PROCEEDINGS
OF THE 47th ANNUAL MEETING
FERTILIZER INDUSTRY
ROUND TABLE
1997

October 27, 28, and 29, 1997
TradeWinds Resort
St. Pete Beach, Florida

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The 47th Annual Meeting Fertilizer Industry Round Table 1997

Opening Remarks

Olie H. Lie, Chairman

Dear friends of the Fertilizer Industry Round Table, ladies and gentlemen,

It is indeed a pleasure and a privilege to welcome you all to the Forty-Seventh Annual meeting of the Fertilizer Industry Round table.

The Fertilizer Industry Round Table is an independent, non profit organization whose existence is upheld and fueled by the enthusiasm and tenacity of the good people involved: the board of directors as the organizer of the Annual Meeting and the producer of the Meeting proceedings, the excellent speakers who willingly accept our invitations to come and speak to us without getting any compensation even though their agendas are already overcrowded, and you, dear friends, as the interested and interactively participating audience.

As the 47th anniversary implies, the organization started shortly after the 2nd World War by industry people and scientists who saw the importance of the industry in the food chain and the need for bringing the prevailing, mostly empirically based fertilizer production practices over on a more solid, quantitative scientific footing. And, as we all know, Vince Sauchelli was the guiding light in the important first years and his work on granulation became mandatory reading for fertilizer people around the world. And the Round Table has over time also attained an international flavor. The board of directors have now members from around the globe, and many people from around the world participate in the Annual meeting.

My own association with the Round Table started nearly thirty years ago and has been fairly continuous, since I always thought I returned from the meetings with a wider and better perspective of fertilizers and agriculture. Furthermore, the people I met gave me, and other participants from abroad, the feeling of being welcome, and, last but not least, they provided me with a new set of jokes which I successfully used when I returned home.

I was always impressed how the dedicated supporters and board directors of the Round Table such as the Prossers, Paul and Joe, Walt Sackett, Joe Reynolds, Frank Achorn, Tom Athey, Rodger Smith and many, many others, seemingly effortlessly, were able to put together excellent programs with limited funds but with first class relations to Academia, the Fertilizer Industry, and to the regulating bodies in this country. However, after becoming the chairman of the board it has become clear to me how much of their own time and money these gentlemen have put — and still put — into the Round Table. Truly a labor of love. They deserve our praise!

As the fortunes of the US Fertilizer Industry have ebbed and flowed in recent years, and the periods of low profitability have indeed been long and painful, the structure of the industry has changed markedly. To shave costs and benefit from size, the fertilizer companies, both in the US and abroad, through mergers and acquisitions have become larger and fewer.

One of the consequences of these developments has been that the many of the conferences and meetings of yesteryear for discussing and exchanging information about innovations and developments in fertilizer technology and fertilizer use have disappeared. TVA's fertilizer development activities are gone, and modest amounts of development are done in the major fertilizer companies.

The Fertilizer Industry Round Table has been able to uphold its activities in these trying times, and has retained its role as an important forum for discussing new developments and common problems in an informal, open manner. This is a place where industry people can meet and listen to papers by leading university scientists on fundamental developments in agriculture, where experiences with application of new production technology are reported and shared by fertilizer plant operating people from around the U. S, and indeed the whole world, where new and better agricultural methods and fertilizer application techniques are discussed and know how disseminated and where regulating authorities and Industry meet and discuss problems and challenges — environmental and others — within the production, sale and use of fertilizers.

The Fertilizer Industry is already a key link in the food production chain, indirectly providing food for more than 40% of the world population. Considering the challenges the world is confronted with in adequately feeding a constantly expanding population on a limited amount of land in a sustainable way and in harmony with the environment, the importance of fertilizers and their intelligent use become crucial, as can be seen in the following figures:

Figure 1 is a depiction the necessary developments in grain yield and nutrient need in the next 20 years. Most of the added requirements for nutrients must come from mineral fertilizers.

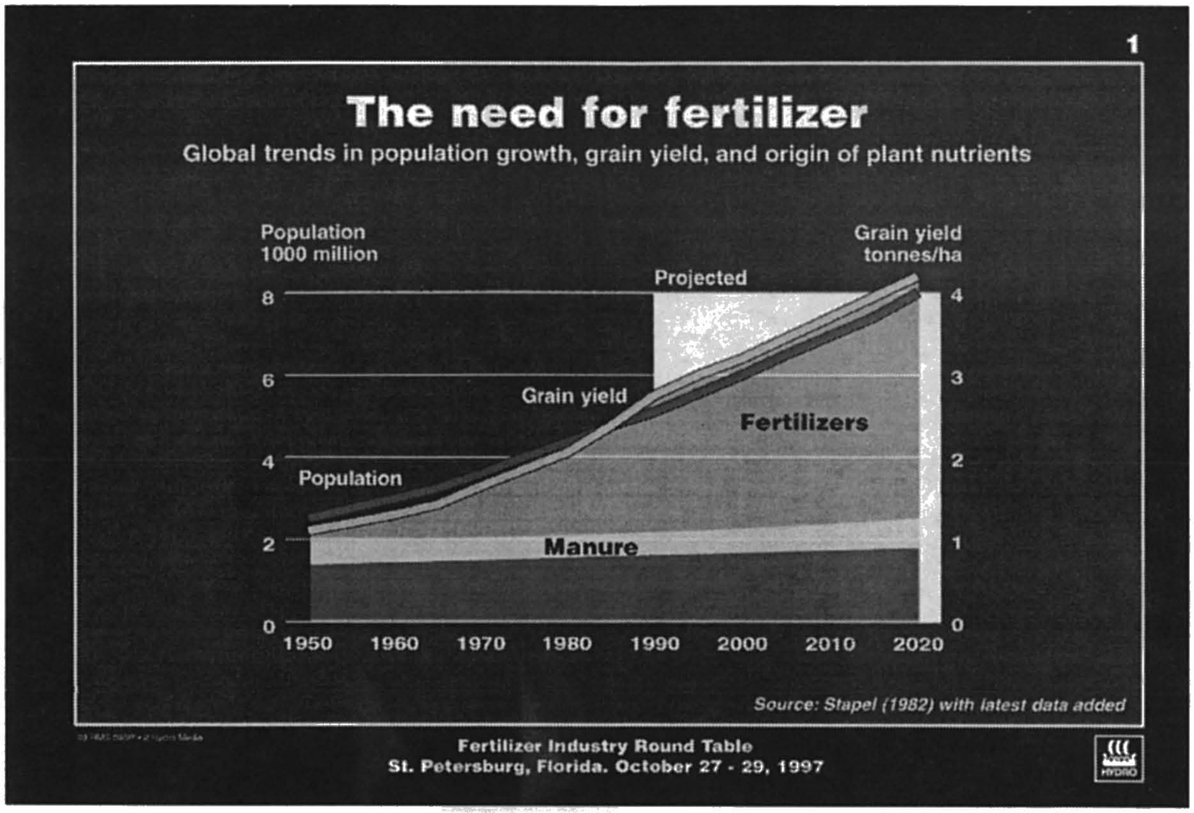
Figure 2 shows the expected increase in food demand during the period 1990 - 2020.

Figure 3, 4, 5 and 6 show these developments will look in China. Chinas ambitions of increased food production and upgrading of their diet must take place on a reduced land base, increased irrigation and significant increase in fertilizer use. China's situation is typical for many developing nations.

Concurrent to this situation, the world is facing the possibility of global warming, Figure 7 and 8. Many of you probably read/heard Bill Clinton's speech about limiting the emissions of greenhouse gases - mainly carbon dioxide, methane and nitrous oxide - to the level of 1990 by the year 2010. Other countries and the environmental NGOs talk about the need for much lower emissions than the 1990 level. The outcome of the Conference of the Parties meeting in Kyoto, Japan, in early December this year will be of great importance for everybody, Figure 9.

Reduction of greenhouse gas emissions is essentially a reduction in carbon based energy use (burning of fossil fuels). How this situation will affect fertilizer use and agriculture is unclear. Agriculture emits considerable amounts of greenhouse gases, Figure 10, but at the same time removes carbon dioxide from the atmosphere by contributing to vegetation. The Fertilizer Industry, however, will be put under strong pressure to reduce its energy consumption.

Ladies and gentlemen, let me stop here. My main point is that life in the Fertilizer Industry in the future will at least be as interesting and challenging as it has been in the past. And I expect the Fertilizer Industry Round Table to continue to be an important meetingplace.


