate, lead to the high concentrations of bioactive compounds present in Ascophyllum. In comparison, tropical species, or the kelps that grow further out to sea, produce lower concentrations of these bioactive compounds and higher levels of cellulose; a compound that is neither novel or able to stimulate plant growth.

From a review of the marketing material for microalgae-based extracts, it would appear the only advantage being claimed over brown seaweed extracts is a lower sodium content, due to their cultivation in fresh water. However, microalgae cultivation is a rapidly developing area of phycology and so new insights and products are expected in the coming years.

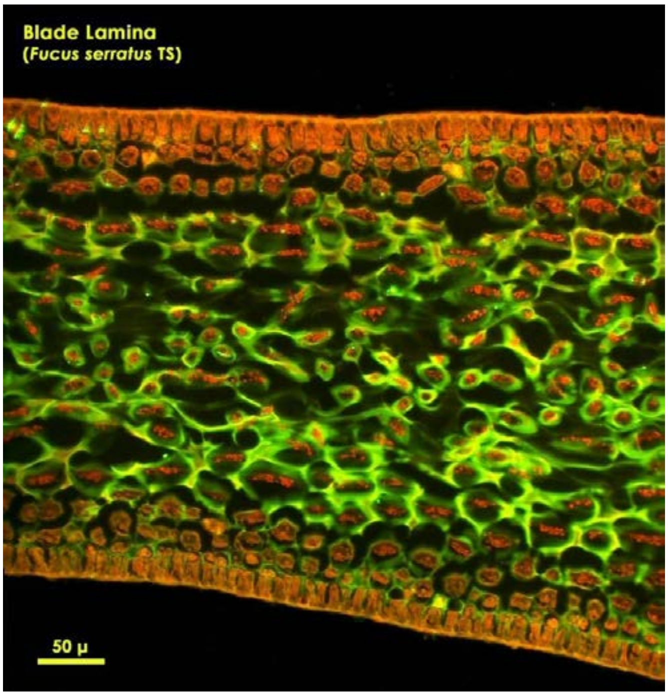
Plant hormones or analogues

It is known that algae contain plant hormones and when seaweed extracts are applied to plants the crop exhibits similar responses to when purified/synthetic plant hormones are applied. However, it is questionable whether these responses are actually due to plant hormones in seaweed extract. This is because a) many plant hormones are known to readily break down in the presence of light, heat, and oxidizing conditions (all of which an extract will experience during its time from extraction to delivery in the field), and b) when people have analyzed extracts for known plant hormones they have found comparatively low concentrations.

Instead, the current accepted paradigm is that seaweed extracts contain plant hormone analogues. These analogues possess different chemical structures to the corresponding plant hormone, but induce the same/similar response when applied to the plant. As a result, positive growth responses similar to the action of cytokinin and/or auxin are commonly cited.

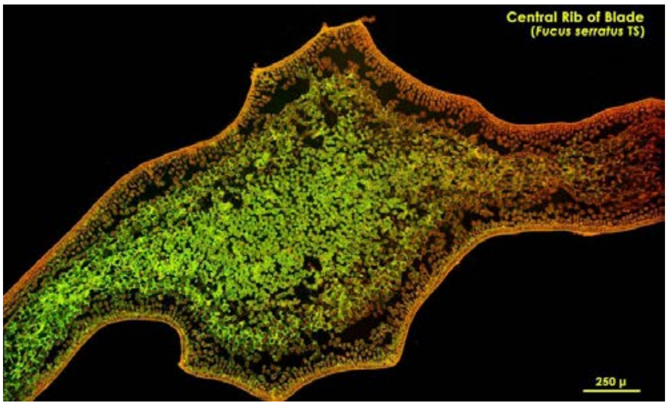
Algal polysaccharides, monosaccharides and sugar-alcohols

A range of polysaccharides are unique to algae and make up the bulk of seaweed biomass. This is illustrated in the following microscope pictures where various polysaccharides can be seen fluorescing (Mike Asquith, 2017).



The principal component of green algae cell wall is ulvans, in red seaweed cell walls it is agarans and carrageenans, and in brown seaweeds alginates and fucans are found in the cell walls and laminarin as a storage polysaccharide. These polysaccharides, along with the oligosaccharides and monomers that result from their depolymerisation during any extraction process, have been found to induce positive responses when applied to crops.

One positive response of plants to treatment with algal polysaccharides repeatedly reported in academic studies is the induction of plant defense mechanisms. As these compounds are unique to algae, plants are known to detect the presence of these polysaccharides as "non-self". Detection of algal polysaccharides at the cell membrane has been demonstrated to activate the jasmonic acid, salicylic acid, and ethylene signalling pathways.



These hormonal pathways stimulate the accumulation of a range of chemical and physical protective compounds. The activation of plant defenses by seaweed extracts can thus be used to pre-emptively protect against abiotic and biotic stress in crops. However, it should also be noted that there is no current evidence for a specific receptor in plants for these compounds, so they most likely work by stimulating a receptor for another polysaccharide microbe-associated molecular pattern (MAMP) such as chitin. Therefore, if induction of plant defenses is your primary objective, you should consider products that act directly on key cell membrane receptors as these should prove more efficacious in the field. There may also be regulatory reasons in your region that might dissuade you from using seaweed extracts to prime against biotic stresses.

In addition to plant defense priming, there are a number of other modes of action for algal polysaccharides based on their specific biochemical properties;

Alginates (alginic acid)

Alginates are the polysaccharide that give brown seaweeds their gelatinous nature. They are present in very high levels in all brown seaweed. Alginates are extracted from brown seaweed for medical use (e.g., Gaviscon). In agriculture, the gel-forming property of alginates allows for the formation of microcolloids over the surface of plants, that are thought to act as a protective film. Alginates will also act as a feed and nutrient source for beneficial microbes. This includes antagonists that exclude pathogens from colonizing the leaf surface, and those that exude plant hormones.

Mannitol

The sugar alcohol mannitol is found in high concentrations in brown seaweeds. Being water soluble, many seaweed extracts contain good levels of mannitol. Mannitol is a multifunctional compound and has three main areas of activity:

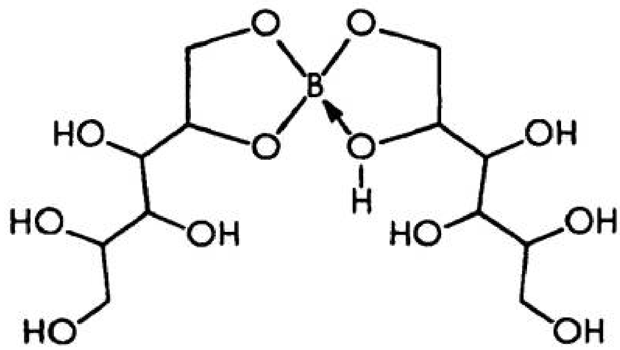


Figure 1. Mannitol is able to form a complex with boron atoms

· **Antioxidant.** Mannitol is able to "mop up" the reactive oxygen species (ROS) that create the free radicals that damage plant

tissues. ROS are produced in high levels when plants are under abiotic stresses and thus a seaweed extract containing mannitol would be a good choice in stressful growing conditions.

· **Boron complexing.** Mannitol is able to form a complex with boron atoms, effectively chelating an important plant nutrient.

· **Signalling in fungal attack.** Pathogenic fungi also use mannitol to quench ROS when attacking a plant. The interplay between mannitol and the plant's enzymes that degrade mannitol is an important interaction in the fight between a crop plant and pathogen that determines if a disease takes hold (reference). As a result, I recommend that seaweed extracts should not be applied if a crop is already suffering from a fungal disease.

Fucans

Brown seaweeds also contain significant levels of sulphonated polysaccharides known either as fucans or fucoidans. Unfortunately, there is a paucity of studies on how these function when applied to plants, however, their use and effects on animal and human is far better studied.

Vitamins and minerals

Iodine. It is well known that seaweed is a good source of iodine, in the form of iodide. As is the case for fucans, the function of iodine in human/animal health is far better understood than it is for how it functions in plants. It has been proposed that it could influence the interaction with beneficial microbes or help with the biofortification of crops destined for feed/food but reports are limited.

Vitamin B12 (cobalamin). Vitamin B12 is well known for its importance in human health. However, for plants it can also prove useful. If you study its chemical structure (see image), you will see it is a natural chelation of cobalt. Cobalt is thought to be essential for the growth of a number of crop plants, and improve the growth of others. Furthermore, cobalt is essential for the enzymes involved in nitrogen fixation by bacteria. Vitamin B12 is not synthesized in plants or animals, but seaweeds contain high amounts and seaweed extracts are a good source of this nutrient.

However, vitamin B12 is highly sensitive to alkali conditions (reference), so if cobalt is of interest consider using a cold-pressed seaweed extract. Interestingly, it is thought that the vitamin B12 found in seaweed is not

synthesized by the algae themselves but by the bacteria growing on their surfaces in their natural intertidal (littoral) habitat (reference).