1
The need for fertilizer
Global trends in population growth, grain yield, and origin of plant nutrients
Population
1000 million
Grain yield
tonnes/ha
Projected
8
6
4
2
0
4
3
2
1
0
Grain yield
Fertilizers
Population
Manure
1950
1960
1970
1980
1990
2000
2010
2020
Source: Stapel (1982) with latest data added
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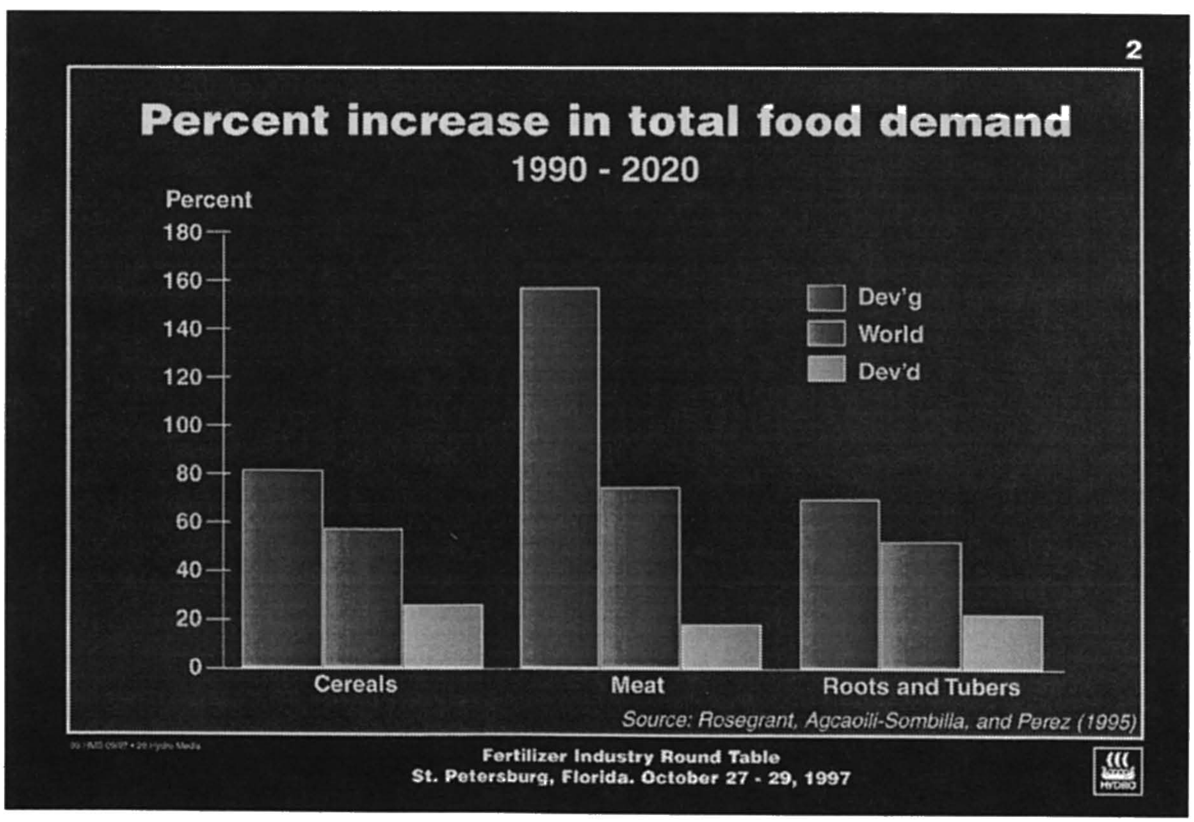
2
Percent increase in total food demand
1990 - 2020
Percent
180
160
140
120
100
80
60
40
20
0
Dev'g
World
Dev'd
Cereals
Meat
Roots and Tubers
Source: Rosegrant, Agcaoili-Sombilla, and Perez (1995)
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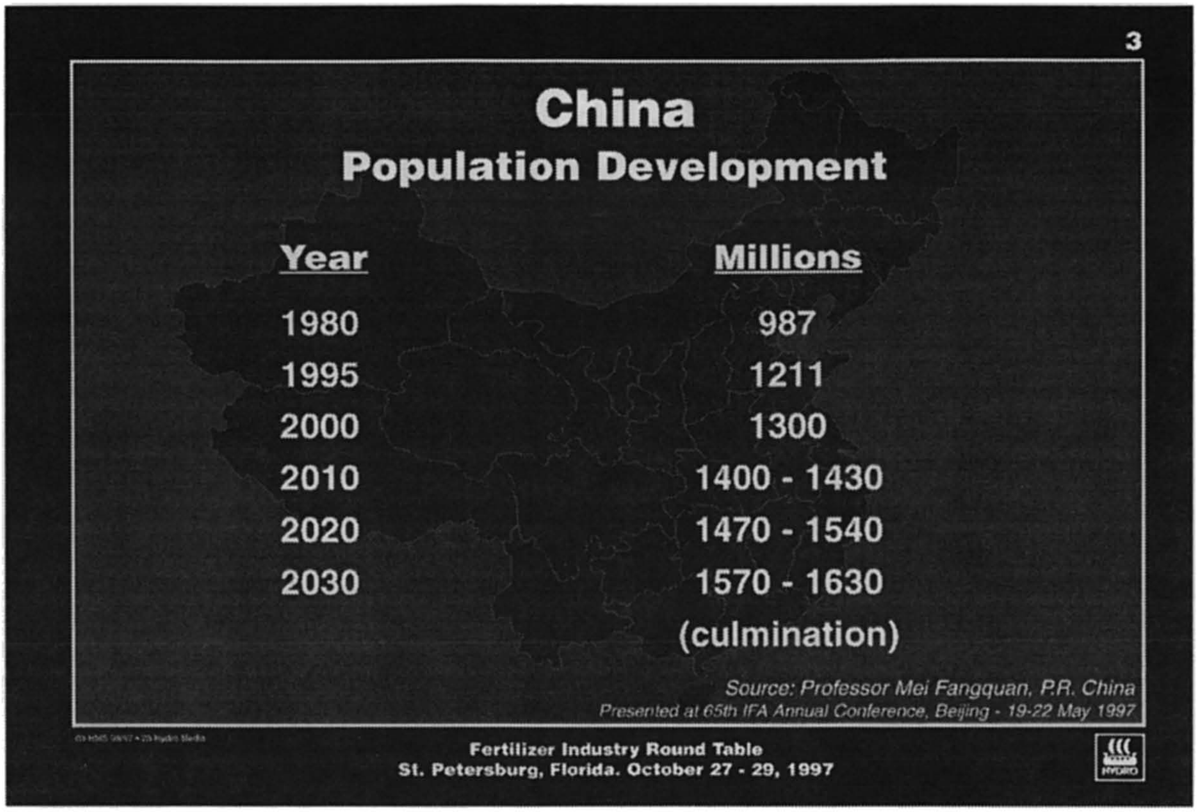
3
China
Population Development
Year
Millions
1980
987
1995
1211
2000
1300
2010
1400 - 1430
2020
1470 - 1540
2030
1570 - 1630
(culmination)
Source: Professor Mei Fangquan, P.R. China
Presented at 65th IFA Annual Conference, Beijing - 19-22 May 1997
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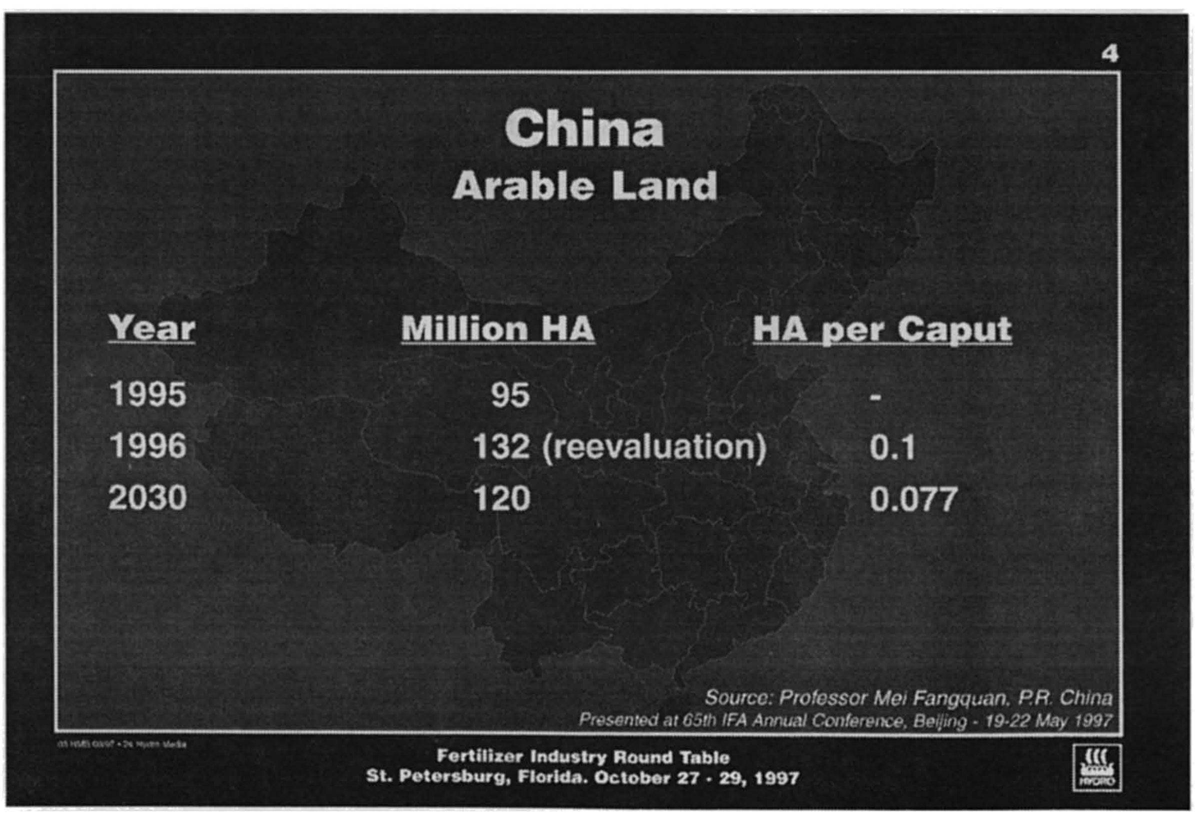
4
China
Arable Land
Year
Million HA
HA per Caput
1995
95
-
1996
132 (reevaluation)
0.1
2030
120
0.077
Source: Professor Mei Fangquan, P.R. China
Presented at 65th IFA Annual Conference, Beijing - 19-22 May 1997
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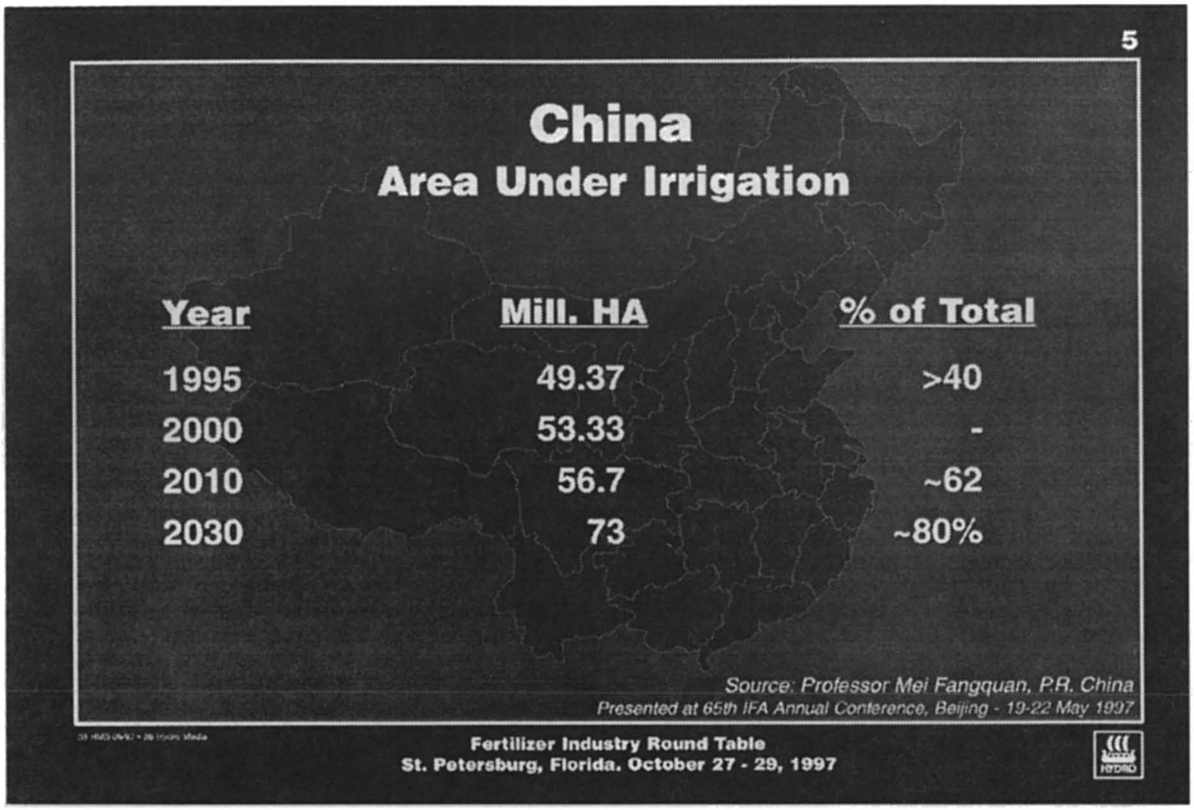
5
China
Area Under Irrigation
Year
Mill. HA
% of Total
1995 49.37 >40
2000 53.33 -
2010 56.7 ~62
2030 73 ~80%
Source: Professor Mei Fangquan, P.R. China
Presented at 65th IFA Annual Conference, Beijing - 19-22 May 1997
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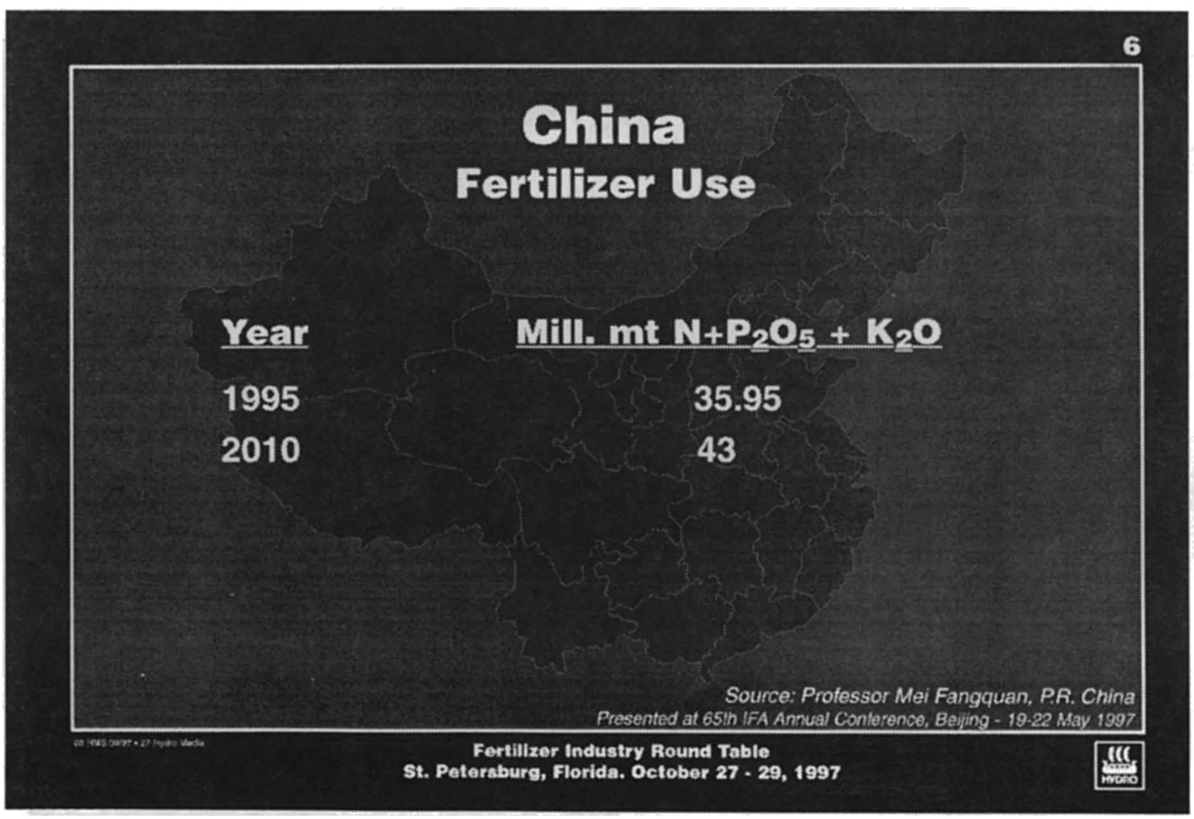
6
China
Fertilizer Use
Year
Mill. mt N+P2O5 + K2O
1995 35.95
2010 43
Source: Professor Mei Fangquan, P.R. China
Presented at 65th IFA Annual Conference, Beijing - 19-22 May 1997
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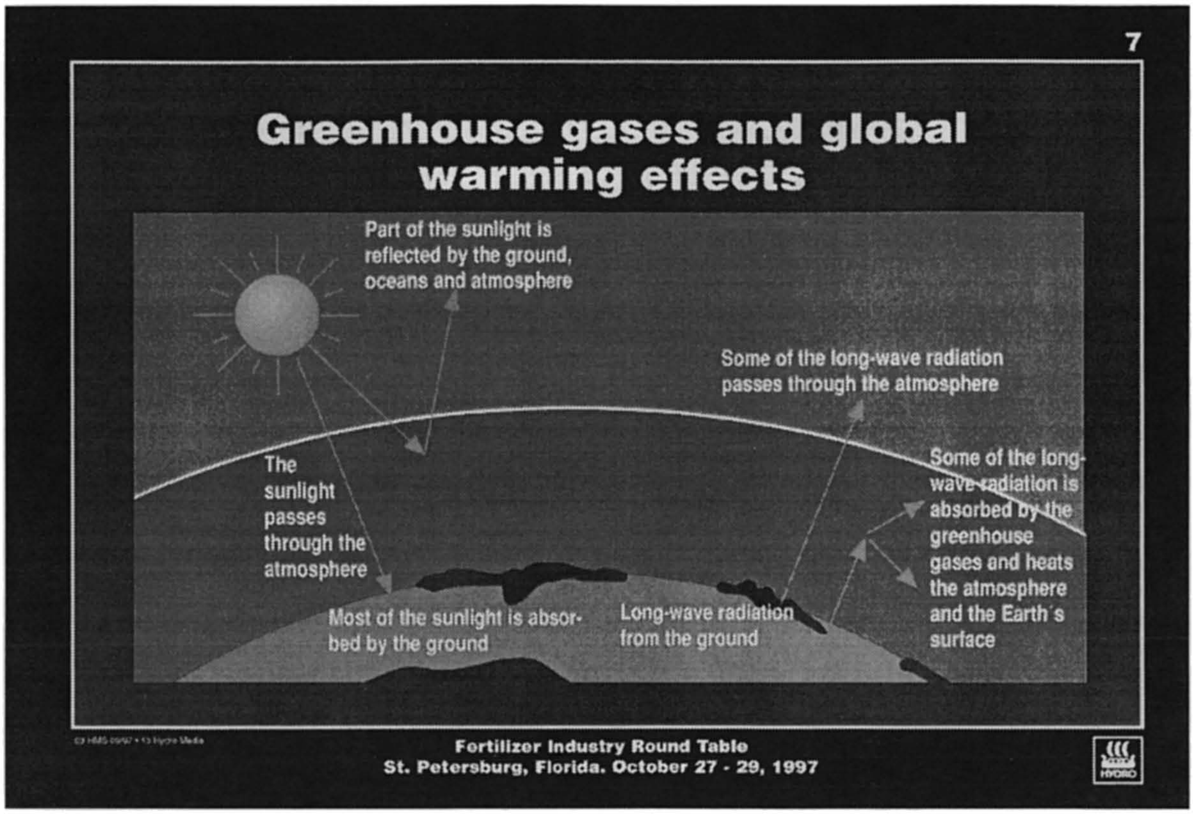
7
Greenhouse gases and global warming effects
Part of the sunlight is reflected by the ground, oceans and atmosphere
Some of the long-wave radiation passes through the atmosphere
The sunlight passes through the atmosphere
Some of the long-wave radiation is absorbed by the greenhouse gases and heats the atmosphere and the Earth's surface
Most of the sunlight is absorbed by the ground
Long-wave radiation from the ground
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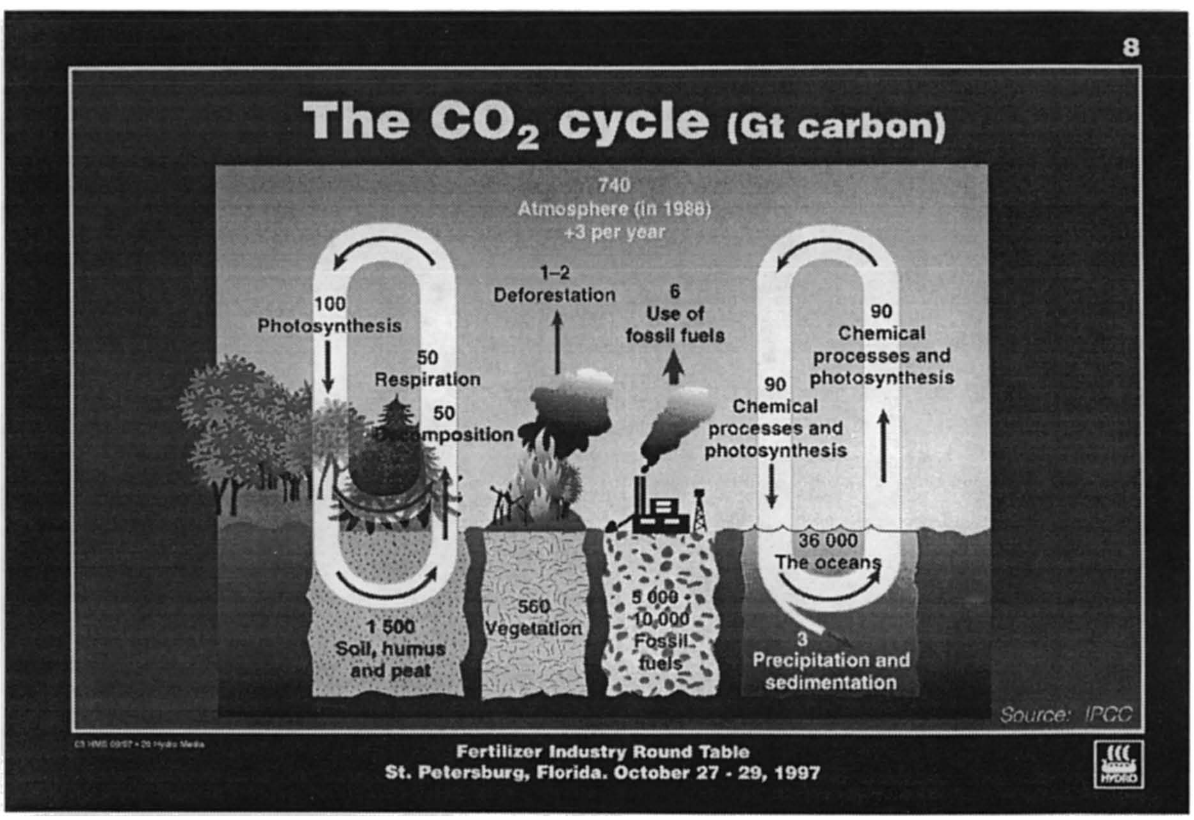
8
The CO_2 cycle (Gt carbon)
740
Atmosphere (in 1988)
+3 per year
1–2
Deforestation
6
Use of fossil fuels
100
Photosynthesis
50
Respiration
50
Decomposition
90
Chemical processes and photosynthesis
90
Chemical processes and photosynthesis
36 000
The oceans
1 500
Soil, humus and peat
560
Vegetation
5 000 - 10 000
Fossil fuels
3
Precipitation and sedimentation
Source: IPCC
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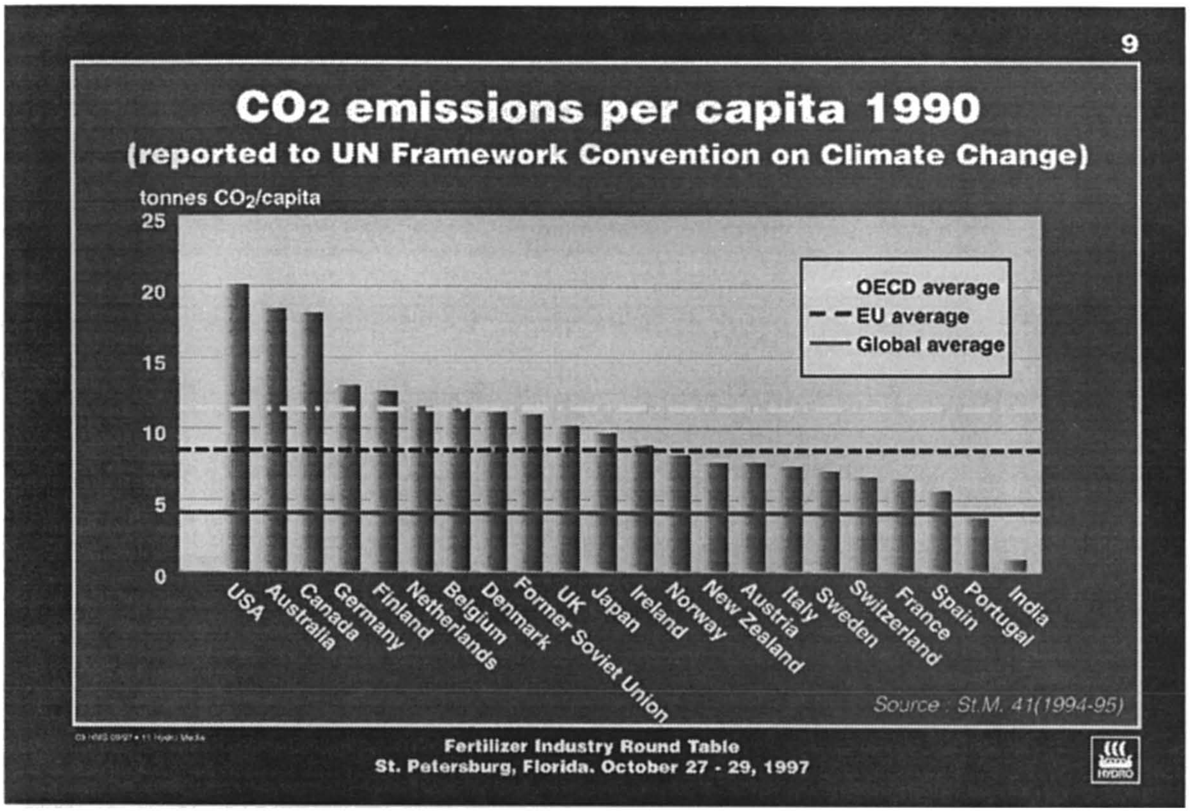
9
CO2 emissions per capita 1990
(reported to UN Framework Convention on Climate Change)
tonnes CO2/capita
25
20
15
10
5
0
OECD average
EU average
Global average
USA
Australia
Canada
Germany
Finland
Netherlands
Belgium
Denmark
Former Soviet Union
UK
Japan
Ireland
Norway
New Zealand
Austria
Italy
Sweden
Switzerland
France
Spain
Portugal
India
Source : St.M. 41(1994-95)
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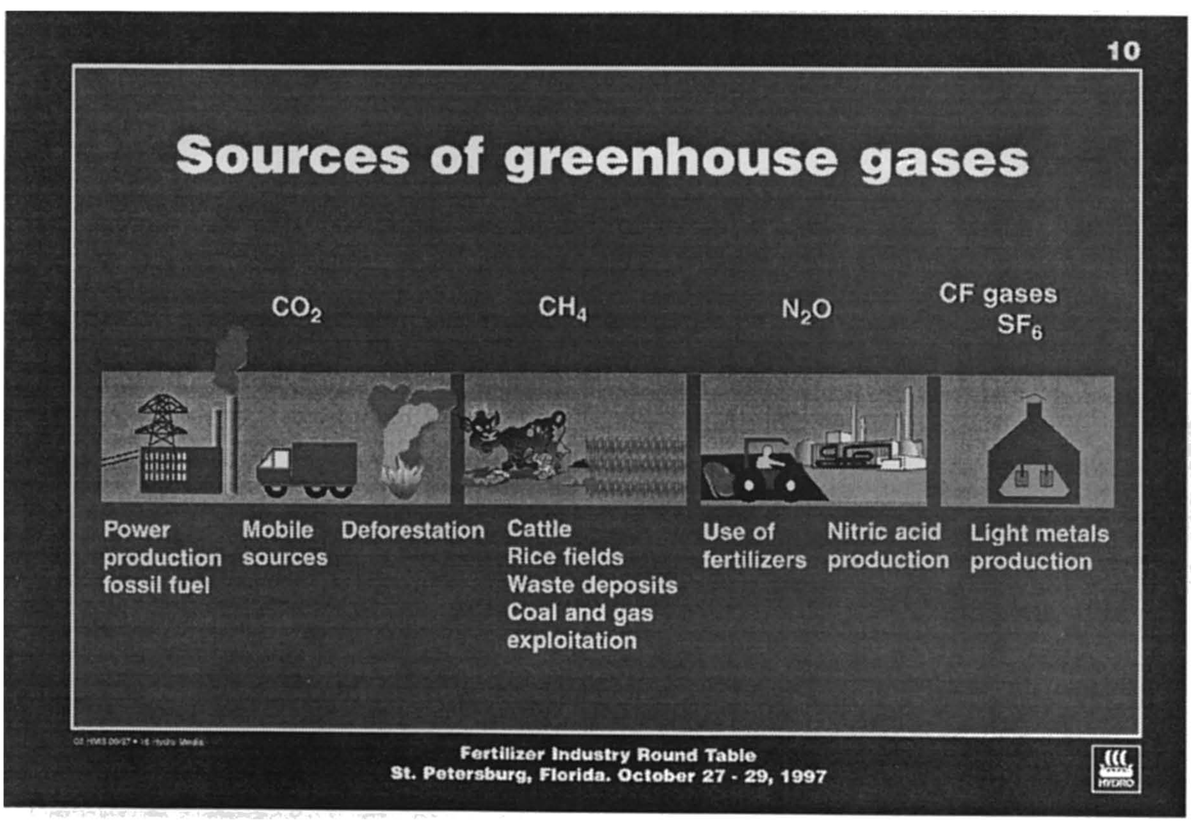
10
Sources of greenhouse gases
CO2
CH4
N2O
CF gases
SF6
Power production fossil fuel
Mobile sources
Deforestation
Cattle
Rice fields
Waste deposits
Coal and gas exploitation
Use of fertilizers
Nitric acid production
Light metals production
Fertilizer Industry Round Table
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HYDRO

Monday, October 27, 1997

Session I
Moderator:

Ole H. Lie

Keynote Address

Steve Rutz
Assistant to Comissioner
State of Florida

Much of the Department's and Commissioner Crawford's time and energy are spent standing up for agriculture in Florida. This includes working to educate people about the importance of agriculture and helping to make sure that state, national and international policies are fair and equitable.

A strong, economically healthy agricultural industry greatly benefits the citizens of our state and other areas of the country and the world by providing an inexpensive source of fresh fruits and vegetables that are an extremely important part of a healthy diet.

It also, of course, helps to fuel our economy and provides jobs. This year we expect total Florida farm gate receipts will again exceed 6 billion dollars and that this production will generate more than 18 billion dollars in farm-related economic activity.

Florida's 39,000 commercial farmers provide more than 75 percent of the U.S.' citrus and led the nation in the production of 19 other major agricultural commodities. These include items such as sugarcane, fresh tomatoes, grapefruit, bell peppers, ferns, watermelons, tropical fish, poinsettias and many others. Florida agriculture helps to put dinner on America's table by growing more than 240 different commodities on farms, ranches and groves that encompass over 10.8 million acres.

Regrettably, the challenges facing agriculture in Florida abound and sometimes seem to be growing faster than the State's population. The fact is that agricultural environmental practices around the U.S. are getting closer scrutiny every year and that the internal and external risks from other problems, including new pests and diseases, are on the rise.

This past summer, we experienced the State's third largest Mediterranean Fruit Fly outbreak in history starting just across the bay from here in the Brandon area. As the Director of the Department's Environmental Services Division, it was my job to rapidly deploy resources and develop capabilities to address a number of issues associated with assessing environmental impacts and in dealing with compliance and health related questions about the program.

The technical and logistical issues we faced were challenging, but were pretty quickly addressed in a straightforward fashion through close work with program staff, the USDA, the EPA, the Department of Health and others. The greatest challenge involved risk communication and the problems that resulted when a large body of scientific information dealing with complex issues was interpreted by varying groups and reported by the media.

We were fortunate that a majority of the media reports were balanced and fair. We visited a number of newspaper editorial boards to share the facts about the program and believe that the resulting coverage provided a more informed and balanced representation of the issues and trade-offs involved.

We also worked quickly to get technical information and test results out to address questions about health and environmental quality concerns.

Its interesting to note that as soon as the environmental sampling information we generated started flowing, concern and interest in the data by the media dropped off almost immediately. What the data meant didn't seem to be nearly as important as the issue of its mere existence or nonexistence.

But it also became clear that the communication of conflicting information by a single prominent media source was having a major impact on the level of public confusion about the necessity of the eradication program and the risks involved if decisive actions were not taken immediately. Unfortunately, the best efforts of responsible environmental and public health professionals to communicate a consistent message were significantly frustrated, even though the conflicting message came mostly from a single media source.

As with the medfly, its likely that a number of different agricultural issues involving public concerns about health and the environment will continue to take front stage in Florida. By the year 2050, its estimated that Florida's population will triple to about 43 million people. This explosive growth will certainly increase the stresses and strains at the urban/agriculture interface and the level of interest in environmental and quality of life issues that affect public policy dealing with agriculture.

The Department believes that Florida agriculture is on the right track in the development of common sense solutions to a number of environmental issues. Good progress has been made in the development of applied research information that shows growers how to more precisely use chemical inputs and apply best management practices that not only protect water quality, but also decrease water consumption and increase profits. Progress is being made in a number of other key areas including best management practices for fertilizer plants and in the beneficial recycling of agricultural and municipal wastes.

We're optimistic that voluntary, incentive-based best management practices can be successfully developed and used as a model elsewhere to improve environmental quality in ways that support a viable agricultural economy. We're also hopeful that this approach will be embraced in Florida in the development of watershed protection measures to meet Total Maximum Daily Load limits required under the Federal Clean Water Act, and among other things, can also be used in lieu of some permits required by the State's Water Management Districts.

The key to success on these and other agricultural environmental issues will be the maintenance of strong public-private partnerships, recognition that progress requires a long term vision, and that everyone needs to be involved in communicating agriculture's message. Two other, and in my view very critical keys, are that we must continue to generate and use the best scientific information available as the foundation of our message, and avoid the temptation to follow the easy path using traditional command and control solutions that reduce innovation.

Outlook for Nitrogen

Trygve Refvem
Norsk Hydro

1. Outlook for nitrogen

My task today is to express an opinion on the world nitrogen situation, and I will place special emphasis on Urea since this pure nitrogen product constitutes the most important nitrogen source today. I will do so representing an international fertilizer company with strong ties to the agricultural sector.

2. Norsk Hydro's diversification

Let me say a few words about Norsk Hydro. The company was formed in 1905 to utilise the hydroelectric potential of Norway by fixing nitrogen utilising a plasma reactor (The Birkeland-Eyde Process). This was the first large scale industrial fixation of nitrogen in the world. Nitrogen fertilizers have consequently been a key area for Hydro for more than 90 years.

Norsk Hydro switched to the Haber-Bosch process in the 1920's, and has remained faithful to its commitment to fertilizers, even though the hydroelectric power production in Norway has long ceased to be important in fertilizer production. This power has, however, been put to good use in Magnesium and Aluminium productions, where the company has become a major world producer. Later, Norsk Hydro became an important participant in the development of the oil-and gas fields on the Norwegian continental shelf, and further developed its position in petrochemicals by entering into Ethylene, VCM and PVC production.

3. Norsk Hydro

The population basis in Norway is just 4 million people, so the company became international very early. At present, more than 90% of its products are sold outside Norway, and most of its expansions during the later years are in the rest of Europe, North and South America, Africa and in Asia. Of the 35.000 employees, more than half are located outside Norway. The yearly sum-over is around 13 billion USD. 51 percent of the company is owned by the Norwegian State, while the remaining shares are traded on American and European stock exchanges.

4. Hydro Agri

In recent years, Norsk Hydro's Agricultural segment has grown to become a world leading fertilizer producer and marketer with world wide sales last year of 16.2 mill. tons of fertilizer products, a level which we expect will increase in coming years. Norsk Hydro has 30 sales offices, 70 terminals with storage bagging operations, domestic marketing organisations providing agronomic advice and service.

The agricultural activity is split into two geographical divisions . On the production side, Hydro Agri Europe has now 16 major fertilizer plants in Europe with a total annual capacity of 12.2 million tons finished fertilizers and 3.5 mill. tons of ammonia.

Hydro Agri International is responsible for the fertilizer activities outside Europe, including marketing, terminal operations, production, projecV joint venture developments and fertilizer technology licensing. Important joint ventures are ammonia at Trinidad (Hydro Agri Trinidad/ Tringen), ammonia/urea in Qatar (QAFCO) and DAP in Florida (Farmland - Hydro). In addition, HAI is responsible for ammonia supply and trading as well as other raw material sourcing. HAI is increasingly engaged in counter-trade of raw materials, intermediates and finished products, as well as non-fertilizer products. To get deeper into the markets and closer to the customers, HAI is also involved in several bulk blending operations and domestic marketing.

Norsk Hydro has now been in the fertilizer business for more than 90 years, and we have recently celebrated our long term local presence in most markets - 50 years in North America, 25 years in Asia, 20 years in Latin America and 10 years in Africa.

5. World Population Growth

In 2010, less than 15 years from now, there will be more than 7 billion people on the planet according to the official United Nations prognoses. The population in the industrialised world is more or less stable, while there will be a major population increase in developing countries where the average income level still is quite low. Especially in the areas with high population density like Asia, where nearly 60% of the world population will live by year 2010, there is little virgin farmland available.

6. Economic Growth and Food Demand

Economic growth is close to two digit levels in the prosperous nations of the developing world. As household income increases, people tend to eat more food. More important for the food demand situation may be a shift in diet towards more meat at the cost of direct consumption of grains and vegetables. About 85 percent of the energy is lost if grain is used in beef production instead of being consumed directly. Pork production is a little more efficient with a loss of 75 percent. A change in diet will hence entail a corresponding increase in demand for primary agricultural production. The first chart shows the percentage of grain consumption used as livestock feed on regional levels in 1994. In Asia, with its high share of world population, just 18 percent of the grain is consumed as livestock feed, compared to developed regions like North-America with 65 percent and Europe with

59 percent. This illustrates that the diet change that has occurred already, as shown in the second chart, is just the beginning. The consumption of pork per capita in China has increased 11 times from 1960 to 1990, while poultry consumption is nearly three times as high.