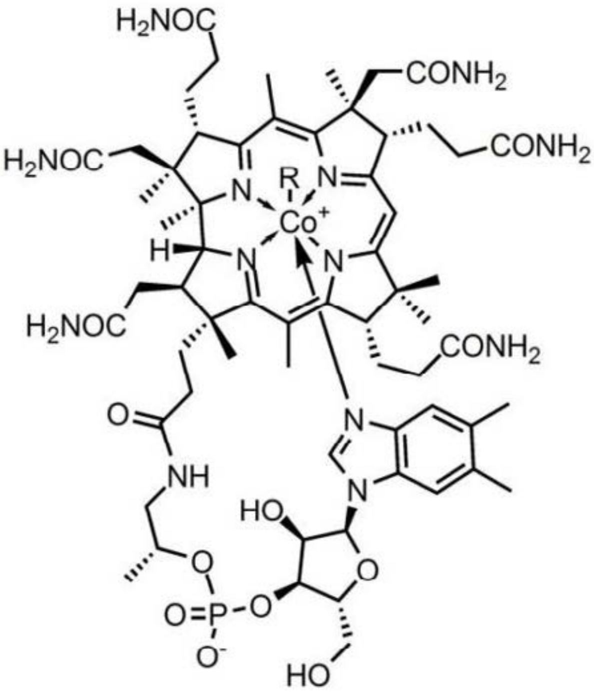


Figure 2. If you study vitamin B12's chemical structure, you will see it is a natural chelation of cobalt.

What you won't find in seaweed extracts

As well as all the active ingredients in seaweed, there are claims made that they are also a good source of other compounds. Quite often you will see claims made that seaweed extracts are a good source of amino acids, but if seaweeds were a good source of amino acids, we would eat them for their protein content, but this is not true. As a result seaweed extracts only contain very low levels of amino acids naturally and if you are looking for an amino acid biostimulants there are far better alternatives available.

Some seaweed extracts are formulated to contain high levels of plant macronutrients. However, seaweed extracts naturally contain very low levels of all macronutrients, with typical values of less than 1% w/v. Those seaweed extracts sold with much higher NPK values will have had extra nutrients added, or in the case of alkali extracts, there will be potassium present due to the use of potassium hydroxide required for the chemical extraction. Therefore, it is recommended that you do not choose a seaweed extract purely on its nutritional content.

In conclusion, as we gain more insights into the mechanisms by which seaweed extracts function in crops I hope we will start to see the industry move away from the "use to improve plant growth" marketing approach toward a more scientific and informed strategy. If you would like to know more about seaweed extracts, how to use them, or the difference between extraction methods please get in touch. ***(Source: Agribusiness Global, by Russell Sharp)***

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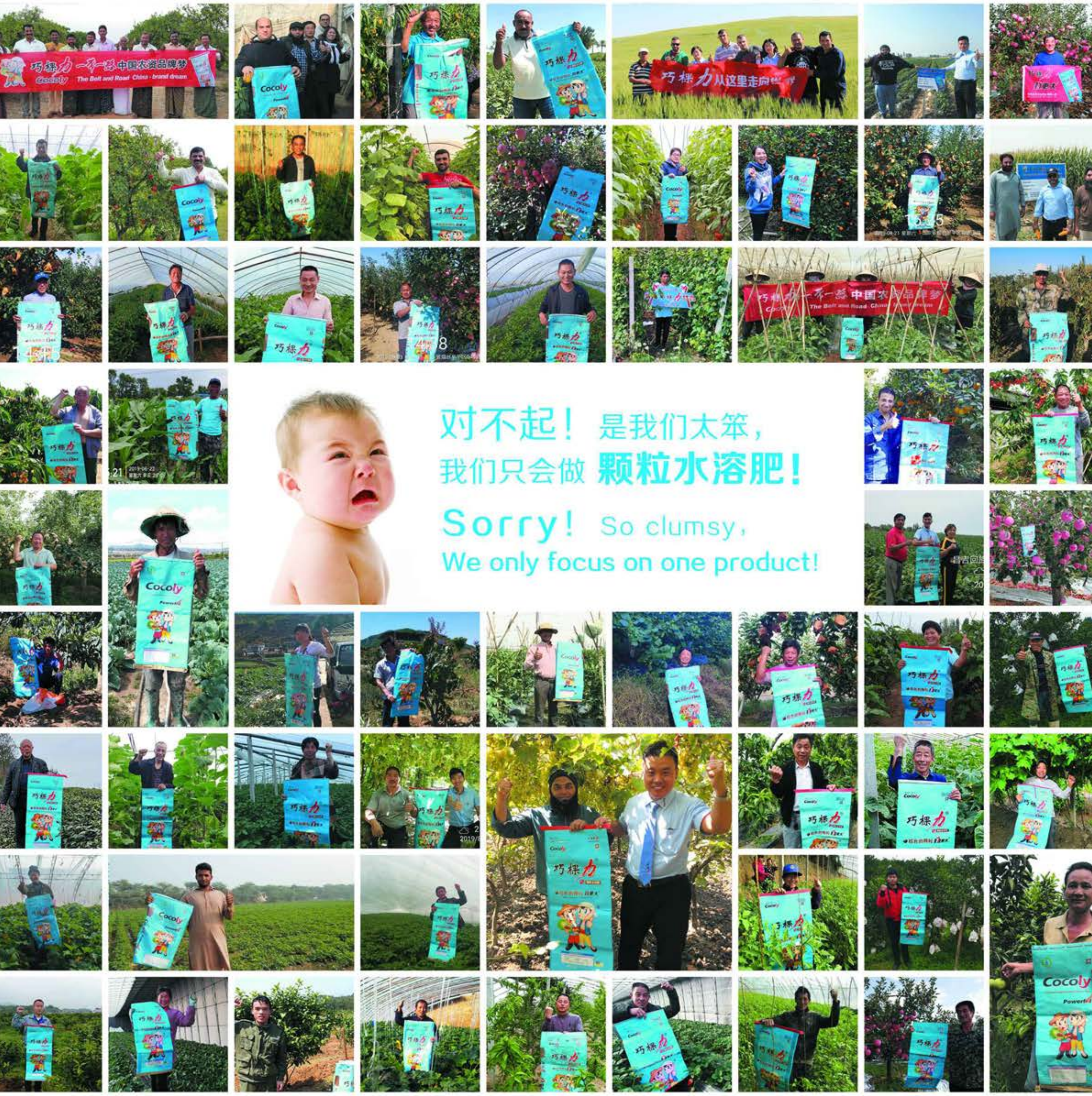

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Physiological Functions of

Mineral Micronutrients (Cu, Zn, Mn, Fe, Ni, Mo, B, Cl)

By **Robert Hänsch, Ralf R Mendel,** Institut für Pflanzenbiologie, Technische Universität

Micronutrients are involved in all metabolic and cellular functions. Plants differ in their need for micronutrients, and we will focus here only on those elements that are generally accepted as essential for all higher plants: boron (B), chloride (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), and zinc (Zn). In this review, we focus on the major functions of mineral micronutrients, mostly in cases where they were shown as constituents of proteins, making a selection and highlighting some functions in more detail.

Introduction

Micronutrients are elements that are essential for plant growth but are required inmuch smaller amounts (Table 1) than those of the primary nutrients such as nitrogen, phosphorus, sulfur, and potassium. This list may grow as more protein structures are elucidated. All organisms have to acquire appropriate amounts of each micronutrient that requires a metal homeostasis network involving mobilization, uptake and distribution within the plant, intracellular trafficking, and storage. Several essential metal ions are redox-active that is the basis for their occurrence as catalytically active cofactors in many metalloenzymes. Other metals (like zinc) fulfill in addition to their catalytic role a structural role in stabilizing proteins.

Micronutrients are involved in virtually all metabolic and cellular functions, like energy metabolism, primary and secondary metabolism, cell protection, gene regulation, hormone perception, signal transduction, and reproduction among others. Historically, their physiological role was first described on the basis of deficiency symptoms. In this review, we focus on the major functions of mineral micronutrients, concentrating on cases where the micronutrient is a constituent of a particular protein.

Table 1

Micronutrients in plants.

Element	Symbol	Absorbed by plant	Concentration in plant [$\mu g\ g^{-1}$ dry weight][a]	Protein complexed with the micronutrient (or other effects)
Boron	(B)	H_3BO_3	3–100	Rhamnogalacturonan II
Chlorine	(Cl)	Cl^-	20 000[b]	Oxygen evolving complex
				Seismonastic movement
Copper	(Cu)	Cu^{2+}	1–20	Ascorbate oxidase
				Polyphenol oxidase
				Cu–Zn superoxide dismutase
				Cytochrome *c* oxidase
				Plastocyanin
				Cu-metallothionein
				Ethlyene receptor
				Mo-cofactor biosynthesis
Iron	(Fe)	Fe^{3+}, Fe^{2+}	50–150	
	Fe–S-cluster			Aconitase
				Succinate dehydrogenase
				NADH-Q oxidoreductase
				Thioredoxin reductase
				Xanthine dehydrogenase
				Aldehyde oxidase
				Ferredoxin
	Heme			Cytochromes
				Catalase, Peroxidase
				Cytochrome *c* oxidase
				Nitrate reductase
				Nitrite reductase
				Cytochrome P450
				Leg hemoglobin
	Non-heme			Fe-superoxide dismutase
				Lipoxygenase
				Alternative oxidase
				Ferritin
Manganese	(Mn)	Mn^{2+}	10–100	Mn-superoxide dismutase
				PEP-carboxykinase
				Allantoate amidohydrolase
				Malic enzyme
				Isocitrate lyase
				PEP carboxylase
Molybdenum	(Mo)	MoO_4^{2-}	0.1–1	Nitrate reductase
				Sulfite oxidase
				Aldehyde oxidase
				Xanthine dehydrogenase
Nickel	(Ni)	Ni^+	15–22	Urease
				Ni-chaperone
Zinc	(Zn)	Zn^{2+}	15–50	SPP
				Carbonic anhydrase
				Cu–Zn superoxide dismutase
				Alcohol dehydrogenase
				Peptide deformylase
				α-Mannosidase
				Matrix metalloproteinase