7. World Fertilizer Consumption

The best altemative today in order to satisfy this increased demand for food, is to add more mineral fertilizers to the soil where there still is a lack of nutrients. According to IFA, the world consumption of fertilizers has increased from 32 million MT of nutrients in 1961 to 136 million MT today, and is expected to be close to 150 million MT by the end of the millennium. The changing composition of the major nutrients in world consumption, with the share of nitrogen increasing from 37 to nearly 60 per cent in the same time period, reflects the unique effect of nitrogen to increase yields immediately. In the transition from traditional to modern agriculture, it takes longer time before the lack of the other nutrients in the soil appears.

8. Proiected Ammonia Consumption

Since the basis of all nitrogen fertilizer production is ammonia, either as a purchased input factor or as the intermediary in an integrated production process, there is a strong link between the two markets. Just 14 percent of the ammonia production is consumed in other industries. Prices of the two products may develop separately in the short run, but they correlate in the long run. If the ammonia price is very high compared to the urea price, then urea producers may be tempted to sell the ammonia directly instead of upgrading it to fertilizers. And on the other hand, if the price is very low a persistent period, then ammonia producers may invest in a new urea upgrading plants. The total ammonia production is believed to grow in proportion to the nitrogen fertilizer market.

9. Historical World Nitrogen Consumption

Urea has become the nitrogen fertilizer above others in the later years. Urea constituted just 23 percent of the total consumption on nitrogen in mineral fertilizers in 1973, while its share rose to 43 percent in 1994. Its success is probably due to both production and consumption aspects. It is easy to produce and the high nitrogen content of 46 percent reduces the transport cost.

10. Surplus on the urea trade balance

The urea-price has a volatile history. The FOB price in Yushnny is now approaching 80 USD/MT, while the peak in late 1995 was close to 220 USD for East-European products. The high profitability in the Urea business was tempting, and many new projects are now implemented. In addition, China stopped all imports of urea this spring which pulled the plug of the market, since Chinese imports normally represents 20-25 % of world trade. Fertecon estimates that the realised change in world imports in 1997 is a reduction of 1.8 million MT. compared to last year. The policy of self-sufficiency in China and India, resulting in new plants coming on stream, is the main explanation factor. On the other hand, new capacity in export oriented countries amounts to 1.5 million MT. in 1997. This implies a surplus capacity of 3.3 million MT. this year. And the situation is getting worse! Further new capacity is projected to be built the following years in countries with access to natural gas with low alternative value. If we anticipate that the new capacity estimated by Fertecon in their analysis actually comes on stream, the surplus capacity increases, and reaches more than 9 million MT. in 2005!! There are three basic me.phanisms. First: A low price level reduces the profitability and hence the number of new projects that are realised. Second: Inefficient plants, and plants in regions with high energy cost, close down. And third: Low prices cause demand to increase faster, including substitution effects.

11. Urea Price Development

Short term, the urea prices should level out at the producers variable cost. Poor liquidity and debts will after some time imply closures. As time passes by, demand increases in proportion to the population growth and economic prosperity, and the prices will rise. New projects will be built in close connection with existing infrastructure. It may take considerable time before we see price levels where new grassroots plants are showing acceptable return on capital.

12. Conclusions

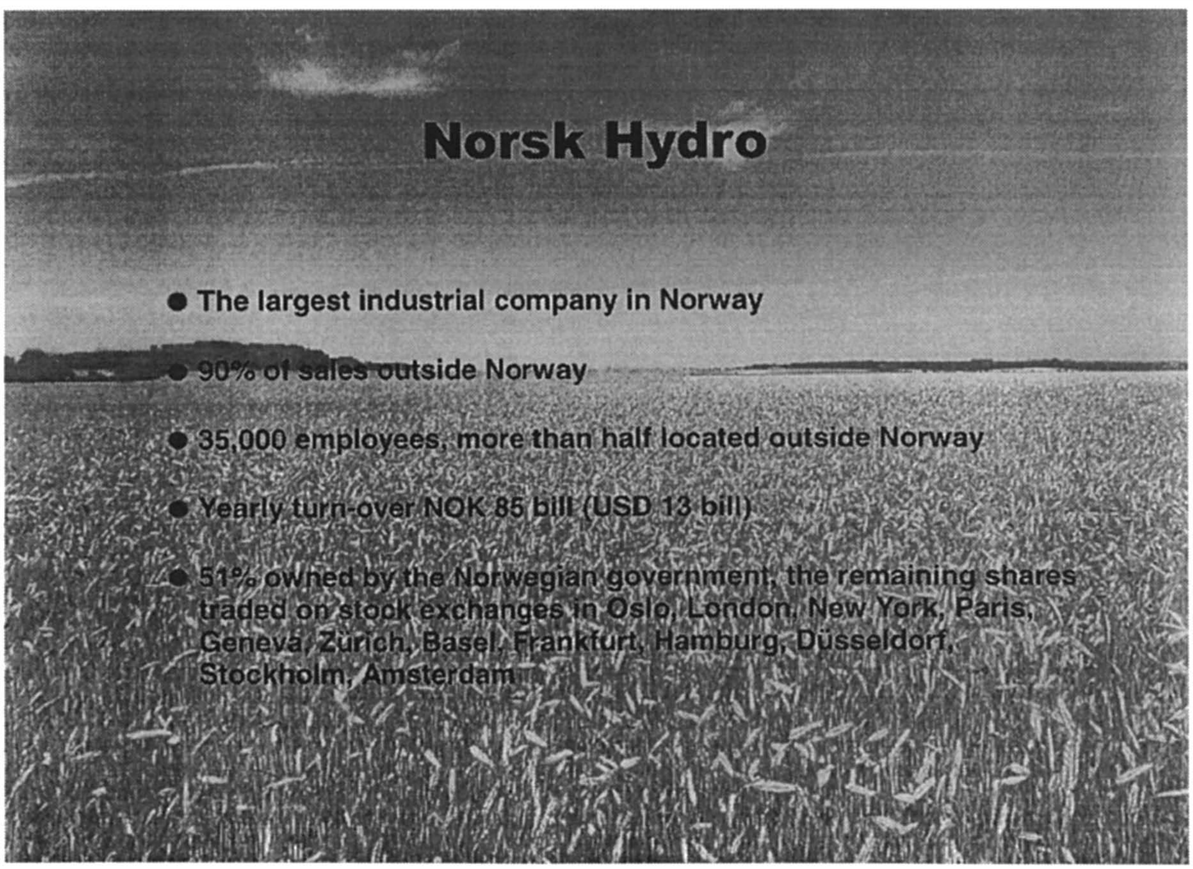
China and India strive to achieve self-sufficiency in nitrogen fertilizers. Their ability to reach this ambitious goal will be decisive for the world fertilizer trade. High alternative value for the limited gas resources and the availability for low cost imports may reduce the appetite for self- sufficiency.

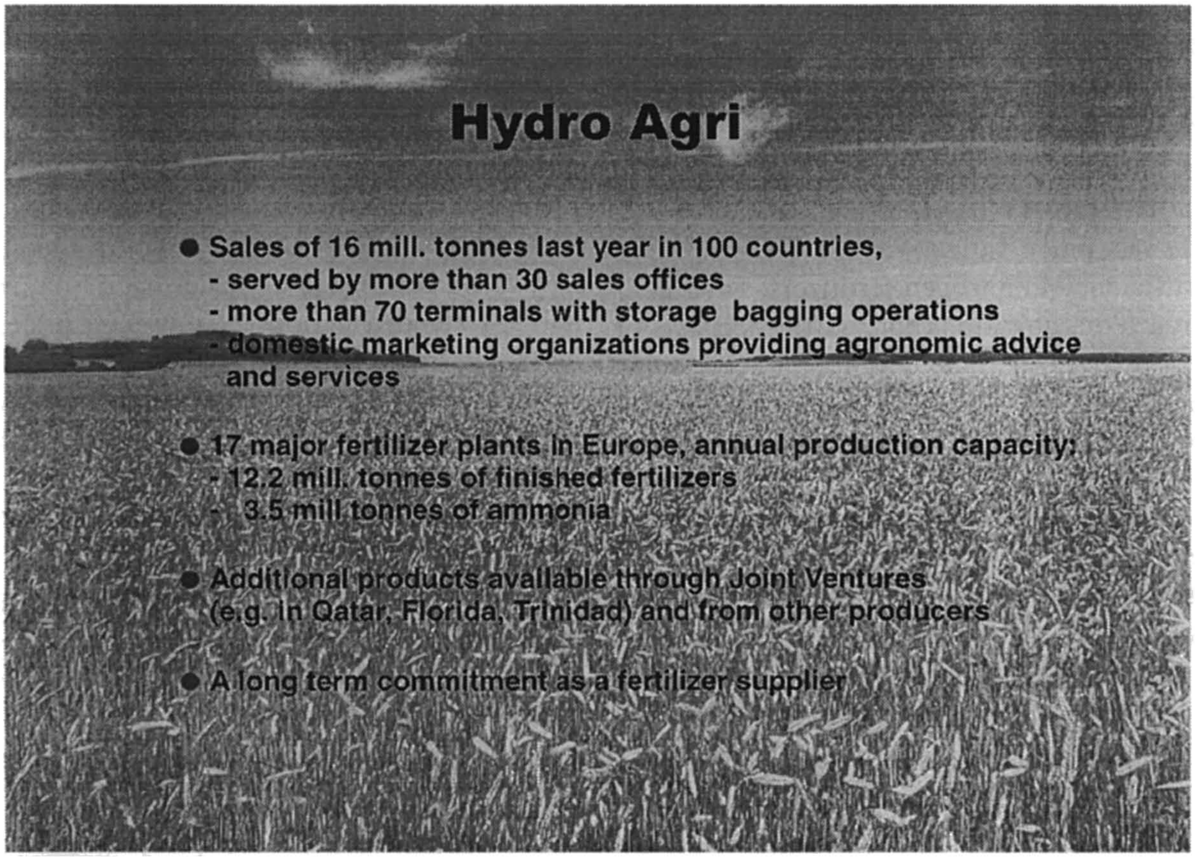
Relatively speaking, the urea demand will be slowed by the need for balanced fertilization, since the lack of phosphorus and potassium is becoming quite apparent in many importing regions.

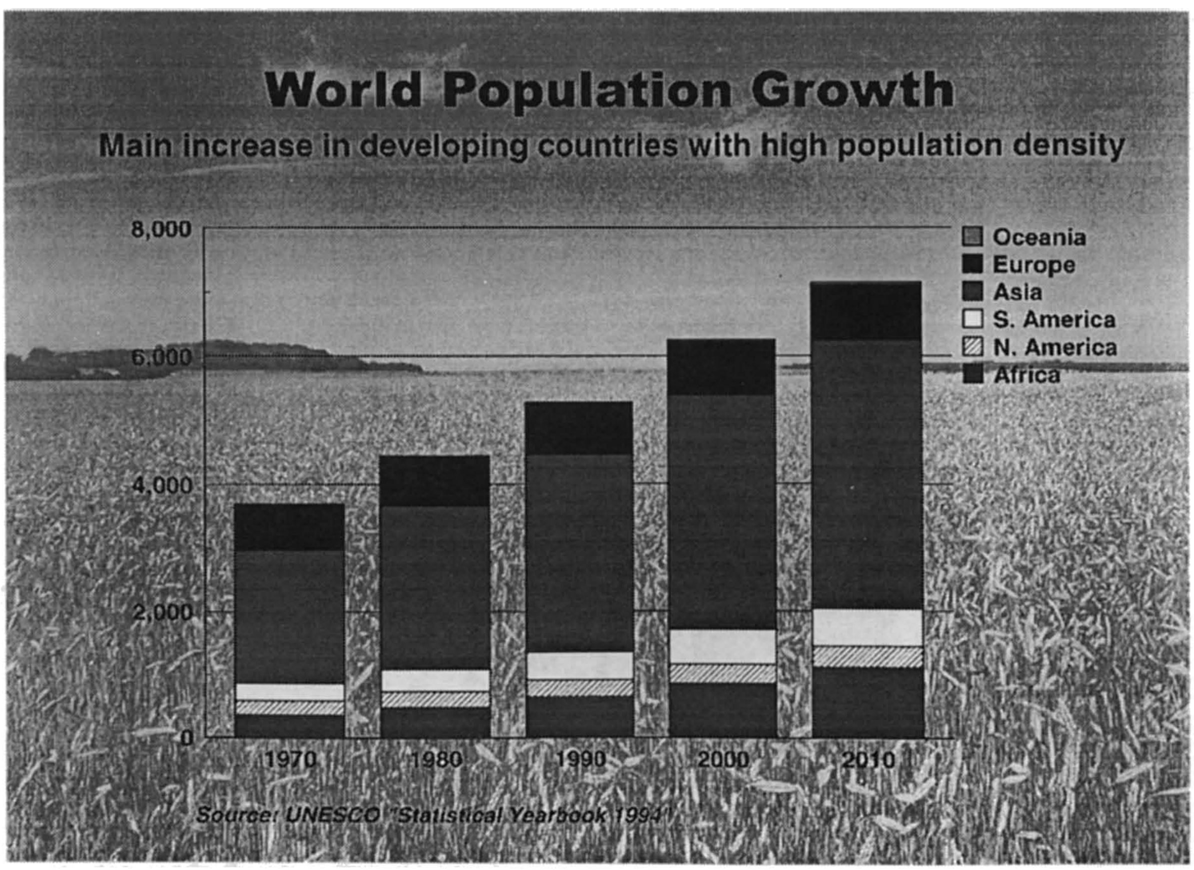
Countries with vast amounts of natural gas in areas where there are few other alternatives than converting it to fertilizers, will construct new plants even if the payment for the gas is close to the gas production cost.

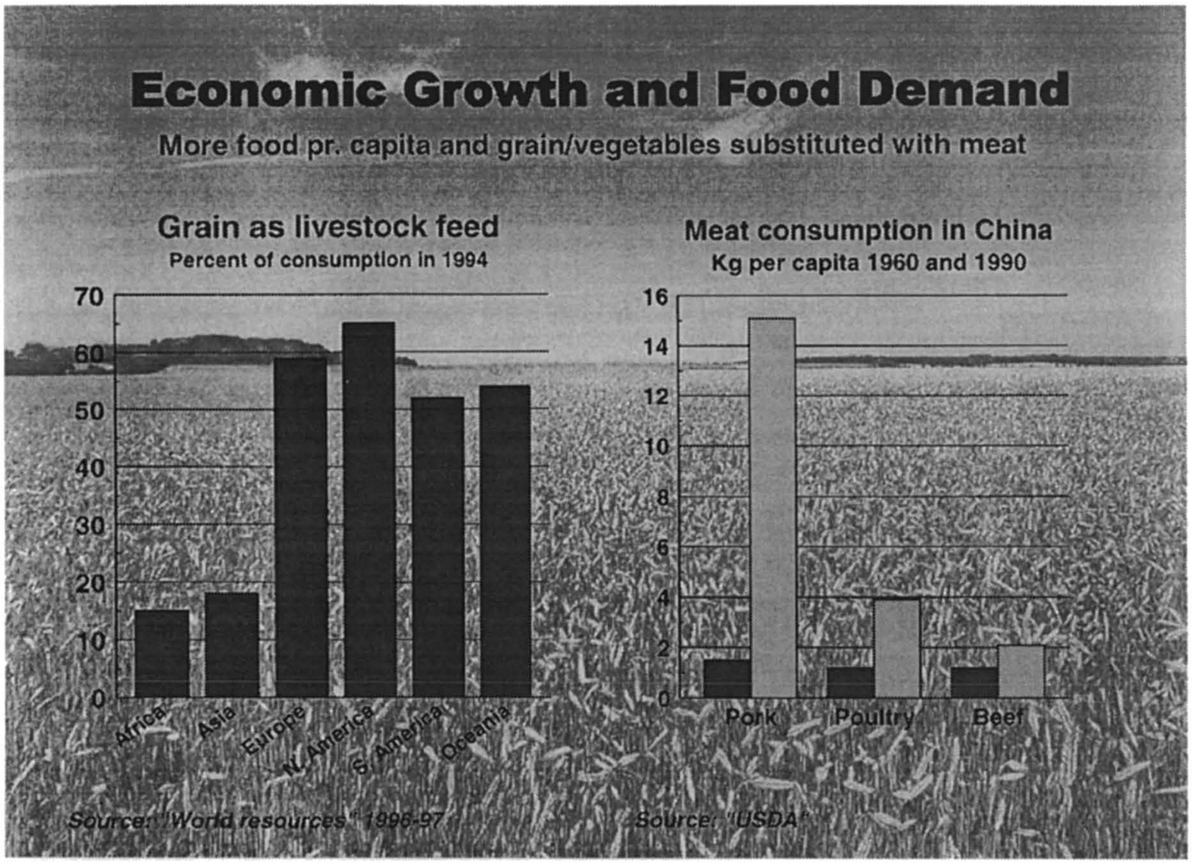
On the positive side, we may experience strong demand increases in many regions in Africa, Latin-America and Russia where the level of application is minimal, and a positive change in food prices may make the change to modern agriculture profitable. Extended periods of low urea prices will definitely trigger new demand.

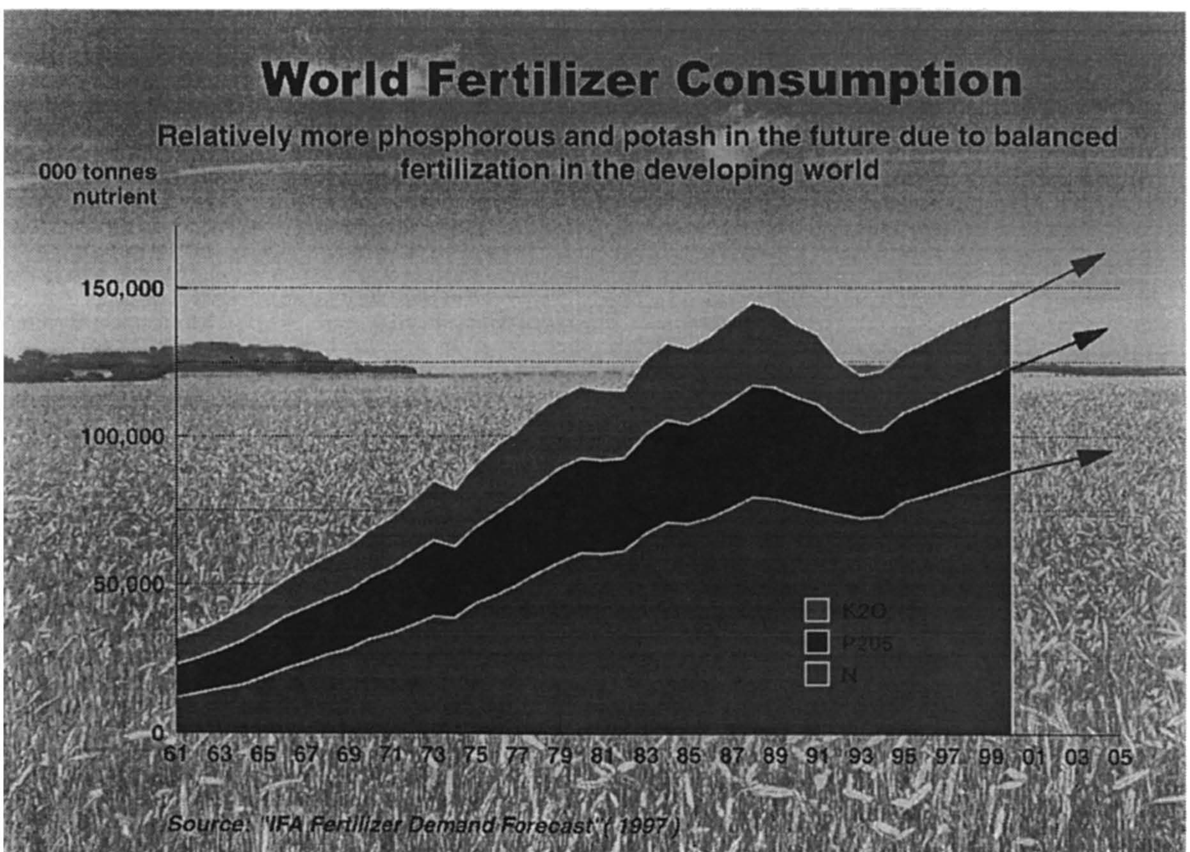
In the long run, we may also experience a whole new framework for this business. Taxation on CO_2 emissions may affect both the composition of production and the regional distribution. Moreover, the shift towards market economy in those parts of the world where most of the people live will have a profound impact on the world market in the years to come, particularly in the food and energy markets.

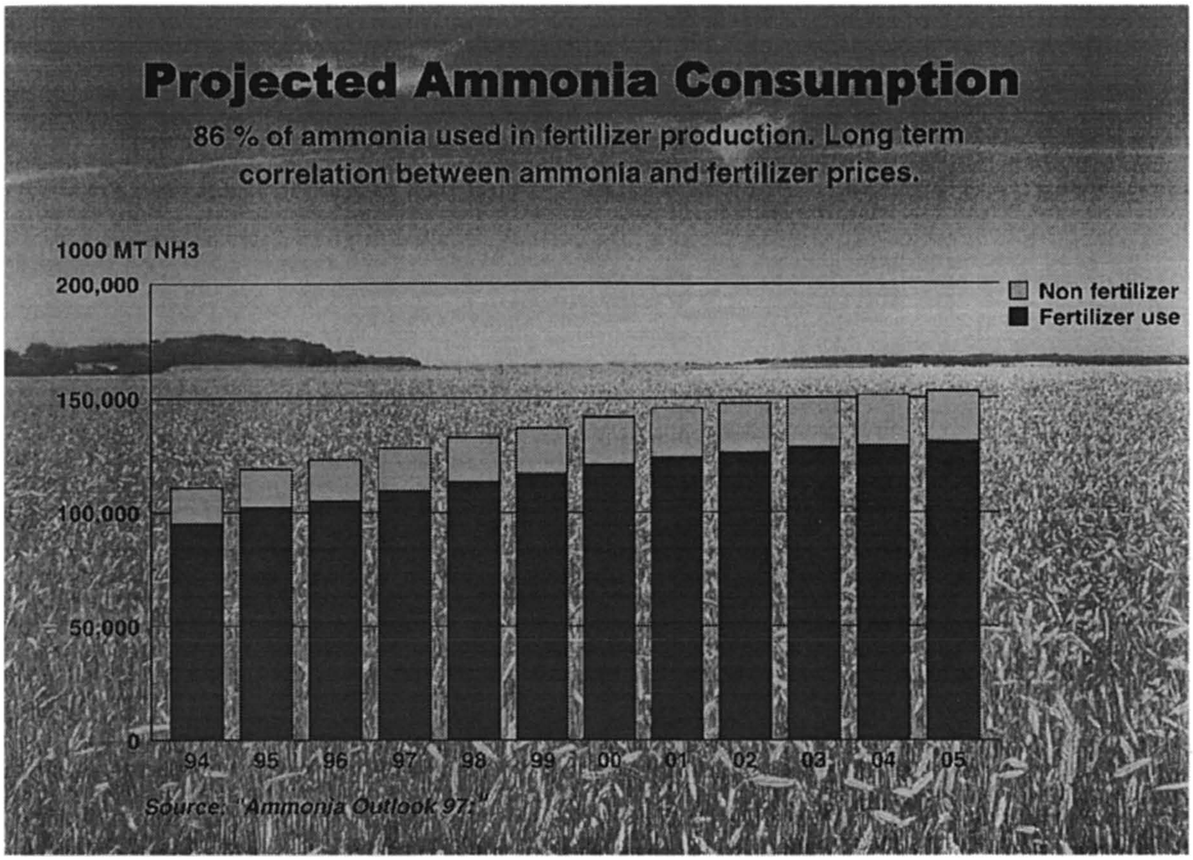


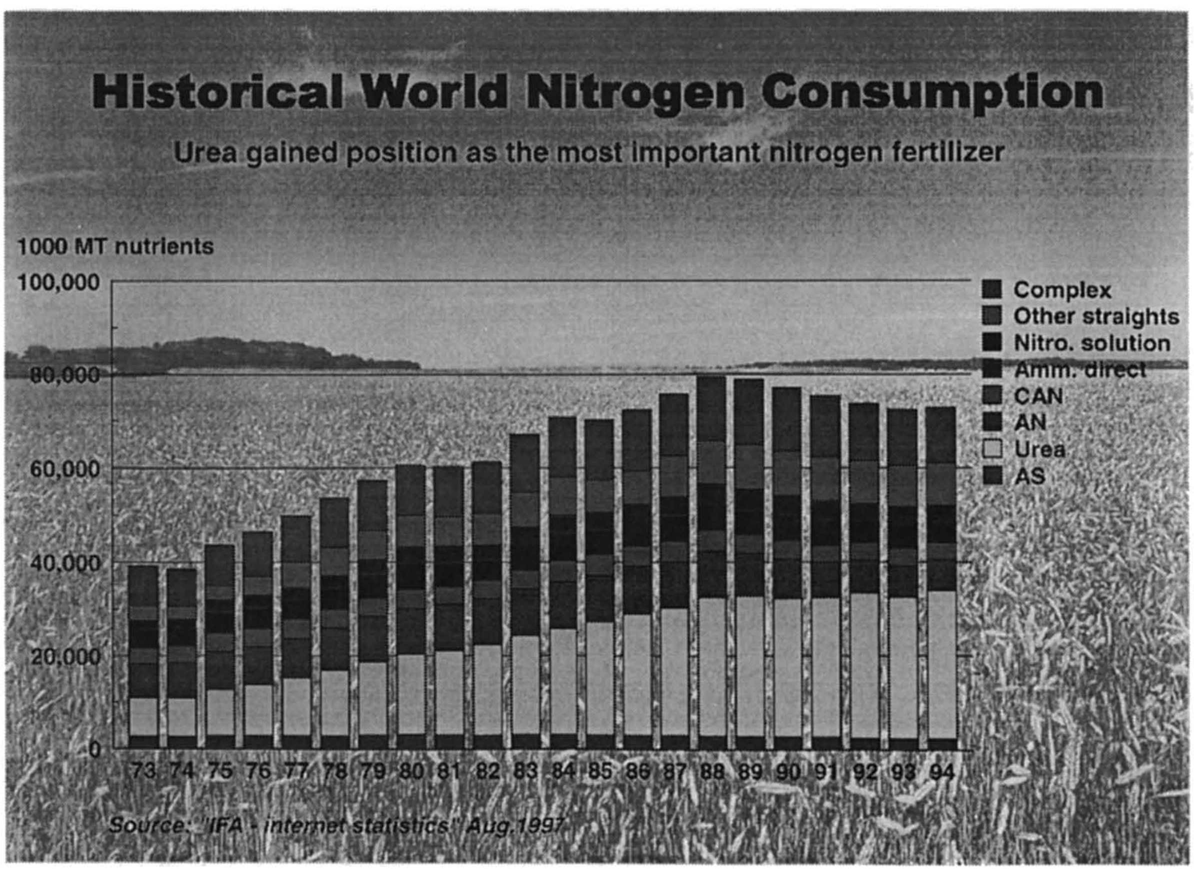

Hydro Agri
● Sales of 16 mill. tonnes last year in 100 countries,
- served by more than 30 sales offices
- more than 70 terminals with storage bagging operations
- domestic marketing organizations providing agronomic advice and services
● 17 major fertilizer plants in Europe, annual production capacity:
- 12.2 mill. tonnes of finished fertilizers
- 3.5 mill tonnes of ammonia
● Additional products available through Joint Ventures (e.g. in Qatar, Florida, Trinidad) and from other producers
● A long term commitment as a fertilizer supplier

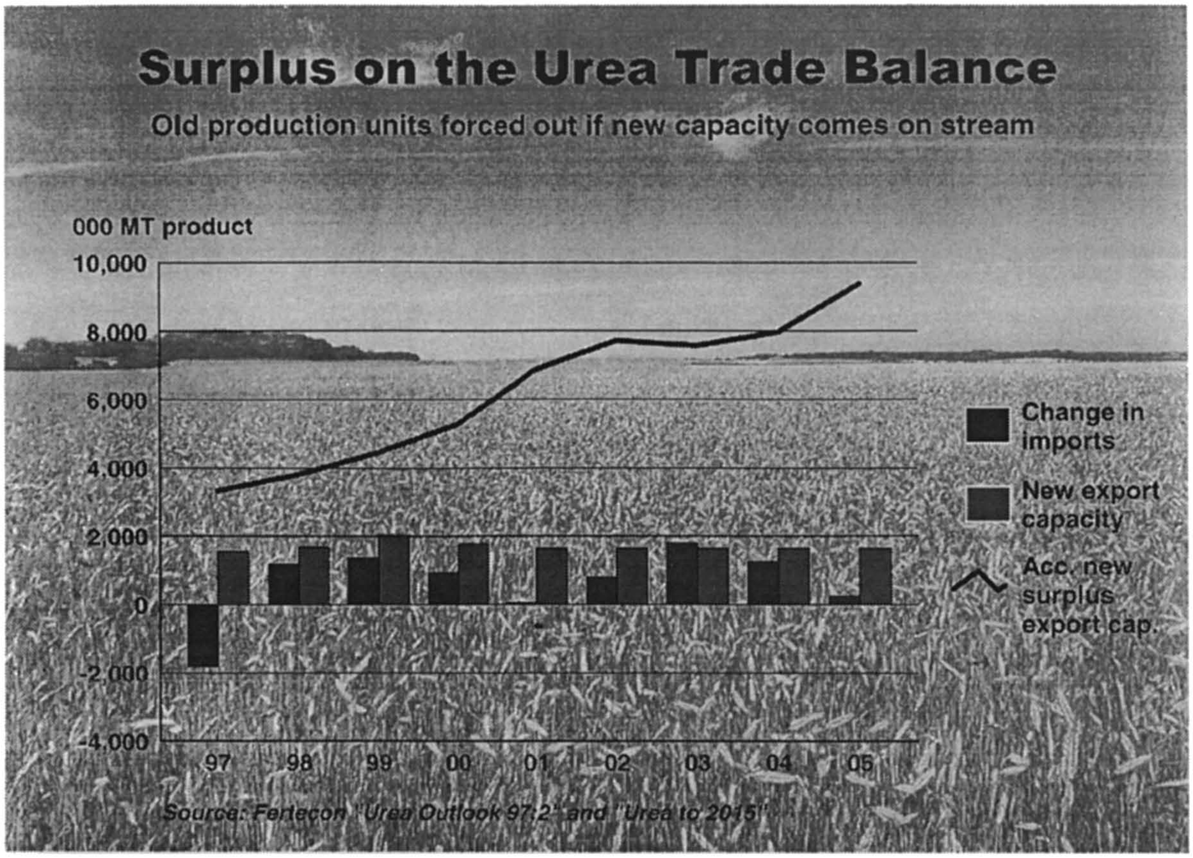

World Population Growth
Main increase in developing countries with high population density
8,000
6,000
4,000
2,000
0
1970
1980
1990
2000
2010
Oceania
Europe
Asia
S. America
N. America
Africa
Source: UNESCO "Statistical Yearbook 1994"

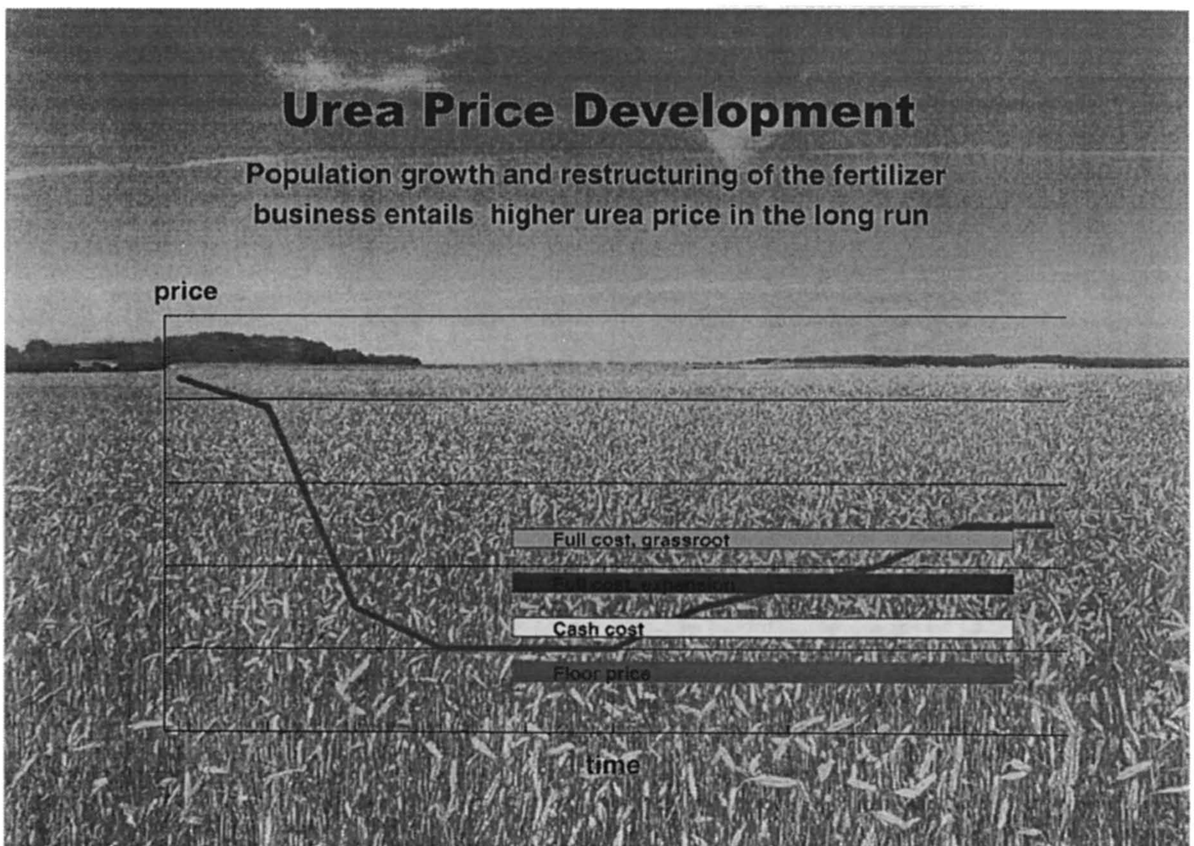

Economic Growth and Food Demand
More food pr. capita and grain/vegetables substituted with meat
Grain as livestock feed
Percent of consumption in 1994
70
60
50
40
30
20
10
0
Africa
Asia
Europe
N. America
S. America
Oceania
Meat consumption in China
Kg per capita 1960 and 1990
16
14
12
10
8
6
4
2
0
Pork
Poultry
Beef
Source: "World resources" 1996-97
Source: "USDA"

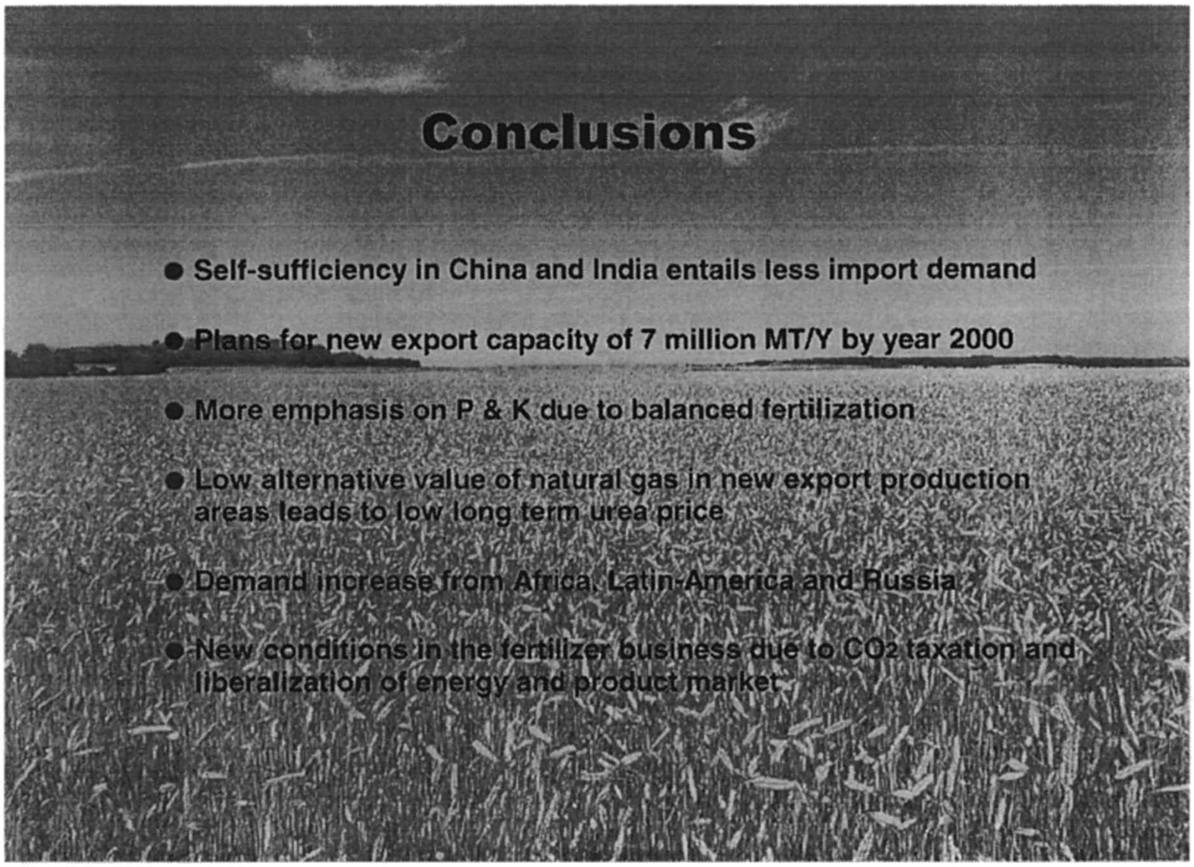

World Fertilizer Consumption
Relatively more phosphorous and potash in the future due to balanced fertilization in the developing world
000 tonnes nutrient
150,000
100,000
50,000
0
61 63 65 67 69 71 73 75 77 79 81 83 85 87 89 91 93 95 97 99 01 03 05
K2O
P2O5
N
Source: "IFA Fertilizer Demand Forecast" (1997)


Projected Ammonia Consumption
86 % of ammonia used in fertilizer production. Long term correlation between ammonia and fertilizer prices.
1000 MT NH3
200,000
150,000
100,000
50,000
0
94 95 96 97 98 99 00 01 02 03 04 05
Non fertilizer
Fertilizer use
Source: "Ammonia Outlook 97."


Historical World Nitrogen Consumption
Urea gained position as the most important nitrogen fertilizer
1000 MT nutrients
100,000
80,000
60,000
40,000
20,000
0
73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94
Complex
Other straights
Nitro. solution
Amm. direct
CAN
AN
Urea
AS
Source: "IFA - internet statistics" Aug.1997

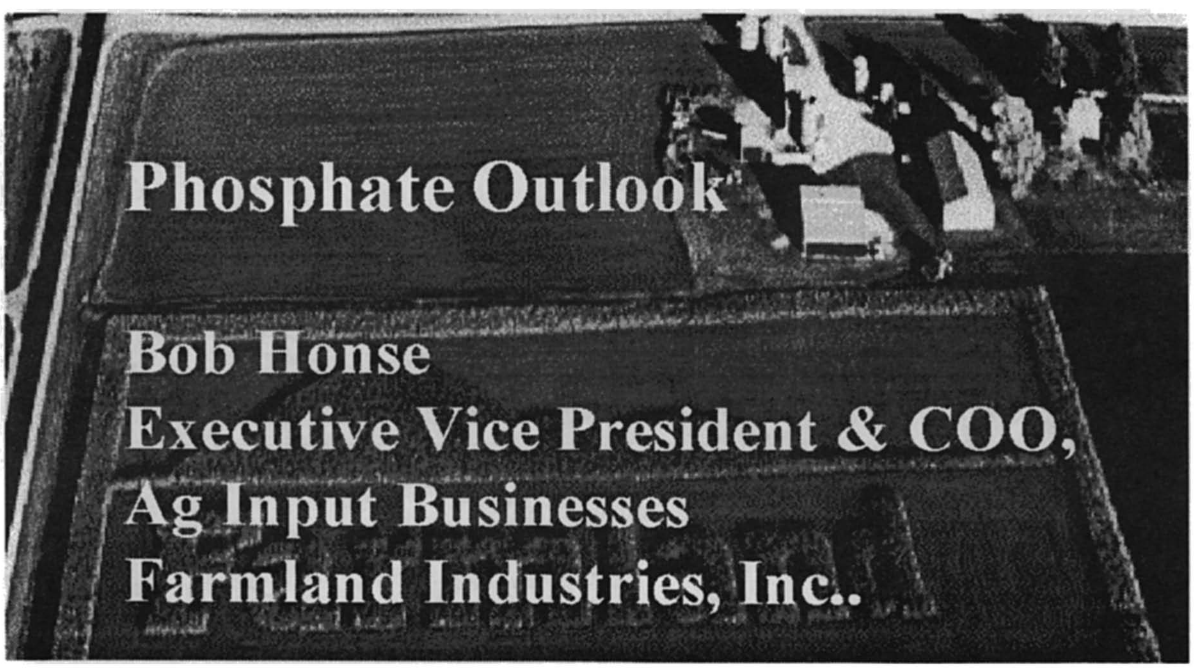

Surplus on the Urea Trade Balance
Old production units forced out if new capacity comes on stream
000 MT product
10,000
8,000
6,000
4,000
2,000
0
-2,000
-4,000
97
98
99
00
01
02
03
04
05
Change in imports
New export capacity
Acc. new surplus export cap.
Source: Fertecon "Urea Outlook 97:2" and "Urea to 2015"


Urea Price Development
Population growth and restructuring of the fertilizer business entails higher urea price in the long run
price
Full cost, grassroot
Full cost, expansion
Cash cost
Floor price
time



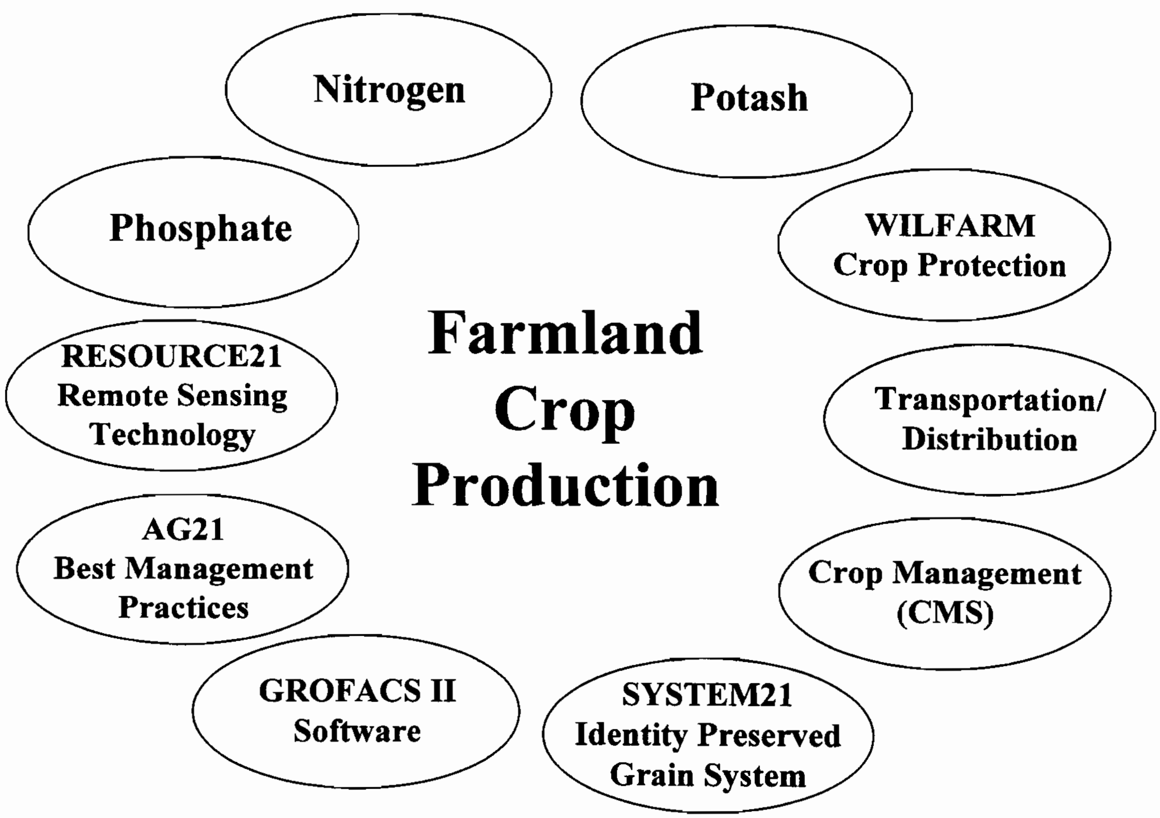
Outlook for Phosphates

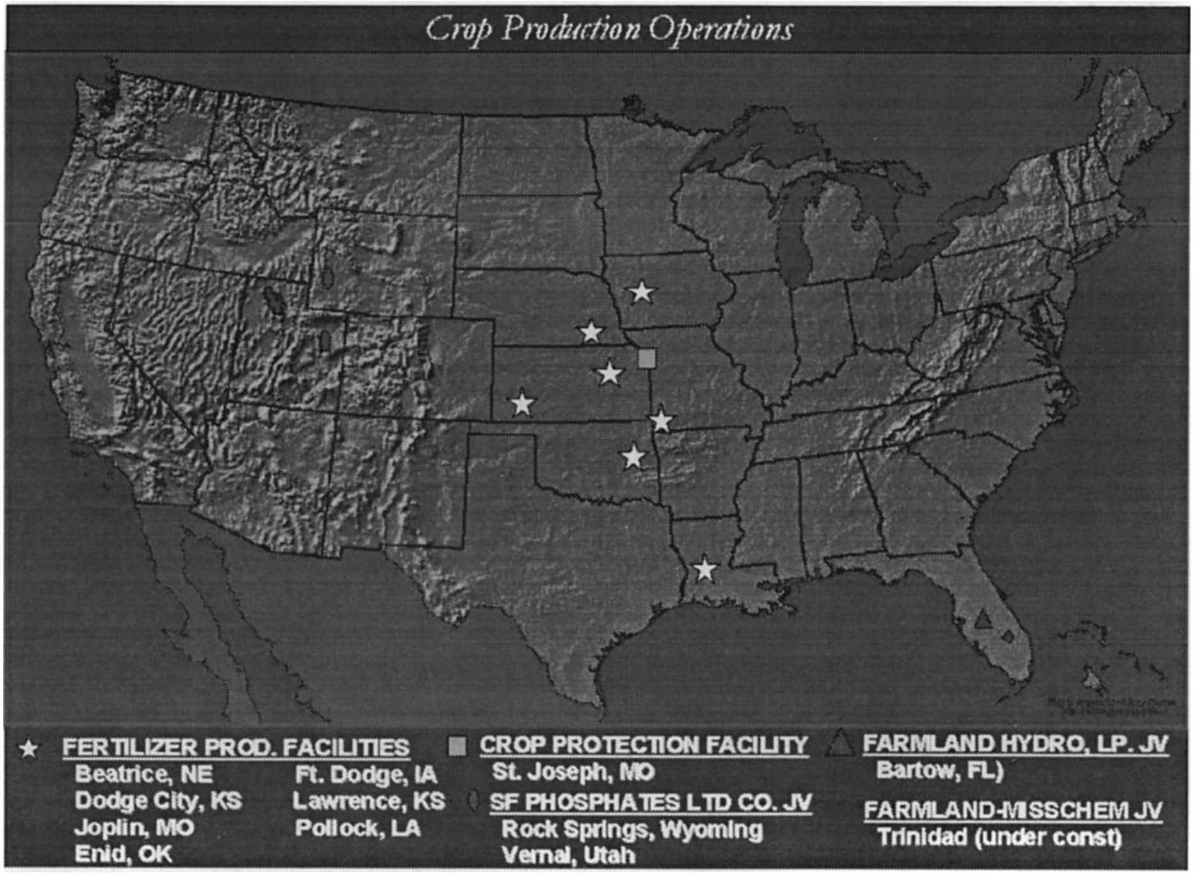
Robert W. Honse
Farmland Industries, Inc.