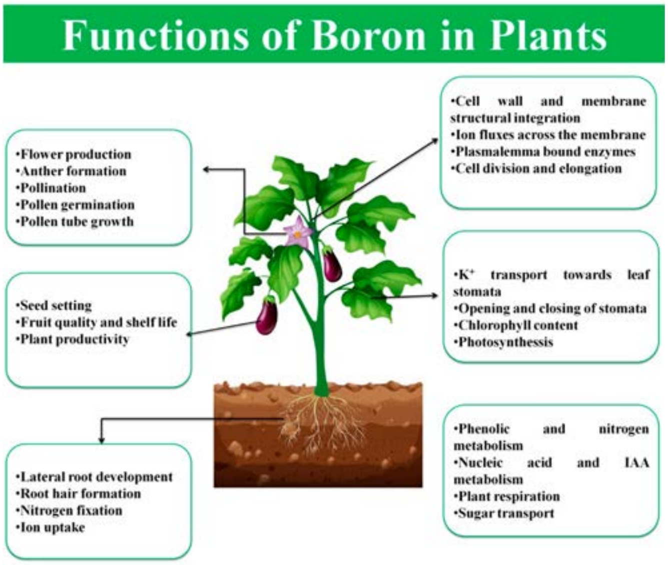
[a] The concentration of micronutrients in plants can vary widely depending on the species, genotype, organ, tissue, and growth condition. Therefore ranges are given.
[b] Requirement for optimal growth: 200–400 $\mu g\ g^{-1}$ dry weight.

Boron

The unusual nature of boron chemistry suggests the possibility of a wide variety of biological functions for the micronutrient; however, the exact metabolic functions are not finally understood. Boron is involved in numerous important processes, including protein synthesis, transport of sugars, respiration, RNA and carbohydrate metabolism, and the metabolism of plant hormones (indole acetic acid). Moreover, functions of boron are related to cell wall synthesis, lignification, and cell wall structure by cross-linking of cell wall polysaccharides as well as the structural integrity of biomembranes. It increases the transport of chlorine and phosphorus as a result of plasmalemma ATPase induction.

More than 90% of the boron in plants is found in cell walls, and rhamnogalacturonan II was shown to bind boron. Because the wall-associated kinase in the plasmamembrane has an extracellular matrix connection with the pectin molecule, the membrane cell wall connection is finally also boron-dependent. Boron was found to promote the structural integrity of biomembranes and the formation of lipid rafts].

Since all these functions are fundamental to meristematic tissues, boron deficiency is predominantly damaging actively growing organs such as shoot and root tips so that the whole plant may be stunted (rosetting). Flower retention, pollen formation, pollen tube growth or germination, nitrogen fixation, and nitrate assimilation are also affected by boron.



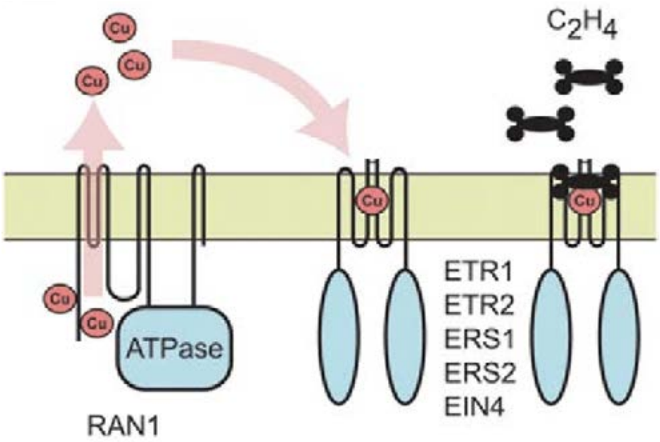
Chlorine

Chlorine is known to exist in more than 130 organic compounds in plants [7]. Most soils contain sufficient levels of chlorine. However, chlorine deficiencies have been described in sandy soils in high rainfall areas or could be created artificially in experiments to prove its requirement as a micronutrient for higher plants. Because chloride is a mobile anion in plants, most of its functions are related to electrical charge balance.

In the chloroplast, chloride is a structural constituent of photosystem II in the oxygen evolving complex as one of the three important cofactors. Proton-pumping ATPase at the tonoplast is specifically stimulated by chloride . The overall chlorine concentration in the whole plant is too low to be an effective osmo-regulator; however, chlorine is accumulated in certain tissues or single cells (e.g. guard cells). Opening and closing of the guard cells is mediated by the flux of potassium and anions such as malate and chloride. Therefore, chlorine indirectly affects plant growth by stomatal regulation. Reduction of leaf surface area, wilting of the plant, and restricted, highly branched root systems are the main chlorine-deficiency symptoms. On the contrary, seismonastic leaf movement of Mimosa pudica is directly chlorine-dependent. The 'osmotic motor' for the leaf movement is powered by a plasma membrane proton ATPase, which drives KCl and water fluxes. The movement results from different volume and turgor changes in the two oppositely positioned parts in the specialized motor leaf organs called pulvinus.

Copper

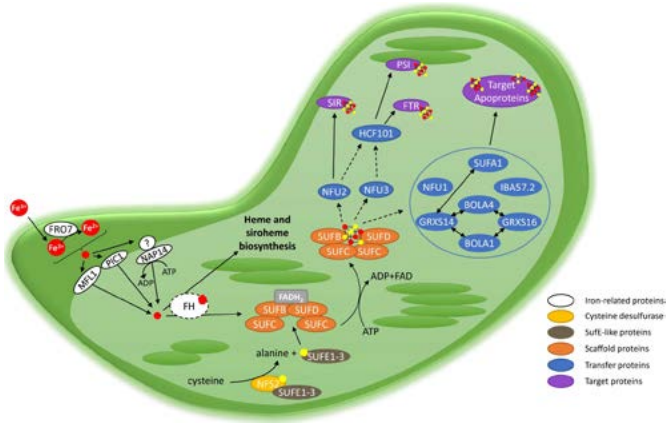
Copper is of utmost importance for life. Copper is essential for photosynthesis and mitochondrial respiration, for carbon and nitrogen metabolism, for oxidative stress protection, and is required for cell wall synthesis. Under physiological conditions, copper exists in the two oxidation states Cu^{1+} and Cu^{2+} and can interchange between these forms (monovalent copper is unstable). This allows copper to function as a reducing or oxidizing agent in biochemical reactions.



Copper has a particularly high affinity to dioxygen molecules that explains why copper is the catalytic metal in many oxidases. More than half of the copper in plants is found in chloroplasts and participates in photosynthetic reactions. Hence, copper deficiency becomes first visible in young leaves and reproductive organs, later consequences are stunted growth of the whole plant and pale green leaves that wither easily. Interestingly, copper metabolism is intimately linked to iron metabolism. Finally, copper is also part of the ethylene receptor and is involved in molybdenum cofactor biosynthesis.

Iron

Like copper, iron is also of great importance for life. As redox-active metal it is involved in photosynthesis, mitochondrial respiration, nitrogen assimilation, hormone biosynthesis (ethylene, gibberellic acid, jasmonic acid), production and scavenging of reactive oxygen species, osmoprotection, and pathogen defense. Up to 80% of the cellular iron is found in the chloroplasts that is consistent with its major function in photosynthesis. Depending on the type of iron ligand, three groups of iron-containing proteins can be defined: (1) proteins with iron–sulfur clusters (Fe–S), (2) heme-containing proteins, and (3) other iron proteins.



Fe–S proteins: Fe–S clusters have pivotal functions in electron transfer, they constitute part of substrate binding sites in enzymes, they form iron storage moieties, they are involved in transcriptional or translational regulation, they can control protein structure in the vicinity of the cluster, and finally they have been shown to be involved in disulfide reduction and sulfur donation (e.g. thioredoxins). Hence, Fe–S proteins serve functions as enzymes, as electron carriers (e.g. ferredoxin), and as regulator proteins (e.g. aconitase).

Heme proteins: The well-known hemoproteins are the photosynthetic and respiratory cytochromes, involved in electron transfer, and the globins that bind oxygen. Other examples include the oxidative enzymes catalase, peroxidase, and NADPH oxidase, involved in the production and/or scavenging of free radicals, and the very large group of cytochrome P450 enzymes. In plants and microbes, these latter catalyze mono-oxygenation reactions in biosynthetic pathways, such as for sterols and many secondary metabolites, whereas in animals their major role is in the detoxification of xenobiotics. Further, globins like leg-hemoglobin are involved in oxygen binding and transport.

Other iron proteins: These proteins (that are sometime also grouped as non-heme proteins) bind iron ions directly, i.e. neither as heme nor in the Fe–S form. Among these proteins, ferritins are most prominent. Ferritins are plastidic iron storage proteins and control the interaction between iron homeostasis and oxidative stress in Arabidopsis. Ferritins occur mostly in nongreen plastids like etioplasts and amyloplasts but not in mature chloroplasts.