Farmland - Who We Are

- **Ownership:**
  - **1,400 Local Producer-Owned Cooperatives**
    - **500,000 Farm Families**
      - **(US, Canada, Mexico)**
  - **13,000 Livestock Producers**
- **Core Businesses:**
  - **Crop Production, Petroleum**
  - **Feed, Grain, Grain Processing**
  - **Livestock Production**
  - **Beef and Pork Beef Processing**





World of Phosphate - Key Issues

- **Ongoing Changing of the Guard**
  - **Consolidation and Mergers**
- **Access to Supply**
  - **Capital**
  - **Geography**
  - **Environmental Situations**
- **Growing Demand**
  - **Expanding Global Economy**
  - **Accelerating Population Growth**
  - **Global Soil Fertility**

Rapidly Changing Playing Field

Number of Owners
North American Phosphate Production

	1970	1980	1990	1996	2000?
US	26	24	17	14	
Canada	7	7	4	1	
Mexico	1	3	4	3	
Net Total	34	34	25	18	17-18

Source: Blue, Johnson
(stated on a Phosrock-Wet Phosacid Basis)

Why the Changes?

- **Capital**
  - **Return on Investment**
- **Economies of Scale**
  - **Spread Costs Across Greater Output/Sales**
- **Growth/Market Share**
  - **Acquisitions versus New Development**
- **Company Focus**
  - **Change in Parent Company Strategic Focus**

Reserves Becoming more Geographically Concentrated ..

% of World Phosphate Rock Reserves

	1993	1997	2001
North America	9.4%	8.6%	7.9%
Central America	5.1%	5.0%	4.9%
Europe/FSU	4.6%	4.5%	4.5%
North Africa	74.1%	74.9%	76.2%
West Asia	4.2%	3.8%	3.5%
Other	2.6%	3.1%	3.0%

Source: Blue, Johnson & Associates, Farmland

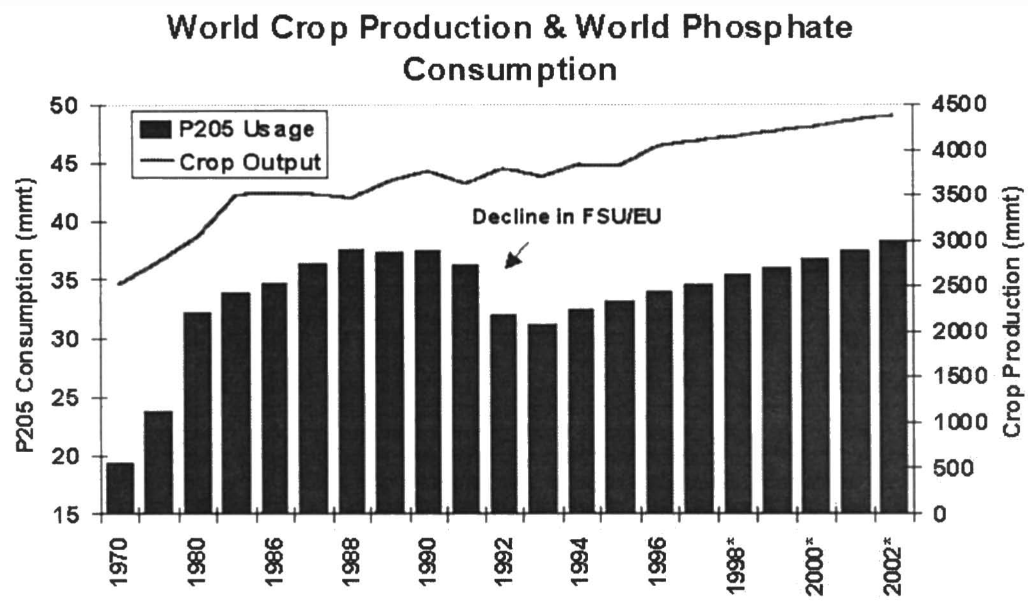
... than Actual Production

% of World P205 Production Capacity

	1993	1997	2001
North America	33.6%	33.0%	31.7%
Africa	16.3%	16.0%	16.3%
Latin America	4.6%	4.7%	4.5%
EU/FSU	30.4%	28.6%	27.4%
Asia	13.8%	15.0%	16.2%
China	1.2%	2.7%	3.9%

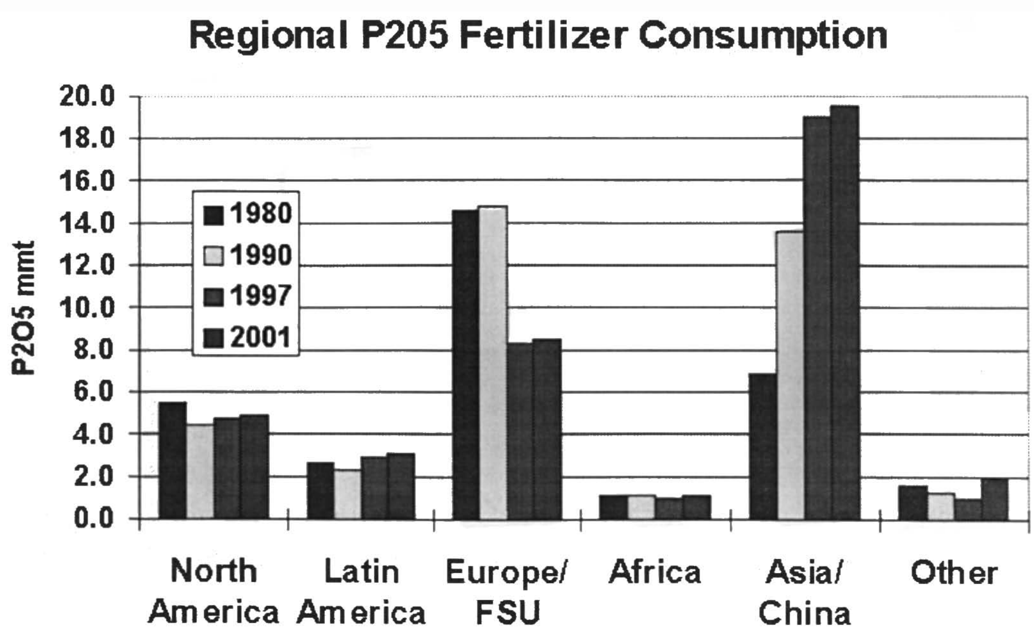
Source: Blue, Johnson & Associates

Meanwhile... Phosphate Fertilizer Usage Rebounds



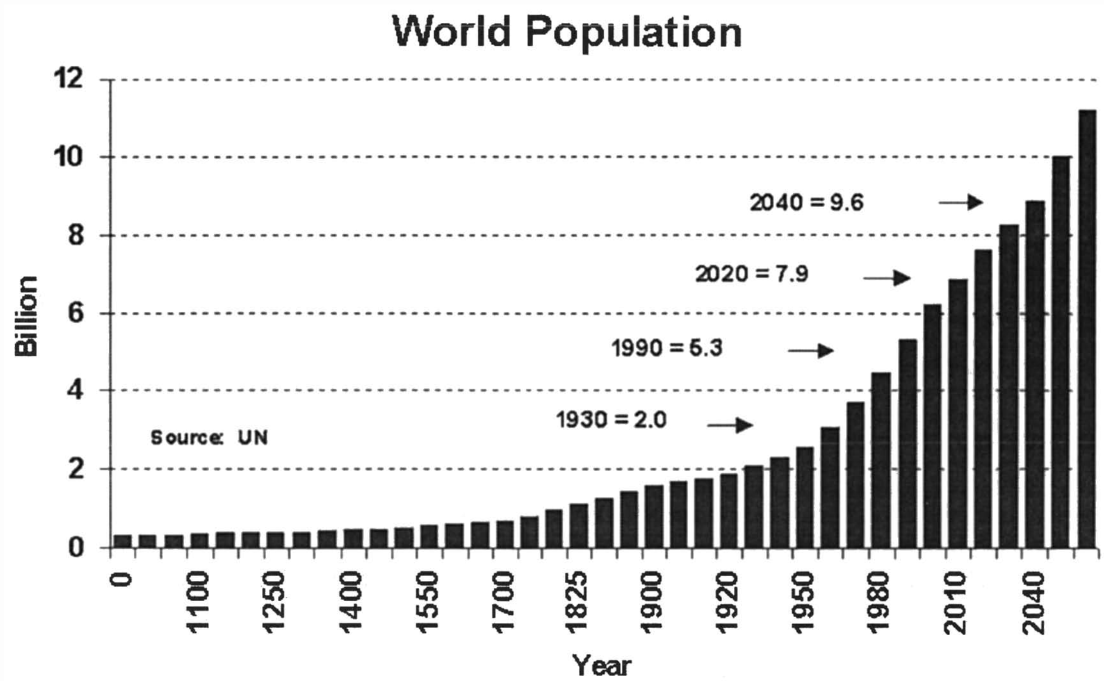
Source: Blue,Johnson, Farmland

Asia/China ...

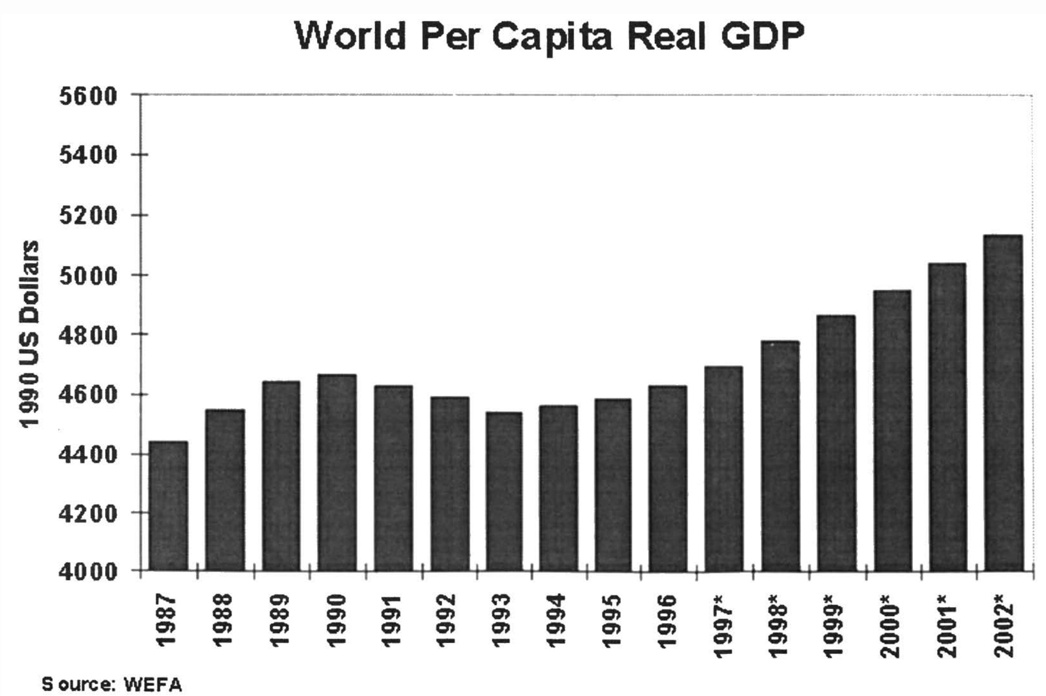


Source: Blue, Johnson & Assoc.

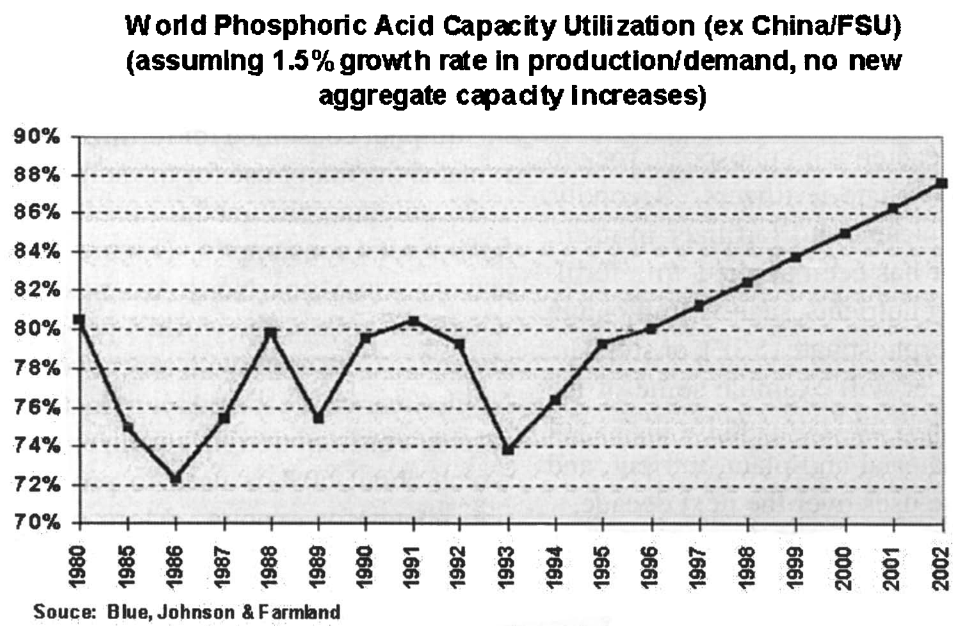
as Food Demand Increases



and Economic Growth Continues



Increased Capacity Utilization Needed. Can We Meet this Challenge?



The End Results ....

- **Distribution and Logistics Gain Importance**
- **Consolidation Will Continue**
  - **Reduce Costs/Gain Efficiencies**
  - **Capital Requirements**
- **Short Term Capacity Challenges**
- **Longer Term Growth?**
  - **Expansion versus Mergers/Acquisitions**

Outlook for Sulphur

Robert J. Morris
The Sulphur Institute

Introduction

Sulphur and sulphuric acid are important to the fertilizer industry in two distinct areas. First, sulphur as a raw material may be converted to sulphuric acid and reacted with phosphate rock to produce various phosphate fertilizers. Secondly, sulphur is a plant nutrient and fertilizer in itself. Historically, sulphur has been applied with fertilizers containing other nutrients, such as ammonium sulphate, single superphosphate (SSP), or sulphate of potash. This paper will examine some of the factors affecting supply and demand for the use of sulphur as a raw material and plant nutrient, and the outlook for these uses over the next decade.

Sulphur Consumption

Global sulphur demand has fluctuated by more than 15% over the past fifteen years, with consumption at a high of 60.1 million tons in 1988. From 1988 to 1993, sulphur consumption declined, reaching its low point of 50.3 million tons in 1993. The declining trend, caused mainly by negative growth in the economies of Eastern Europe and the Former Soviet Union (FSU), has reversed itself. In 1996, world sulphur demand increased for the third consecutive year, reaching 55.0 million tons (Figure 1). Consumption in 1996 increased by nearly 1.0 million tons or 1.8% from 1995, which was lower than the 4.5% growth in 1994. Of this total demand, sulphur consumed for fertilizer manufacture increased by 1.1%; whereas, non-fertilizer sulphur consumption increased by 2.6%. While there has been positive economic growth in the major economies of Eastern Europe, namely Poland, Hungary, and the Czech Republic, and an expected turnaround in the Former Soviet Union in 1997, leading to increased sulphur consumption, the gain is small, as compared to consumption prior to the change in economic structure. From 1991-1996, aggregate sulphur consumption declined 1.5 million tons; however, on a regional basis the changes were more dramatic, as shown in Figure 2. The significant consumption increases in Africa, North America, Latin America, and East Asia, were more than offset by the striking declines in consumption in the Former Soviet Union, Eastern Europe, and Western Europe over the past decade.

Sulphur Consumption by End Use

Sulphur consumed for fertilizer manufacturing remains the major use for the sulphur industry. In 1996, sulphur consumed for fertilizer use reached 53% of total consumption (Figure 3). Most of this activity is in Africa, North America, and East Asia, where the bulk of the world's phosphate industry abounds. Consistent with recent years, Africa and North America accounted for more than half of total sulphur consumption for fertilizer use in 1996, of which about 60% is used to produce processed phosphates for exports. More specifically, this demand is the result of significant phosphate rock reserves in the United States and Morocco, and the subsequent sulphur-based phosphate production.

Although the phosphate fertilizer industry of Western Europe historically has played an important role in sulphur consumption, regional phosphoric acid capacity declined from 5.5 million tons to 1.9 million tons from 1980-1996. The bulk of this decline was due to overcapacity within the region and foreign competition. In addition, European Union agricultural policies have affected phosphate demand and, thus, sulphur consumption. Western European phosphate fertilizer consumption declined from 2.3 million tons in 1991 to 1.6 million tons in 1996. The decline in consumption appears to have stabilized.

The impact of the change in economic policies of Eastern Europe and the FSU during the 1990s on phosphate consumption and sulphur consumption has been dramatic (Figure 4). Phosphate consumption reached its low point during this transitional period, but now is expected to recover steadily from its low base in 1996 at an average annual rate of about 5% for Eastern Europe through 2006 and nearly 4% for the FSU. Even so, for Eastern Europe, this brings total phosphate consumption to only about half of its 1989 level and for the FSU only to a level of only about 20% of the 1988 level.

In recent years, the growth in East Asia has been dramatic, accounting for nearly one-third of 1996 phosphate fertilizer consumption. Phosphate fertilizer consumption in the region was at 4.6 million tons in 1986 and reached 10.7 million tons in 1996, accounting for nearly one-third of global 1996 phosphate fertilizer consumption (Figure 5). The 1996 figure was slightly lower than the 11.3-million-ton high for the period.

In addition to sulphur's use in manufacturing fertilizers, there are a variety of non-fertilizer industries that include sulphur and accounted for 25.7 million tons of sulphur consumed in 1996. These include fibers, hydrofluoric acid, metallurgical processing, paints and pigments, pulp and paper, petroleum refining, and feed and industrial phosphates, which collectively represented about half of the non-fertilizer sulphur markets.

A Look at Future Sulphur Consumption

The Sulphur Institute (TSI) estimates that total sulphur consumption will grow to nearly 70 million tons in 2006, representing a 2% annual growth rate, with fertilizer manufacture, primarily for phosphates, requiring 57% of total consumption (Figure 6). The remainder will go for non-fertilizer uses, with annual growth at 1.1%.

On a regional basis, North America, Africa, and East Asia will remain major sulphur consumers through 2006 (Figure 7). The United States, with its dominance in phosphate fertilizer manufacture, will maintain its role as the lead phosphate exporter for the foreseeable future. Phosphate plants in the United States are expected to operate at high utilization rates with little increase in capacity due to environmental constraints. This could change if new capacity planned for North Africa or West Asia is delayed, China's imports continue to increase, or a change in farm policy results in a significant increase in domestic demand. Assuming that no new capacity is built through 2006, North American phosphoric acid production for fertilizer use will remain relatively constant at about 11 million tons, with a corresponding sulphur requirement of 9.7 million tons—a 0.33% average growth rate.

In East Asia, China, currently the largest sulphur consumer, with about 60% of the 11.3-million-ton market, will increase in regional and global importance, and show significant growth in consumption through 2006. Since 1986, there has been a steady growth of sulphur consumption in the developing countries of Asia for both fertilizer and non-fertilizer uses; however, in industrialized countries, such as Japan and the Republic of Korea, fertilizer sulphur consumption has leveled off recently as phosphate production has declined.

China holds significant potential for the sulphur and phosphate industries. In 1995, less than 2% of China's sulphur requirement was satisfied in the form of brimstone; domestic acid production from pyrites satisfies the bulk of its sulphur requirements. Although TSI expects that China will rely on domestic pyrites for many years to come, the increasing costs associated with mining and transporting this material, as compared to the cost of importation of brimstone, suggest that all incremental increases in demand will be satisfied from brimstone, with some substitution of pyrites. This has been demonstrated by China's importation of 800,000 tons of brimstone in 1996 and an estimated equivalent amount for 1997.

With limited resources of phosphate rock in East Asia, there is limited potential for increased sulphur consumption for fertilizer manufacture other than in China and Vietnam. In Vietnam, there are plans to expand an existing SSP plant and build new capacity for SSP and triple superphosphate, based on domestic phosphate rock. Within China, there are phosphate rock reserves, particularly within Yunnan Province, that are expected to be developed.

African sulphur consumption will continue to grow, depending almost entirely on increased demand for processed phosphates in the export market. There are significant reserves of phosphate rock in Morocco, Senegal, and Tunisia. The Republic of South Africa, which also has reserves of phosphate rock, has become one of the top-four phosphate-producing countries in the region since the end of apartheid in 1991. Morocco and Tunisia are the second- and third-largest phosphate exporters, led only by the United States. In 1996, sulphur consumption for fertilizer manufacture was 5.2 million tons, as compared to only 1.2 million tons used in non-fertilizer applications. While regional sulphur consumption for fertilizer manufacture is expected to grow 35% by 2006, little growth is expected for non-fertilizer uses.

In the FSU, there is significant opportunity for increased sulphur consumption. In 1996, sulphur consumed for fertilizer manufacture reached 2.6 million tons—still less than half its 1991 level. While there is significant plant capacity for phosphate fertilizer manufacture within the FSU, the operating capacity is low due to increased raw material transport costs since the change to a market economy. However, this condition is expected to improve. The World Bank has reported that the FSU has reached the turning point from decline or stagnation to positive economic growth. With this improved growth and better economic conditions, more capital is expected to be available to improve transportation problems and permit additional phosphate production. The Sulphur Institute estimates that sulphur consumed for fertilizer manufacture will increase by about 5% per annum through 2006. Improving economic conditions will also increase sulphur consumption for non-fertilizer applications, which TSI estimates will increase 25% by 2006.

In Latin America, Brazil and Mexico have historically reflected the position of the phosphate fertilizer market and, thus, regional sulphur consumption. These two main consumers account for 90% of all sulphur consumed in the region and more than 60% of regional sulphur consumption. The fertilizer industry in Brazil and Mexico has changed in recent years with the privatization of their facilities. Although there was a significant drop in phosphate use during the transition, consumption is improving and is expected to grow marginally by 2006. However, a significant increase in future sulphur consumption is forecast for non-fertilizer use, especially in ore leaching processes, with additional projects in Chile, Mexico, and Peru.

Sulphur Production

Sulphur is produced from three major sources: elemental sulphur (brimstone), sulphur in other forms, and pyrites. Brimstone sulphur is derived predominantly as a by-product of natural gas and oil refining, and, to a lesser degree, natural deposits primarily mined through the Frasch process. Brimstone represented 67% of total production in 1996, with sulphur recovered from oil and natural gas at 58%. Sulphur in other forms, comprised mainly of supplies coming from sulphur recovered in the form of sulphuric acid from various processes, namely from the smelting of non-ferrous metals, represented 19% of total production. Lastly, sulphur can be supplied from pyrites, which are processed to produce sulphuric acid. Pyrites represented 14% of total world production in 1996—a decline from 20% in 1986. The contribution to sulphur production from pyrites is expected to continue to decline worldwide. However, pyrites production will remain a significant contribution to sulphur supply in certain countries, primarily China, through 2006.

Similar to the recent trend seen with sulphur consumption, sulphur production increased slightly from 55.8 million tons in 1995 to 56.2 million tons in 1996, following a steady increase from its recent low in 1993 (Figure 8). While the recovery in sulphur production closely paralleled demand, the rate was lower. Despite regional increases observed in North America, West Asia, and East Asia, the reduced production in Eastern Europe and the FSU resulting from economic decline and restructuring limited overall production increases.

Historically, North America has dominated in regional sulphur production (Figure 9). In 1996, North America supplied 38% of total production. Most of this production was in the form of brimstone from sour gas production in Canada and oil refineries in the United States. The predominance of sulphur coming from the oil and gas industry is a relatively new situation. Some 30 years ago, the sulphur production within North America was predominately from Frasch mining. In recent years, this contribution has been reduced. In 1994, Frasch sulphur contributed 29% of U.S. brimstone production, as compared to 40% in 1986.

East Asia is the second-largest sulphur-producing region, with 21% of the world total, primarily from recovered sulphur and sulphur in other forms in Japan and pyrites in China. Japan will continue to be the regional leader, with increasing recovered sulphur in the Republic of Korea and other countries, while China will undergo changes in the coming years. Sulphur production from pyrites has become increasingly expensive for the Chinese to the point where it is now cheaper to import sulphur. China produces approximately 6 million tons of sulphur annually from pyrites. Realizing the current favorable economics associated with the use of brimstone, as compared to pyrites, substitution of brimstone for sulphur production from pyrites is likely.

Western Europe, the FSU, West Asia, and Eastern Europe follow North America and East Asia in contributions to total production. Worldwide, brimstone will continue to predominate the market and gain an even larger portion through 2006 (Figure 10), with North America becoming an ever larger producer (Figure 11). This predominance by North America will continue as a result of Canadian sour gas and U.S. oil refining operations.

The FSU is a big unknown for the sulphur industry. Production within this region could increase dramatically. Production in Kazakstan is already contributing to recovery in the region, while recovery from sour gas in Astrakhan could increase production significantly and return to levels seen before the changes in economic policies. The balance between this production and regional sulphur demand will influence the sulphur market for several years to come.

West Asia is another area where changes in production could affect worldwide market conditions. Saudi Arabia, the largest regional producer, is projected to increase production, followed by Iran, the second-largest regional sulphur. Current United Nations sanctions are preventing Iraq from bringing its Frasch sulphur production to the world market place; however, when sanctions are lifted, this material is expected to impact regional market conditions.

Sulphur Balance and Inventory

Africa and North America represent the regions with the greatest supply and demand imbalance. In 1996, North American production exceeded supply by about 5 million tons. In contrast, Africa had a supply deficit of over 5 million tons. This situation is unlikely to change. And, Africa, with its anticipated additional phosphate capacity, will have an even larger deficit situation in 2006. Within North America, increasing sulphur demand in the United States will closely reflect increased production and be in relative balance; however, Canada, currently supplying 39% of world brimstone trade, will increase production, further outpacing demand and will play a larger role in the export market or be forced to stockpile additional material. Current worldwide inventories are estimated at 16.2 million tons (Figure 12). In recent years, worldwide sulphur inventories have increased from a low point in the early 1990s. Canada leads the world, with about 60% of the world's inventories and, thus, will be critical in future supply scenarios. It's followed by West Asia and the Former Soviet Union.

Plant Nutrient Sulphur

A significant portion of this paper has indicated how the phosphate fertilizer industry affects sulphur consumption. However, there is another component of the fertilizer market that is growing and, thus, will affect future sulphur consumption. This is the use of sulphur as a fertilizer in itself. Currently, about 9 million tons of sulphur in fertilizers are applied worldwide, mainly with nitrogen and phosphorus additions as ammonium sulphate and SSP. In recent years, the fertilizer industry and farmers have begun to recognize these fertilizers as the multi-nutrient fertilizers that they are with sulphur as a needed nutrient.

In the developed countries of Western Europe and, to a lesser degree, in North America, significant reductions in sulphur dioxide emissions have reduced a sulphur source for crops. These reductions, 30% to 50% for many countries, have resulted in a rapid increase in sulphur deficiencies and the need for farmers to make deliberate applications of sulphur fertilizer. In 2006, the additional market potential within Western Europe will be about 400,000 tons from the use of sulphur fertilizers.

North America, namely the United States, has trailed Western Europe in reducing sulphur dioxide emissions. The Clean Air Act, which went into affect in 1990, calls for a 50% reduction in sulphur dioxide emissions. As this source of sulphur for crops is reduced, North America will follow Western Europe's position and accelerate deliberate sulphur fertilizer applications. The Sulphur Institute estimates that the market for sulphur fertilizers will be an additional 1.4 million tons in 2006.

In developing countries, rapid increases in production levels per unit area have increased sulphur fertilizer demand. This demand is not being met in many areas, which is the primary cause leading to increasing sulphur deficiencies within these countries. Increased production per unit area increases demand on the soil system to provide all nutrients. Sulphur is no exception. The Asian region is where crop production has increased dramatically in recent years. This trend is expected to continue. Thus, this region holds the most opportunity for increased use of sulphur fertilizers in coming years. While this potential market is considered a long-term market, particularly as compared to Western Europe and North America, the potential is immense. The Sulphur Institute estimates that the potential market for sulphur fertilizers within this region will reach 5.8 million tons in 2006, with China and India representing the bulk of this deficit.

The estimates for potential presented above for Western Europe, North America, and Asia are calculated from a model developed by TSI to quantify the level of plant nutrient sulphur deficiencies. This model considers the amount of sulphur removed in the harvested portion of the plant, the fertilizers applied to the system, and their relative efficiency. With worldwide crop production levels increasing and little increased production of ammonium sulphate or SSP expected, the sulphur fertilizer deficit will grow rapidly. The Sulphur Institute estimates that the worldwide deficit in sulphur fertilizers will reach 10.8 million tons annually in 2006 without any major shifts in fertilizer applications (Figure 13). With no major increases in production of ammonium sulphate or SSP production expected, there has been increased production of various sulphur-containing fertilizers by the industry to capture some of this growing market. This trend is expected to continue, especially since there are significant opportunities for profits. Recent trends in ammonium sulphate pricing show that, when calculating the nitrogen value, the sulphur content has been sold wholesale between $180 and $300 per metric ton equivalent. These values are more than five times recent F.O.B. values for sulphur. If the fertilizer industry focuses on marketing of sulphur fertilizers and captures only 20% of the estimated potential market, this would result in an additional 2.2 million tons in sulphur consumption. The largest potential market for plant nutrient sulphur is Asia, namely China and India, followed by North America (Figure 14). While Western Europe has a relatively small volume potential, the demand for sulphur fertilizers is apparent now and the European fertilizer industry has capitalized on this opportunity.

A Few Final Comments about Future Sulphur Supply and Demand

As indicated in this paper, the phosphate fertilizer industry significantly impacts the sulphur fertilizer industry. This is the most critical variable influencing sulphur demand. Economic conditions, most notably in the FSU and Eastern Europe, also would be an important factor influencing demand in both the fertilizer and non-fertilizer use sector. Activities in other non-fertilizer industries also will affect sulphur demand. Ore leaching projects in Latin America and potential caprolactam projects in Asia are two most notable areas to influence the demand. Finally, the market for plant nutrient sulphur is a significant variable influencing overall sulphur demand.

Regarding supply, recovered sulphur will increase; however, overall industrial development and energy demand will determine the amount available. Mined or Frasch sulphur also will affect supply in a discretionary capacity. As recovered sulphur or sulphur in other forms increases in supply, Frasch production is less likely to increase. However, Frasch production can increase quickly to meet overall or specific region supply needs. Environmental legislation will only increase and with increased regulation additional sulphur supply can occur. Sulphuric acid recycling is one aspect of environmental recovery and supply from this source is increasing, especially in Western Europe. The last variable addressed here that will affect supply is pyrites production. As mentioned earlier, China is the major country involved. The sulphur industry is involved and watching closely what will happen in the Chinese market insofar as substitution of sulphur from pyrites versus brimstone imports.

The Sulphur Institute's Market Study Group has analyzed these outlined variables and their influence on market conditions and developed a supply demand scenario for 2006 based on 1996 data. This baseline forecast estimates that worldwide sulphur supply will continue to increase at a slightly greater rate through 2006. While this would indicate a relatively balanced market situation, this supply or demand forecast could swing widely by 3 million tons in either direction, with a shift in any one of the mentioned variables. Continually improving market conditions could lead to demand outpacing supply and more favorable conditions for the sulphur industry. Nonetheless, there should be ample sulphur supply for the fertilizer industry from growing involuntary sulphur production and, if necessary, available discretionary sources.