Manganese

Manganese is essential for plant metabolism and development and occurs in oxidation states II, III, and IV in approximately 35 enzymes of a plant cell [25]. Manganese can fulfill two functions in proteins: (1) it serves as catalytically active metal, or (2) it exerts an activating role on enzymes. Examples for the catalytic role are manganese-containing superoxide dismutase protecting the cell from damaging effects of free radicals, the oxalate oxidase, and the manganese-containing water splitting system of photosystem II [26]. Examples for the manganese- activated enzymes are malic enzyme, isocitrate dehydrogenase, PEP carboxykinase, and phenylalanin ammonia lyase.

Among the rather large group of manganese- activated enzymes, the role of manganese is less specific as in many cases it can be replaced by magnesium.

Proteins belonging to this group are involved in the shikimic acid pathway and subsequent pathways leading to the formation of aromatic amino acids, lignins, flavonoids, and the phytohormone indole acetic acid. Manganese activation was seen in enzymes of nitrogen metabolism (glutamin synthetase, arginase), gibberellic acid biosynthesis, RNA polymerase activation, and fatty acid biosynthesis.

Molybdenum

Only a handful of plant proteins are known to contain molybdenum. These proteins, however, are very important as they are involved in nitrogen assimilation, sulfur metabolism, phytohormone biosynthesis, and stress reactions. Nitrate reductase is the key-enzyme for nitrate assimilation while nitrogenase is found in nitrogen fixing bacteria inside nodules of symbiotically growing species. The last step of abscisic acid biosynthesis is catalyzed by the molybdenum-enzyme aldehyde oxidase, and sulfite oxidase protects the plant against toxic levels of sulfite (acid rain!). Hence a defect in molybdenum-metbolism leads to the pleiotropic loss of these enzyme activities with lethal consequences for the organism.

In all organisms, molybdenum has to be complexed by a pterin compound thereby forming the molybdenum cofactor in order to gain biological activity. Molybdenum metabolism is intimately linked to iron and copper metabolism at several crosspoints (Figure 1). Another crosstalk was discovered between molybdenum and copper metabolism as copper was found to be essential for the formation of a molybdenum cofactor intermediate.

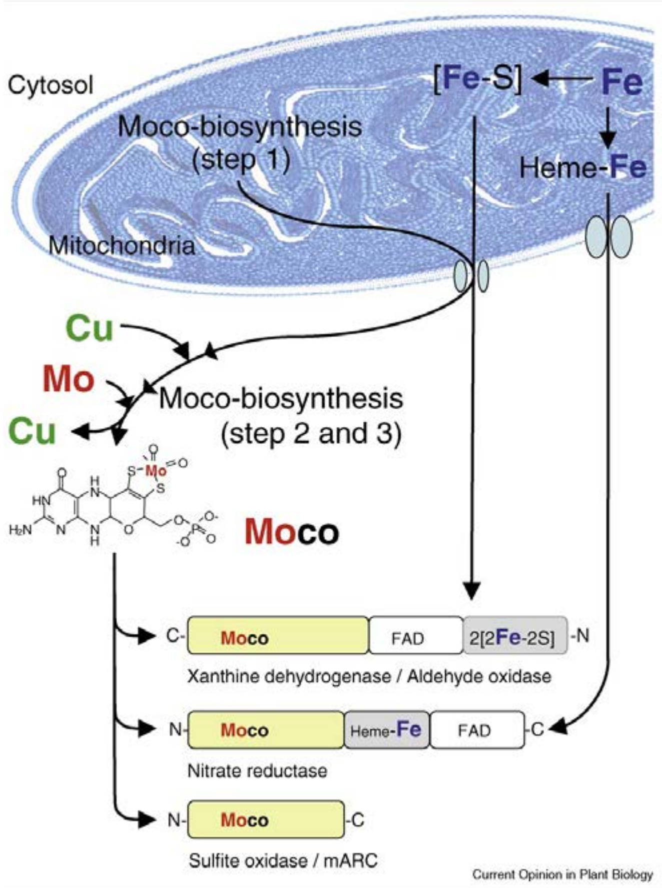


Figure 1 Schematic representation of the metabolic link between the three micronutrients molybdenum, iron, and copper as it is found in molybdenum metabolism. In order to become biologically active, molybdenum has to be complexed by a pterin compound thereby forming the molybdenum cofactor (Moco).

Nickel

Nickel is essential in numerous prokaryotic enzymes like dehydrogenases, hydrogenases, and methylreductases but is barely used as cofactor in eukaryotes. Among plants, it occurs not only in oxidation states II, but also in states I and III. A deficiency symptom in plants is the accumulation of toxic urea that could be explained with the complete loss of urease activity within the cell. Plant urease hydrolyzes its substrate to carbon dioxide and ammonia. An additional Ni^{2+}-binding protein could be identified in soybean that acts as Ni-metallochaperone essential for urease activity. It seems to be possible that a few more Ni-dependent enzymes will be identified in plants in the future.