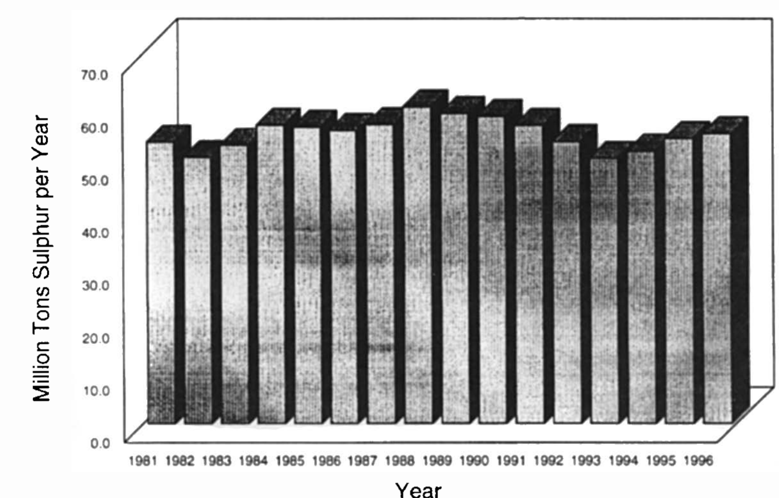


Figure 1: World Sulphur Consumption

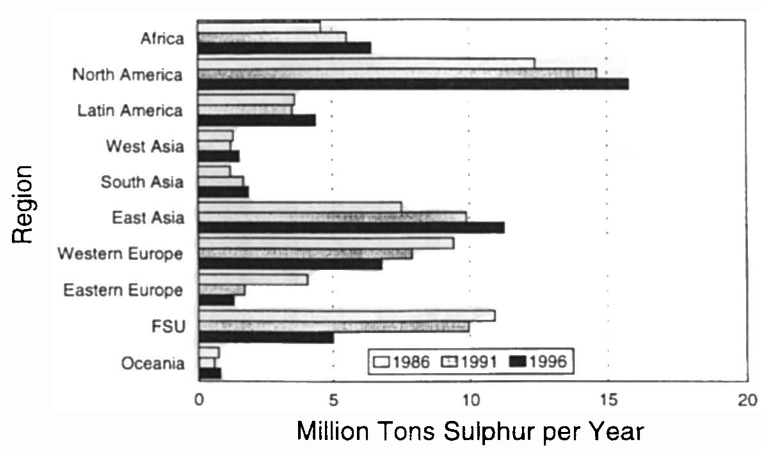


Figure 2: Regional Sulphur Consumption

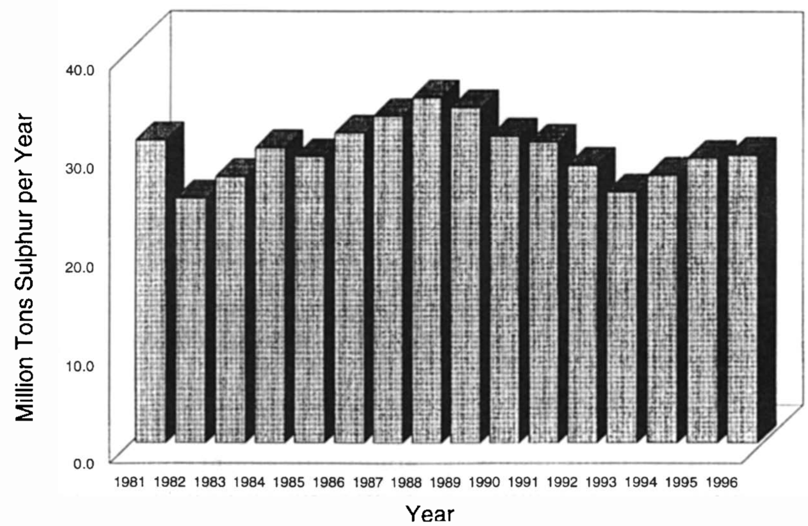


Figure 3: World Sulphur Consumption for Fertilizer Manufacturer

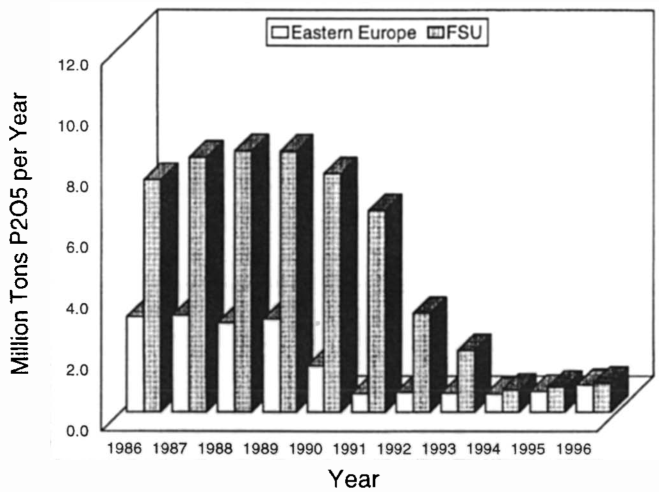


Figure 4: Phosphate Consumption in Eastern Europe and the Former Soviet Union

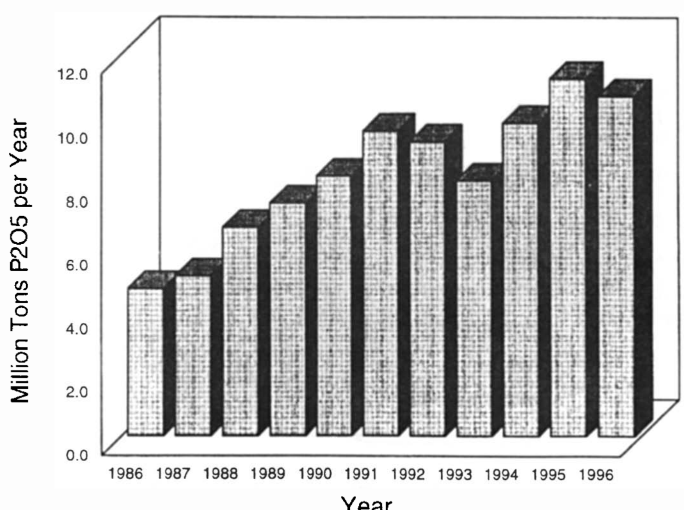


Figure 5: East Asian Phosphate Consumption

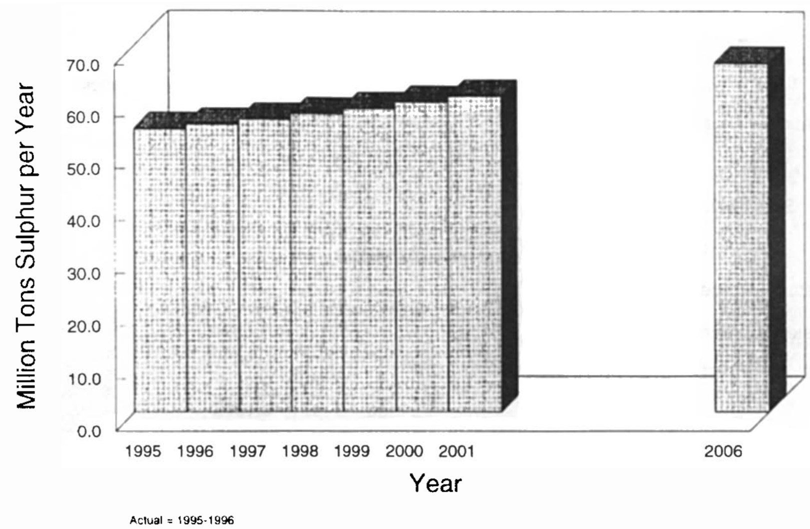


Figure 6: World Sulphur Consumption Forecast

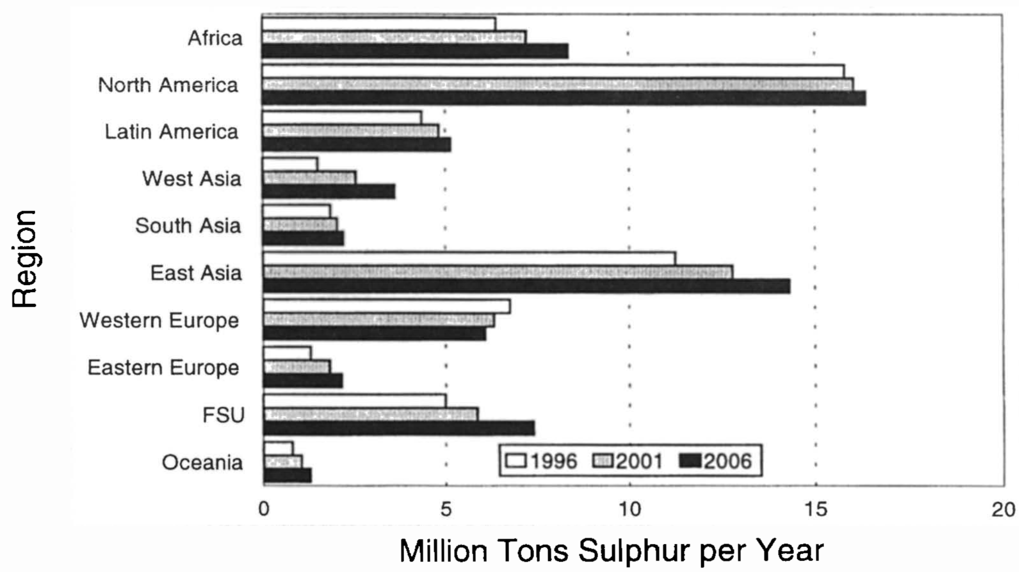


Figure 7: Regional Sulphur Consumption Forecast

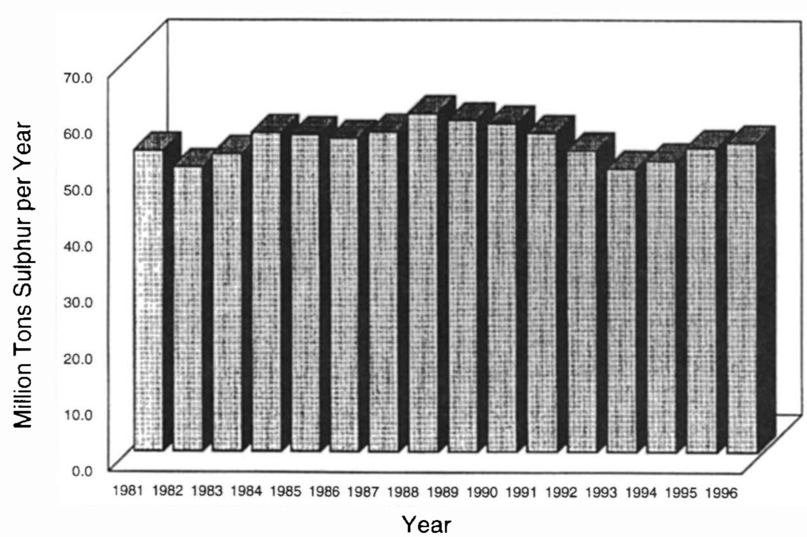


Figure 8: World Sulphur Production

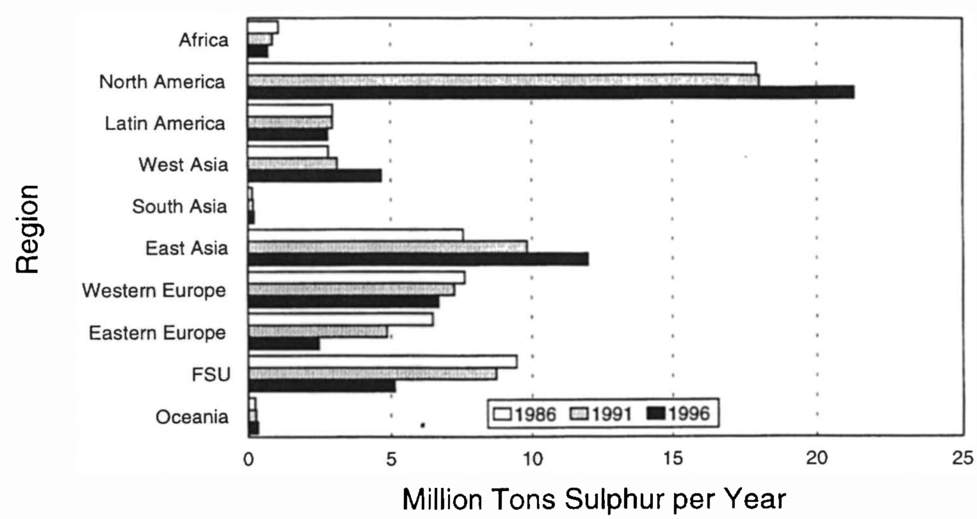


Figure 9: Regional Sulphur Consumption

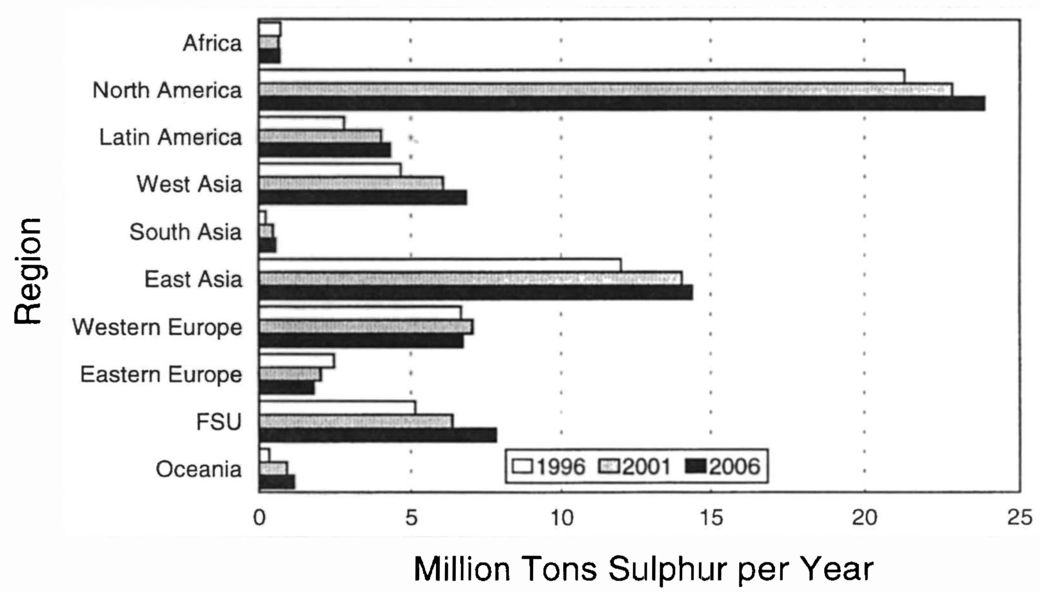


Figure 10: Regional Sulphur Production Forecast

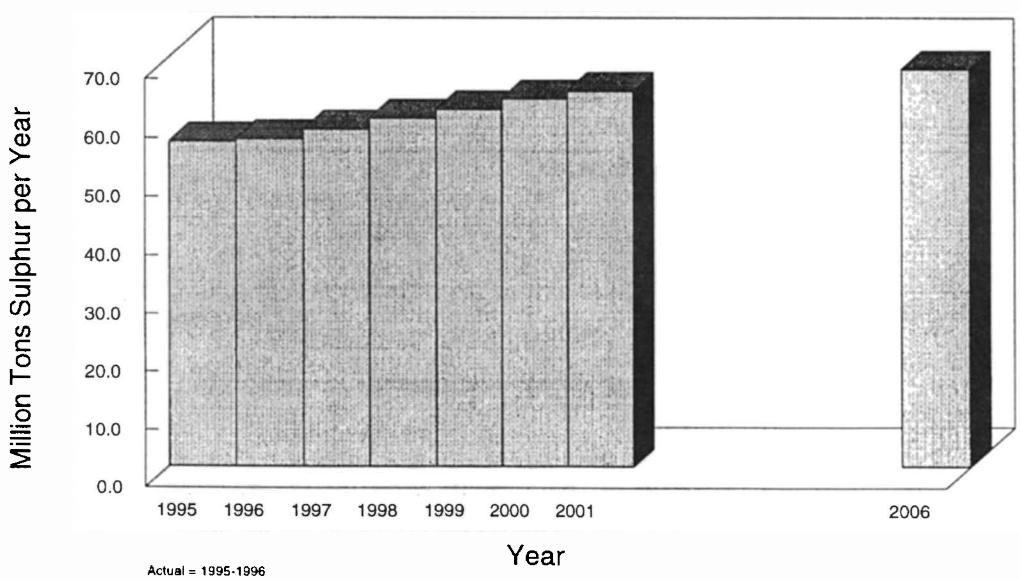


Figure 11: World Sulphur Production Forecast

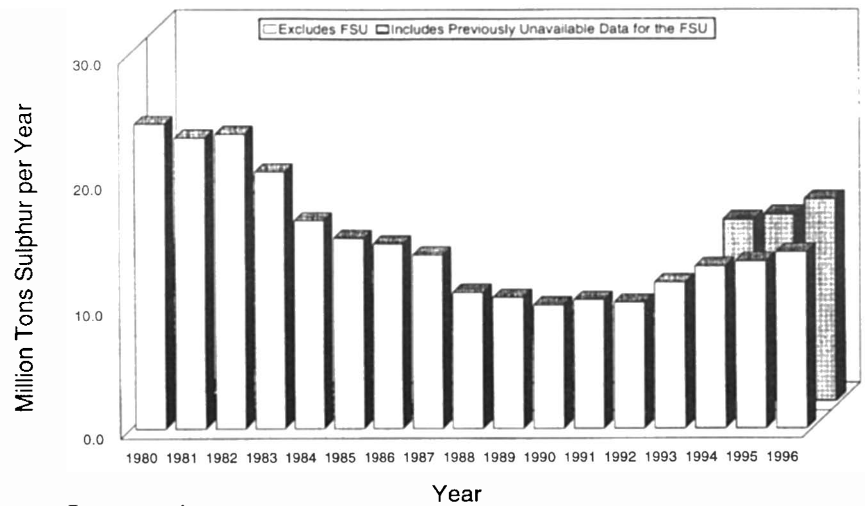


Figure 12: Brimstone Inventories

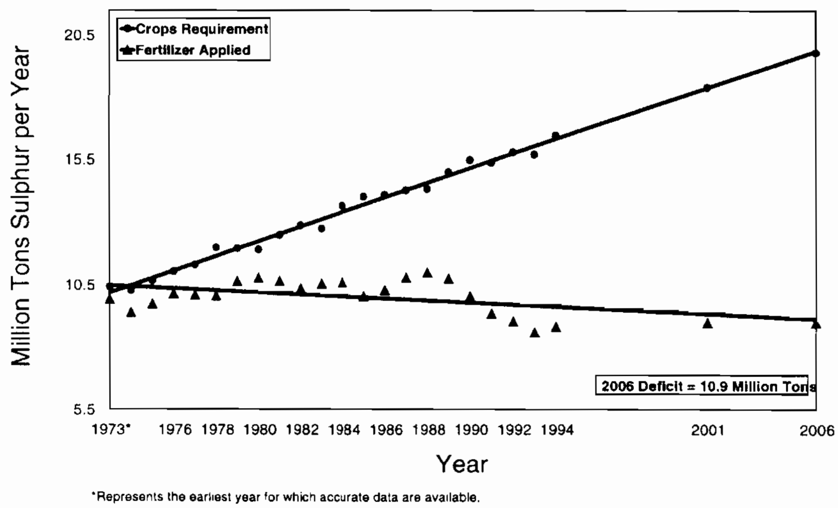


Figure 13: World Plant Nutrient Sulphur Balance

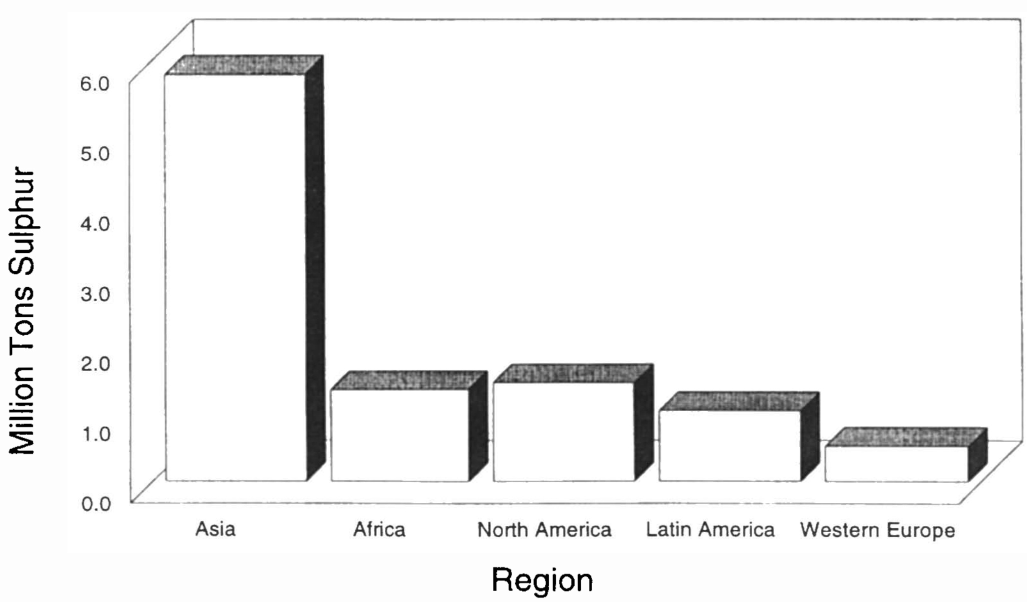


Figure 14: Regional Plant Nutrient Sulphur Deficit in 2006

Outlook for Potash

Kenneth F. Nyiri
Mississippi Chemical Corporation

For more than a decade, the North American and world potash industry faced severe overcapacity, resulting in a prolonged period of soft prices and reduced profitability. This excess capacity, much of which was built in the late seventies and into the eighties, continues to overhang the current marketplace. Nevertheless the outlook for the potash industry looks pretty good. The consolidation of the North American potash industry and the "managed recovery" philosophy administered by the industry's largest player, are succeeding in keeping current potash supply and demand in relative balance.

In the two years since I last appeared before this group, a number of ownership changes have taken place in the potash industry. At that time, eleven companies operated twenty-two potash mines in North America. The table below shows only seven companies remain; only one of those mines closed by mid-year 1997. North American potash capacity is concentrated in the hands of the two largest, PCS and IMC Kalium with an estimated 51% and 30% of capacity respectively.

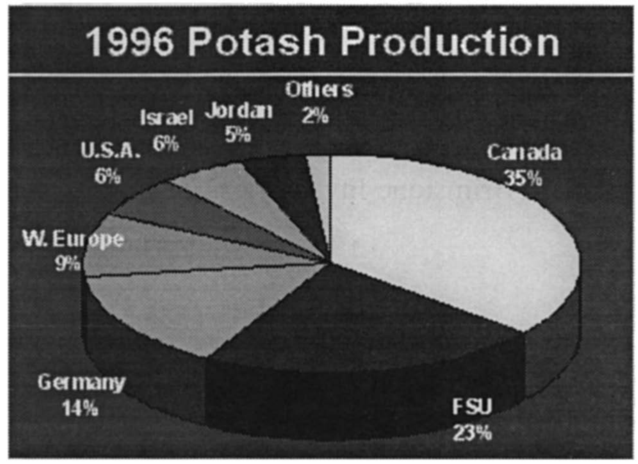
1997 N. American Potash Capacity
('000 st/year)

COMPANY	K_2O	%
PCS (8)	8,205	51.0%
IMC Kalium (6)	4,870	30.0%
Agrium	1,030	6.0%
Potacan	893	5.0%
Mississippi Potash (3)	781	5.0%
Great Salt Lake	250	2.0%
Reilly Wendover	60	1.0%
Total	16,089	100.0%

All forms of K_2O

In the US, potash is produced from nine mines located in three states. New Mexico's five Carlsbad mines account for more than 80% of U.S. output. Three mines produce potash in Utah and one in Michigan. The US potash industry operated at around 87% of capacity in calendar year 1996 while the Canadian industry operated at about the 61% level.

Worldwide, the potash industry is also highly concentrated, with few sources of supply. Canada, the former Soviet Union (FSU) and Germany represent about 72% of the world's potash capacity.



Worldwide, potash is manufactured in fourteen countries, representing about 40.5 million short tons of K_2O capacity. Globally, the number of companies involved in potash production is also relatively small, about twenty-five companies. Six countries have a single potash manufacturer with a single mine. These countries include Brazil, the UK, Jordan, Israel, China, and the Ukraine.

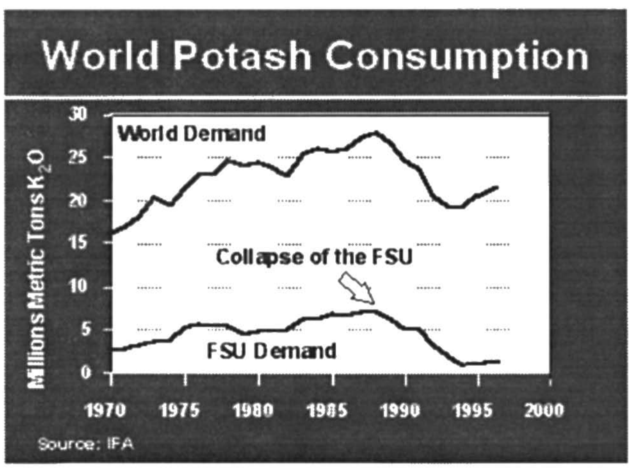
As mentioned earlier, world potash capacity has exceeded demand for more than a decade. The world potash industry operated at about 63% of capacity in calendar year 1996. At this operating level, 15 million tons of surplus capacity currently exists worldwide. Most of this excess capacity existed in the two largest producing countries, Canada (5.6 million tons) and the FSU (4.4 million tons).

The potash industry accumulated much of this excess capacity during the last building boom that occurred in the late seventies and into the early eighties. Those excesses were being slowly worked off during the eighties until the bottom fell out of the market in 1989/90. Potash consumption had been growing at between 2% to 3% per year until the collapse in fertilizer demand in the FSU. From top to bottom, FSU potash demand fell about 6 million tons over the seven years that followed. While much of the decline in supply came from the local FSU potash manufacturers, exports to the West also increased. This was a major setback for the world potash industry that was working off the excess capacity and beginning to reap the benefits with higher prices in the marketplace.

World Potash Operating Rates
(Millions of st/year K_2O)

Country	Capacity - 1996	Operating Rate
Canada	14.4	61%
Russia (FSU)	7.3	40%
Byelorussia (FSU)	6.0	50%
Germany	4.1	90%
Israel & Jordan	2.9	95%
United States	1.7	87%
China	0.1	80%
All Others (5)	4.0	65%
Total World	40.5	63%

(1) Reserves estimates from USGS, January 1997



Worldwide Fertilizer Demand Is Growing

Forecaster's continue to believe that long term fertilizer demand will grow at around 2.0% to 2.5% per year. The annual growth in worldwide fertilizer demand is estimated by the International Fertilizer Industry Association (IFA) at about 5 million tons per year.

Potash demand is expected to grow at 0.8 million tons K_2O per year. If this forecast is accurate, over the next five years, worldwide potash demand could grow by 4 million tons. This growth is well below the 15 million tons of excess capacity that currently overhangs the market. At this growth rate, it would take ten or more years to work off all the excess potash capacity currently in place.

According to the IFA, World Fertilizer Demand Is Growing

	Annual Growth
Nitrogen (N)	3.0
Phosphate(P_2O_5)	1.2
Potash (K_2O)	0.8
Total Demand	5.0

*Source : IFA Fertilizer Demand Group, June 1996

New Potash Capacity is Limited

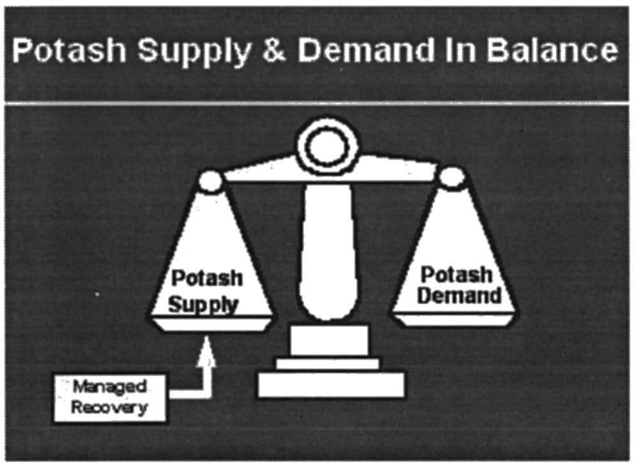
During the next five years, few additions to potash capacity are being planned (table below). Obviously, with the substantial surplus currently overhanging the market, few expansions would be expected. Also, given the current margins, most analysts believe that investments in new potash capacity would be difficult to justify.

This is confirmed by the list of expansions. Except for new mines planned in Thailand and China, this new capacity represents incremental expansions at existing mines. Obviously, the new mine planned in China is directed toward the local market. As far as the large, worldscale project in Thailand is concerned, the jury is still out on this ambitious venture. At times, investments are based on non-market decisions.

On the other end of the scale, one mine in France and another in the US are slated for closure during the next five years. In addition, there are questions concerning possible closures in the FSU and the Potacan mine in New Brunswick that is currently flooding (Potacan recently announced that the New Brunswick mine will close permanently). Nevertheless, the net increase in new capacity will be less than the increase in demand. Worldwide operating rates will increase at existing mines from the current 63% level to around 72% at the end of the five year period.

Potash Expansions to 2002
(Thousand st/year K_2O)

Country	Expansions
Brazil	+ 130
Chile	+ 55
China	+ 410
Israel	+ 110
Jordan	+ 130
Thailand	+ 1,320
United States	+ 175
Total Expansions	+ 2,330



Overall, while the surplus capacity that currently overhangs the potash market is not going to disappear overnight, the long term outlook is still improving. However, as worldwide demand improves, and additions to capacity are limited, the size of the potential surplus is shrinking.

Next Year's Outlook Looking Good

The 1997/98 market outlook for the North American potash market is also positive. Worldwide grain stocks remain tight. Grain prices, while somewhat lower than last year, remain relatively high. US farmers have an incentive to plant fence-row to fence-row again this year. As a result, domestic fertilizer consumption is expected to increase about 2% in 1997/98.

Potash supply was tight this fall. The closure of the Potacan mine in New Brunswick, transportation problems west of the Mississippi River, and low dealer stocks should keep the market tight going into the spring season.

Fertilizer Consumption Increases
(Millions of Short Tons)

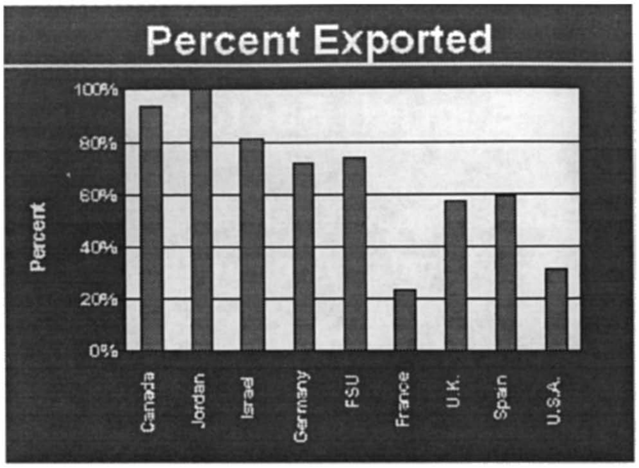
	1996/97	1997/98(f)	Change
Nitrogen (N)	12.3	12.6	0.3
Phosphate P_2O_5	4.7	4.8	0.1
Potash (K_2O)	5.5	5.6	0.1
Total	22.5	23.0	0.5

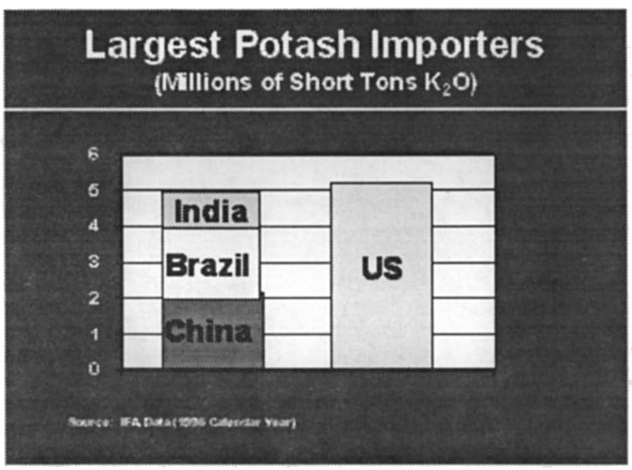
Industry Dominated by World Trade

More than any of the other fertilizer nutrients, the potash industry is dominated by world trade. In 1996, 80% of all potash production was shipped outside the country it was produced. Eight of the fourteen producing countries export more than half of their total potash output. Three countries, Canada, Jordan and Israel export virtually all of their production. These countries have very small domestic potash markets and rely almost solely on the export markets to sell potash and keep their mines running.

Potash marketers aggressively compete for a share of the global market. Lost business is often shifted from one market to another to keep their plants operating at high rates. For many, keeping the plant running is their number one priority.

The United States is, by far, the largest consumer and importer of potash. The U.S. represents more than one-fourth of world consumption and one-fourth of world trade. US potash imports are larger than the next three largest combined in China, Brazil and India. Of course, most of this imported potash supply is brought in from their northern neighbor in Canada. Nevertheless, as the largest import market, changes in world potash trade have a significant impact on the US market, particularly along the Gulf Coast where Canadian, non-Canadian and Carlsbad potash all compete for a share of the market.





As you can see below, international buying can be very erratic. In some years, the international potash buyer will enter the market for large tonnage; but some of these tons may be used to build local stocks. These stocks can be substantial, enough to carry the importer through a portion of the next season. Imports are then reduced the following year. While I believe that international potash demand will continue to be strong next year, much of this strength depends on the decision to continue buying rather than liquidate local stocks.

As with any forecast, a number of uncertainties can impact the market. One of the biggest each year is the weather. This year, in particular, the El Nino effect could create problems at planting time, during the growing season or at harvest. At this time, El Nino promises to be the worst in recorded history. Nevertheless, the surface sea temperatures could go down as quickly as they went up, and the effect of El Nino would be minor.

International Buying Erratic

(Millions of Short Tons K_2O)

	China	Brazil	India	Total
1997 (e)	2.6	2.0	1.3	20.0
1996	2.1	2.0	0.8	19.1
1995	3.0	1.6	1.6	20.4
1994	2.1	1.8	1.4	20.1
1993	1.3	1.7	0.8	16.9
1992	1.7	1.5	1.2	17.7

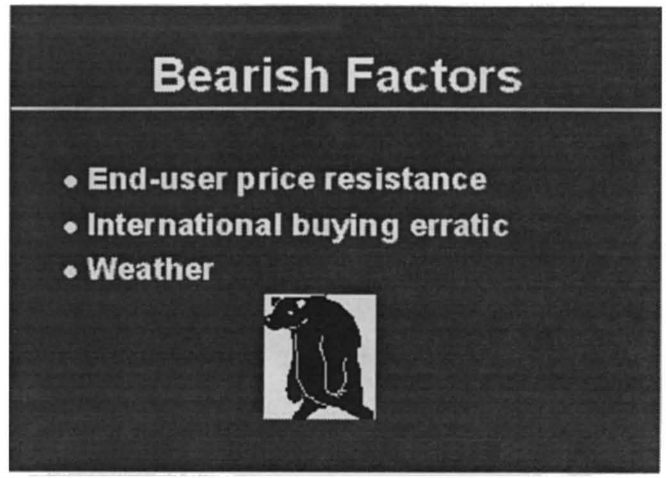
What Could Go Wrong?

- Weather (El Niño)
- Transportation Problems
- International Demand
- And More . . . .

Transportation problems plagued the market in the late summer and into the fall of 1997. Railroad service, particularly west of the Mississippi River has been very slow with some shipments taking weeks to get to market. In addition, the water level in the river system is low, slowing the traffic along the river. Potash customers were being supplied hand-to-mouth during the fall season and dealer potash stocks could be low.

In the international market, no one, maybe even the importers themselves, know how much potash they will purchase this year. International demand must remain strong to keep the potash market in balance.

As always, there are no guarantees. At the current time, the bullish factors outweigh the bearish factors. Both domestic and international potash demand should improve somewhat this year and the supply/demand balance should remain relatively tight. However, on the bearish side, anything could, and often does happen.



Monday, October 27, 1997

Session II

Moderator:

Luc M. Maene

The Future of Ammonium Nitrate in North America and Abroad

D. Ian Gregory

International Fertilizer Industry Association

Introduction

Following the bombing of the Alfred P. Murrah Federal Building in Oklahoma City, Oklahoma, on April 19, 1995, with what was proved to be an ammonium nitrate-fuel oil bomb, the United States Congress formulated the Antiterrorism and Effective Death Penalty Act. This became law in April 1996. Section 732 of the Act directed the Secretary of the Treasury to study:

1. The tagging of explosive materials for purposes of detection and identification.
2. The feasibility and practicability of rendering common chemicals used to manufacture explosive materials inert.
3. The feasibility and practicability of imposing controls on certain precursor chemicals used in the manufacture of explosive materials.
4. State licensing requirements for the purchase and use of commercial high explosives.

Subsequently in November 1996 the International Fertilizer Development Center (IFDC) was contracted by the Bureau of Alcohol, Tobacco and Firearms (BATF), under the direction of the Secretary of the Treasury, to prepare the fertilizer component of the overall study. The overall objectives of the IFDC component of the study were to:

1. Assess the feasibility, practicability, and impact of implementing requirements to render common nitrate-based fertilizers inert.
2. Assess the feasibility, practicability, and impact of imposing controls on those precursor chemicals used as nitrate-based fertilizers.

Regulatory issues and existing or proposed nitrate-based fertilizer tagging and desensitization practices were particularly emphasized. The study focused on the U.S. fertilizer and agricultural sectors with reference to international dimensions of relevance. The study (Imposing Controls on, or Rendering Inert, Fertilizer Chemicals Used to Manufacture Explosive Materials) was completed and submitted to BATF in April 1997.

In general terms the IFDC study did not support at this time: the imposition of further regulations requiring the use of desensitizing agents in nitrate-based fertilizers in the United States, additional regulations designed to thwart illegal access to and use of nitrate-based fertilizers, the tagging of nitrate-based fertilizers for the purpose of identification and/or detection.