Zinc

Zinc is important as a component of enzymes for protein synthesis and energy production and maintains the structural integrity of biomembranes. More than 1200 proteins are predicted to contain, bind, or transport Zn^{2+}, including – among others – a large numbers of zinc-finger containing proteins and transcription factors, oxidoreductases, and hydrolytic enzymes such as metalloproteases. Zinc plays also an important role in seed development, and zinc-deficient plants show a delayed maturity.

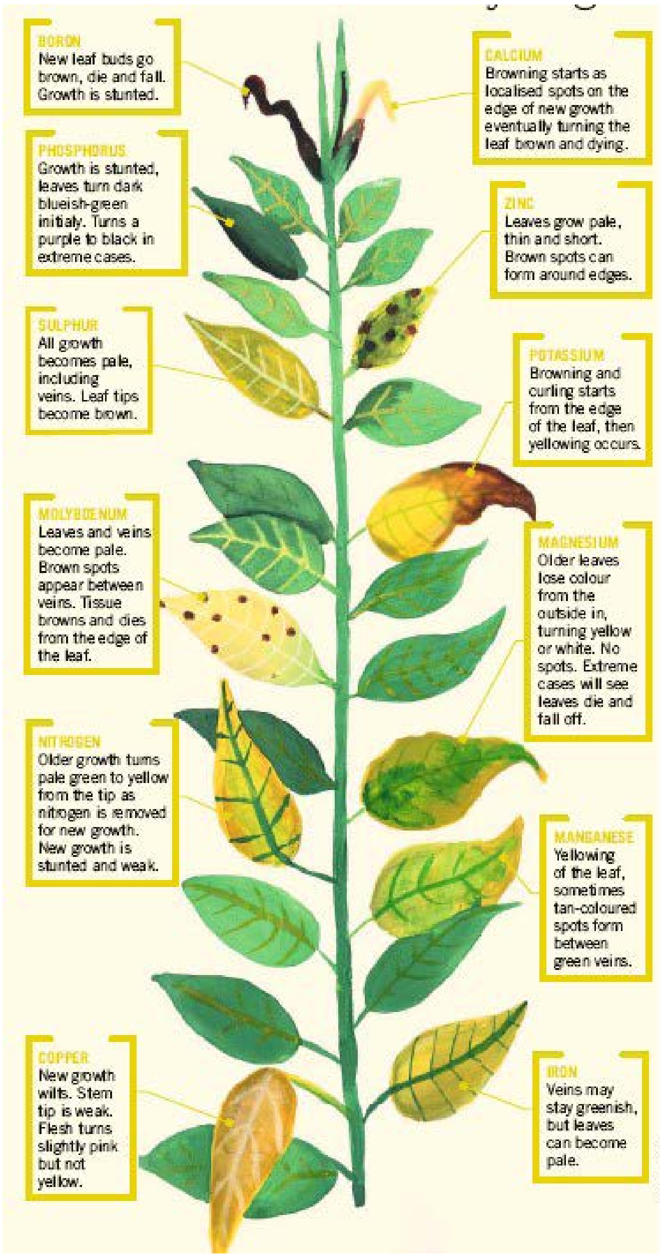
Most of the zinc enzymes are involved in regulation of DNA-transcription, RNA-processing, and translation. In chloroplasts, zinc-dependent enzymes fulfill several major functions. The stromal processing peptidase SPP is zinc-dependent in analogy to the mitochondrial system. Moreover inside the chloroplasts proteolytic activities are dependent on zinc. Zinc deficiency also reduces net photosynthesis in plants by disturbing the activity of carbonic anhydrase.

In addition to chloroplasts and mitochondria, also the cytoplasm, lysosome, and the apoplastic space are compartments with zinc-dependent hydrolytic activities: different nucleases and aminopeptidases, peptide deformylases, the 26S-proteasome, the a-mannosidase, and matrix-metalloproteinases associated with the extracellular matrix. Further, Zinc was found to be involved in signal transduction via mitogen-activated protein kinases.

Conclusion

Essential micronutrients were found as constituents in over 1500 proteins where they fulfill catalytic, (co-)activating, and/or structural functions.

The largest group (>1200) is formed by zinc-proteins (with transcription factors as major subgroup). Proteins containing iron, copper, or manganese make up groups in the range of 50–150 members each, while molybdenum and nickel proteins can be counted on one hand each. Boron and chlorine are very important, but proteins or compounds that were unambiguously shown to contain these micronutrients are very rare and mostly elusive.



FSHOW 2021 第十二届中国国际新型肥料展览会
12th China International Fertilizer Show

展览时间：2021 年 3 月 3–5 日
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