This paper draws heavily on the IFDC study [1] but is restricted to the past, current, and future use of ammonium nitrate (AN) fertilizer in the United States and abroad as a solid and as a component of fertilizer nitrogen solutions (UAN). Emphasis is placed on the agronomic and other advantages of AN and UAN over other nitrogen fertilizers for specific crop and crop management conditions.

The Global Nitrogen Fertilizer Product Mix

Global fertilizer use increased from 27 million nutrient mt in 1959/60 to 143 million nutrient mt in 1989/90. Of the three primary nutrients, nitrogen (N) use recorded the highest absolute and relative growth. N use increased from 10 million nutrient mt in 1959/60 to 79 million nutrient mt in 1989/90. N use decreased drastically in Eastern Europe and the Former Soviet Union (FSU) after the fall of the Berlin Wall in 1988. Consequently, global N use also decreased from 80 million nutrient mt in 1988/89 to 73 million nutrient mt in 1993/94. In 1994/95, global N use increased by 1 million nutrient mt. The regional use patterns for 1959/60-1994/95 are presented in Table 1.

In North America, N use peaked in 1980/81 at 11.8 million nutrient mt. Low crop prices and grain surpluses in the 1980s reduced N use in North America and other developed regions. However, as grain stocks hit their lowest level, increases in grain production and prices induced increases in N use. In 1993/94, N use reached a record high level of 12.9 million nutrient mt.

Nitrogen fertilizer product use patterns for 1993/94 are presented in Table 2. Overall, 25% of global N use was accounted for by nitrate-based fertilizers and AN accounted for 9%. In North America, the proportions were 31% and 5% respectively. However, including the AN content of nitrogen solutions, the total AN proportion was about 15%. Table 2 also illustrates the regional importance of nitrate-based fertilizers in Western and Eastern Europe and the FSU where these products account for 57% to 66% of the total N use. Excluding Asia, Latin America, and Oceania, nitrate-based N fertilizers dominate or are significant in the N product mix and AN, calcium ammonium nitrate (CAN) dominate the European markets, and AN and UAN are significant in North America.

Both demandside and supplyside factors have contributed to this regional contrast in the use of N fertilizer products. In North America, large-scale and highly mechanized farming and distribution economics has promoted the use of bulk blends, anhydrous ammonia, urea, and N solutions. Nevertheless, production of high-value crops has favored the use of AN and other nitrate-based fertilizers. In Europe, relatively higher efficiency (lower losses) of top-dressed nitrate-based fertilizers and availability of suitable equipment for small-scale farming as well as a well-established nitrate-based fertilizer industry have contributed to the dominance of nitrate-based fertilizers. Historically, the preference for nitrophosphate production in Europe, because of the lack of indigenous sulfur for sulfuric acid processing of phosphate rock, led to the co-production of AN and CAN. In Asia, because about 40% of N use is on flooded rice cultivation, urea is the preferred fertilizer. Moreover, in both Asia and Latin America, the nitrogen fertilizer industry developed mostly in the 1970s and 1980s when technology and investment cost considerations favored the construction of large-scale ammonia-urea complexes. In Africa, until recently, most of the nitrogen fertilizer was supplied through imported ammonium sulfate and NPKs. Heavy use of AN and CAN, due to agronomic and soil considerations, in Egypt has also contributed to a relatively larger share of nitrate-based fertilizers in Africa.

Global and U.S. Nitric Acid Production Capacity

Nitric acid is required for producing nitrate-based fertilizers other than naturally occurring salts, but worldwide data for nitric acid capacity are not available. In the United States nitric acid is produced by 30 companies at 59 locations. Total annual capacity in terms of 100% HNO_3 is about 10.6 million mt (11.6 million st). Capacity is expected to increase to 11.7 million mt (12.8 million st) by 2000/2001. Approximately 75% of the U.S. nitric acid production is consumed captively, primarily in producing AN. The remaining 25% is used in the production of synthetic fibers, plastics, and other non-fertilizer products.

Global and U.S. Ammonium Nitrate/Calcium Ammonium

Nitrate Production Capacity

AN or CAN is produced in 62 countries. Much of the world's CAN capacity is in Western Europe (primarily the Netherlands, Germany, Italy, and Belgium). The countries with the largest AN capacities include Russia, United States, China, Ukraine, France, Poland, United Kingdom, and Romania. Some plants produce only AN, some can produce both AN and CAN, and some produce only CAN. In 1966 world AN and CAN capacity was 66.1 million product mt (72.3 million st) [2]. This includes 51.0 million mt (55.8 million st) from plants that produce only AN, 8.6 million mt (9.4 million st) from plants that produce only CAN, and 6.5 million mt (7.1 million st) from plants that can produce either or both AN and CAN.

Converted to nutrient capacity, this represents about 21.5 million mt N (23.5 million st). The largest share (26%) of this capacity on an N basis is in the FSU. The FSU produces only AN. However, much of this capacity is currently underutilized because of low operating rates and low domestic demand. Western Europe accounts for 22% of the combined AN/CAN N capacity. About two-thirds of the global CAN capacity is situated in Western Europe. North America ranks third on an N basis with about a 17% share.

There have been very few plant announcements regarding AN or CAN in any region and thus only about 4% growth in world capacity is projected between 1996 and 2000.

In the United States, 20 companies with plants at 38 locations have the capacity to produce AN. The AN industry is more geographically dispersed than is the ammonia industry with only 23% of capacity located in Louisiana, Texas, and Oklahoma. Production capacity is approximately the same for solid AN and for AN liquor used in UAN solutions. Four plants produce only solid AN, and 19 produce only solutions. The remainder produce both solid AN and AN liquor for solutions. Two companies account for over half of the AN liquor capacity used for UAN production. Solid AN is produced in 20 plants, but the largest 5 companies have about 65% of the total capacity.

The United States has the capacity to produce 9.0 million product mt (9.9 million st) of AN. This includes the capacity for solid AN as both high and low density and the capacity for AN liquor used in fertilizer solutions and for industrial purposes including explosives. This represents about 18% of the world AN capacity (excluding CAN). This capacity in the United States has been increasing steadily in recent years and has increased by 1.0 million product mt (1.1 million st) since 1991/92. Capacity is expected to reach 10.0 million product mt (11.0 million st) in all forms by the year 2000/2001. Nearly all of the increased capacity will be for UAN production. This will be supplemented by conversion of existing solid AN capacity to liquor production for UAN. An industry survey by IFDC revealed that solid AN capacity utilization was only 75% in 1995.

There are five companies in Canada producing AN at five locations. Annual capacity is about 1.2 million product mt (1.3 million st) but is expected to increase to 1.4 million product mt (1.5 million st) by 2000/2001. Mexico has four companies with plants at four locations that produce AN. Annual capacity is 0.7 million product mt (0.8 million st); a modest increase to 0.8 million product mt (0.9 million st) is expected by 2000/2001.

United States Supply of AN and UAN

Total U.S. production of solid AN in 1995 was 3.6 million product mt (3.9 million st), of which almost 2.1 million product mt (2.3 million st) was high-density AN, and 1.64 million mt (1.8 million st) was low-density material. In addition , 0.8 million product mt (0.9 million st) was imported for fertilizer consumption.

UAN solutions are increasing in importance. Production was over 10 million product mt (11.4 million st) in 1995, and imports were 0.86 million product mt (0.95 million st).

United States Trade in AN and UAN

Increased consumption of UAN in the United States during the past 2 years has led not only to an increase in UAN imports but also an increase in AN liquor production devoted to UAN. As a result, an increase has occurred in both AN and UAN imports. AN imports increased from 0.37 million product mt (0.4 million st) in 1991 to 0.8 million product mt (0.88 million st) in 1995 before falling in 1996 to 0.64 million product mt (0.7 million st) in 1996. Imports from Canada of solid AN fertilizer have ranged from 0.3 to 0.38 million product mt (0.33 to 0.42 million st) over the past 4 years. Increased import demand for AN has been met from Russia, Ukraine, Western Europe, Mexico, and Egypt. Some of these imports have been made by U.S. producers to supplement their own production; however, imports by independent traders and regional or national distribution companies have also been important.

UAN imports increased from 0.225 million product mt (0.248 million st) in 1993 to over 0.86 million mt (0.95 million st) in both 1995 and 1996. Imports from Canada shared in this increase with 0.235 million product mt (0.259 million st) in 1996. Imports from Mexico commenced in 1995 and reached over 0.3 million product mt (0.33 million st) in 1996. Eastern Europe and the FSU provided the other sources of UAN imports.

United States Consumption of Nitrogen Fertilizer

Three sets of nitrogen consumption data are presented. The first set, Table 3, summarizes the data published in Commercial Fertilizers, 1996 [3]. The second set, Table 4, was derived from the first set by IFDC in consultation with industry analysts and reflects an apparent under-reporting of AN and UAN in the Commercial Fertilizers data sets. To some extent this may also reflect the inclusion of some AN as a component of bulk blends in the first data set. The total nitrogen consumption in the second data set is assumed to be as reported in Commercial Fertilizers. A third set, Table 5, was derived by IFDC from various data sources to provide a more detailed product data set in which the product components of bulk blends are not separated. The data for several minor products were derived as apparent consumption (production + imports - exports). This data set indicates total annual nitrogen use between 6% and 8% greater than reported in Commercial Fertilizers. This is due to differing data sources and reporting periods. IFDC did not research the quantities of low density AN used in agriculture, and in the above data sets, it is assumed that all low-density AN was used for non-agricultural uses. It is known that at least until 1995 this was not the case, but the quantity was not very significant.

The overall trends in consumption patterns in the three data sets are similar. Overall nitrogen consumption has been increasing at an average annual 1.6% compound rate since 1991. UAN nitrogen consumption has been increasing by almost a 4% compound rate over the same period and solid AN by 1.5%. Anhydrous ammonia use has declined by almost 1% annually and urea has grown by 3% annually over the same period, 1991 to 1996.

United States Nitrogen Use Patterns

In the United States, each of the five popular nitrogen products is used in most states, but use of each product tends to concentrate in states where agronomic characteristics of the product best fit with cropping practices, soil and climatic conditions, price, managerial considerations, and other factors of regional importance. Technical considerations also become very important in the choices that dealers make between AN and urea. Both products have good storage and handling qualities, but when they come in contact with each other, the quality of both deteriorates severely. Dealers usually attempt to handle one or the other, not both products. This factor makes it difficult to substitute a less popular product in the market.

Figure 1 shows nitrogen use by product and Figure 2 nitrogen consumption by region.

Agronomic Considerations in N Fertilizer Choice

A common generalization concerning N fertilizers is that one N source is about as good as any other N source, if they are applied properly. The reason for this is that, ultimately, all N sources, including organic N forms, are converted to nitrate, which is the main form in which N is taken up by most plants. Like all generalizations there are notable exceptions. In certain cropping systems, it is difficult or impossible to incorporate fertilizers or to apply the fertilizers at an exact timing to make them efficiently used. American agriculture is extremely diverse, with many crops and highly variable soil and agroclimatic conditions. Given this diversity and the need to produce crops efficiently and use fertilizers in an environmentally sound manner, different fertilizers function better in certain situations than in others. There are situations in which the use of nitrate forms of fertilizer are critical to efficient crop production. Effective product substitutions are further compounded by market realities.

Nitrate fertilizers have unique attributes that affect their performance as N sources for crops. Because nitrate forms of fertilizers have some or all of their N in the form taken up by plants, they are more quickly usable by plants than other forms of N fertilizers. The conversion of urea to ammonium in soil usually takes from 4 to 10 days; the ammonium is then converted to nitrate by soil microorganisms, which can take several weeks under very wet, very dry, or very cold soil conditions. The substitution of a non-nitrate product for a nitrate product may require earlier application to achieve availability at the desired time. This is not a concern for many crops and cropping situations because the conversion of ammonium and amide (urea) to nitrate can occur within a few days during growing seasons and has little impact on production. The attribute of rapid availability is important for crops such as tobacco, potatoes, tomatoes, onions, many other vegetable crops, and some fruit crops which are fertilized very carefully to avoid excesses as well as deficiencies of N.

The nitrate fraction of AN and UAN cannot be readily lost, and the ammonium N is not as susceptible to loss as is the ammonium in other forms, particularly urea. Ammonia volatilization losses from urea applications occur with any surface application, but are most important on calcareous (high pH) soils and soils that are not tilled. Soils that are not tilled sustain a much higher level of biological activity at the soil surface which causes a rapid conversion of urea to the ammonia form, which can be lost. Most studies have shown crop responses to be on average 15% to 25% better with AN than with urea if the urea is not incorporated.

In addition to rainfall events, wind speed can affect losses. The variability of losses is more important than the absolute losses because it makes it difficult to manage urea on crops that are sensitive to excess N.

No-till or minimum tillage crop production systems have grown rapidly [4], and about one-third of the total crop acreage of the United States is under some form of reduced tillage system. In these systems, urea is particularly prone to losses, and AN is widely used for topdressing wheat and sidedressing corn. Methods to reduce ammonia volatilization losses from urea, including the knifing in and/or high pressure injection of UAN, are more expensive than surface application, and their efficacy can be affected by soil conditions.

The commercial use of a urease inhibitor for use in no-till corn to reduce losses of ammonia from urea commenced in 1996. The inhibitor significantly improves yields compared to use of straight urea, however, the best yields using urea plus the inhibitor were several bushels per acre less than with AN.

Another approach to reduce ammonia volatilization is to apply calcium salts to form calcium carbonate and thereby reduce the pH buffering capacity that sustains ammonia loss. This approach has not achieved significant success.

An effective method to stimulate early crop growth, particularly in cold/wet soils, is to place fertilizer with the seed. AN is safer to use for this purpose than ammonium fertilizers, which release ammonia that is highly toxic to germinating seeds. AN has a distinct advantage when farmers need to place a small amount of N close to germinating seeds.

The process of converting ammonium forms of N to nitrate causes acid formation, which is not a desirable trait in many soils. AN contains half of its N as nitrate and therefore causes less acidification of soils than do ammonium forms. Alkaline soils in the western U.S. may actually benefit from these microbial conversions, whereas most eastern U.S. soils would require more liming materials to be applied. It is interesting to note that many dealers and farmers in the Midwest are discovering from their precision agriculture data that low pH is a primary cause of low yields.

To summarize, farmers achieve better results with AN and other nitrate fertilizers than with other N products when they use them for the following purposes:

1. To achieve a rapid and consistent response to N on crops that are sensitive to the timing of N availability. These crops are principally fruits and vegetables.
2. To achieve more economic and consistent responses to N on pastures.
3. To topdress and sidedress crops under minimum tillage systems to achieve greater efficiency of N use.
4. To achieve better efficiency and more reliable responses to topdressed N on soils with high pH, primarily encountered with grain crops in the western states.
5. To achieve a better response to applied N on cold soils, particularly by cool-season vegetables.

AN Use Pattern

In spite of relatively higher costs, AN has remained popular in southern states where use in the 13-state region exceeded 50% of reported total use of AN (Figure 3). Agriculture in these states is highly diverse, including citrus and vegetables in Florida; tobacco in the Carolinas, Kentucky, Virginia, and Tennessee; cotton in several states; improved pasture in all states; a well-developed livestock production base; and growing acreage of no-till corn, to name the most obvious examples. The agronomic characteristics of AN fit one or more of the specific agronomic needs of each of these crops, and in addition AN has no agronomic disadvantages for any of them except rice. The versatility and ease of management of AN discussed previously, along with soils, topography, farm and field sizes, make AN a preferred source of nitrogen in this region. AN is the only nitrogen product generally available in bags although the tonnage has been decreasing in recent years. Availability in bags is important to small farmers, part-time farmers (ranging from cow-calf farmers to tobacco farmers), nurseries, gardeners, and others from both rural and urban settings.

UAN Solution Use Pattern

UAN has exhibited the fastest growth in the market of all N sources in recent years and this has taken place predominantly in the Corn Belt, the southern and western states. (Figure 4). UAN is second to anhydrous ammonia (AA) as a supplier of N. Typically priced slightly higher than urea, but significantly lower than AN, on a per unit basis its growing popularity and use can be attributed to several factors. These include: its lower production investment cost than AN, lower distribution investment cost than AA, versatility in use as both a straight N form and as a component of mixed liquid fertilizers, ease and safety in handling and accuracy in application, its suitability for tank mixes with crop protection chemicals, the widespread adoption of no-till or minimum tillage crop production systems, and the recent rapid adoption of precision agriculture.

Anhydrous Ammonia Use Pattern

Anhydrous ammonia is the major straight N product, accounting for 30% of actual nitrogen used for direct application. Its price per unit of nitrogen is significantly lower than for other nitrogen products, but it has disadvantages that include significant safety hazards in storage, transportation, and use. Application equipment and methods are more costly, and skills are much more demanding for working with AA at any level.

Soil characteristics and climatic conditions in the 12 states making up the Corn Belt make it possible for those farmers to use AA and take advantage of its relatively low price per unit of nitrogen. These farmers account for 70% of all AA used for direct application in the United States (Figure 5). The advantages offered by autumn application in reducing spring field operations to allow timely sowing for optimum yields offset the higher handling costs associated with the product and ensure that dealers and farmers maintain the necessary skills and attitudes to use the product safely.

Urea Use Patterns

Urea was introduced to the U. S. market in the early 1950s and by 1977 its use exceeded that of AN. Granular urea came onto the market in the early stages of bulk blending and grew along with the growth in bulk blending. Urea owes its popularity to generally relatively lower unit price compared to AN along with more opportunities for spot price negotiation by dealers due to large import tonnages, wider availability, and better particle size match with DAP and potash for blending. Urea is also preferred for rice fertilization, which adds significantly to the total use of urea in the southern states where 900,000 hectares (2.225 million acres) are planted annually. The southern states accounted for 31% of total urea use in 1996 and the Corn Belt 49% (Figure 6). There has been virtually no change in urea consumption in the Corn Belt for the past 10 years.

In summary we have a pattern of fairly static anhydrous and urea markets, strong growth in UAN, and indications of increasing growth in the AN market.

The Future Patterns of Nitrogen Product Use

The current pattern of nitrogen product use in the United States has been established from a sound agronomic base and market realities. Is it therefore going to change and if so how quickly? Eight major factors should be considered for possible impacts. These are:

1. The impact of the 1996 Farm Bill on regional cropping patterns.
2. Trade liberalization and its impacts on regional cropping patterns.
3. The impact of environmental and safety regulations on product choice by dealers and farmers.
4. The impact of conservation tillage on product choice.
5. The impact of precision farming on product choice.
6. The impact of biotechnology on crop production added value.
7. The impact of producer and retailer consolidation on product choice.
8. The impact of nitrogen supply sources for the U. S. market.

The first two factors are really beyond the scope of this paper but will surely have a long-term impact on regional cropping patterns. The third factor, environmental and safety regulations, will continue to impact most on anhydrous ammonia. Will distribution facilities and application equipment be expanded or even replaced? The evidence suggests that because of permitting difficulties and the high investment cost there will be no expansion of AA distribution facilities so that growth will only come from increased throughput at existing facilities. This will curtail growth in the long term. Will dealers and farmers replace existing equipment and facilities? In most cases they probably will because of the cost and timeliness advantages of AA in the market. Therefore a continued strong presence for AA is forecast but with a slightly declining market share.

In 1996 there were 104 million acres in conservation tillage in the United States – 31% of all cultivation. The area has doubled since 1984 (Table 6). Forty-three percent of the conservation tillage was no-till. Environmental and cost pressures are expected to see this trend continue. Early in the next decade it is anticipated that some two-thirds of all cultivation land will be under some form of conservation tillage. The impact on urea usage in the Corn Belt could be significant. This likelihood would be increased with greater availability of granular AN for bulk blends.

Precision farming may today be a technology-driven development, but there is increasing evidence that it is becoming demand driven and offers dealers and farmers the means to capture data that can be used to optimize the use of farm inputs (fertilizers, seeds, and chemicals) and optimize yields. Although variable rate technology for fertilizer application is available for both liquids and solids, it is likely that liquids will prevail and thus provide a further boost to UAN.

Two years after the first introduction of biotechnology developed crop varieties the impact in the market has been dramatic in terms of market penetration. The next decade will see the extensive adoption of crop varieties tailored to specific output markets and requiring specific nutrient and crop protection chemical packages. Precision in fertilizer N application rate and timing will become more important for row crops and broad acre crops. Nitrate-based fertilizers will offer more flexibility in meeting the demands of these crop varieties.

Industry consolidation at all levels has meant that production and distribution decisions have a larger impact on product availability in the market. The speed with which the industry expanded production of UAN to meet increasing demand is a specific example. The nitrate-based industry is more concentrated than the urea industry at present for both AN and UAN. With less import availability of nitrate-based products than for urea or ammonia, availability of AN and UAN is more dependent on industry investment decisions.

The U.S. import requirement for N will continue to grow from sources of comparatively lower priced natural gas. Urea from western Canada and ammonia from the Caribbean and Venezuela will dominate. The conversion of imported ammonia into UAN and AN is an added value opportunity not available for urea production. The long-term continued import of UAN from Europe does not make economic sense compared to importing ammonia from low-cost gas sources. Currently this UAN trade is opportunistic.

As part of the IFDC study for BATF, estimates were made of the global and regional N fertilizer requirements in 2020 by using the methodology developed by Bumb and Baanante [5]. Under his methodology, N requirements are estimated by taking into account the quantity and efficiency of N uptake by cereal crops, the amount of crop residues removed, ratio of N use on cereal crops to N use on all crops, and the supply of N from external sources for arable crops. The International Food Policy Research Institute's (IFPRI) projection for cereal production was used as a base to develop N requirements for cereal crops. The values of various parameters were estimated making adjustments for potential efficiency improvements and trade liberalization policies.

World N requirements in 2020 were estimated to increase by 120% from 1995 – from 74 million nutrient mt N in 1995 to about 163 million nutrient mt. In North America the increase was estimated at 42% from 12 million nutrient mt N to about 17 million nutrient mt N.

The product mix changes for N fertilizers at a global level and for North America are summarized in Table 7. These product shares are applied to the total N estimates to estimate product demand for N fertilizers in 2020. The overall world share of nitrate-based fertilizers does not change from 25% as it was in 1995. In North America the ratio between ammonia-based and nitrate-based fertilizers also remains fairly constant at 69% to 31%. However, there is a decline in market share for urea from 17.2% to 15%, an increase in AA from 35.4% to 38%, an increase in UAN from 20.4% to 22%, and a slight fall in AN from 5.4% to 5%.

In the author's opinion the estimated market share for AA is too high. There would have to be a considerable increase in distribution investment to achieve this increase. It is more likely that UAN and AN will increase in market share to probably 24% and 7%, respectively, for the reasons discussed above. The year 2020 is a long time ahead and obviously many variables, market shocks, technology developments, and policies will intervene to alter the outcome. However, the future role of AN and especially UAN is assured in the U.S. market.

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Table 1. World: Nitrogen Fertilizer Use by Regions, 1959/60-1994/95

Year	North America	Western Europe	Eastern Europe	FSU	Oceania	Africa	Latin America	Asia	World
	(million nutrient mt)								
1959/60	2.55	3.26	0.60	0.71	0.03	0.22	0.29	1.87	9.54
1989/90	11.25	11.17	4.56	9.92	0.50	2.04	3.80	35.91	79.14
1994/95	11.94	9.78	2.03	2.80	0.72	2.02	3.96	40.35	73.60

Source: FAO, 1996 [6].

Table 2. World: N Fertilizer Use by Products and Regions, 1993/94

Product	World	North America	Western Europe	Eastern Europe	Eurasia	Oceania	Africa	Latin America	Asia
	(% shares in total)								
Ammonia Based	**75.1**	**68.6**	**33.3**	**33.6**	**42.5**	**86.8**	**53.8**	**85.4**	**93.0**
Ammonium sulfate	3.3	1.8	2.6	3.7	4.5	1.7	3.8	14.3	2.7
Urea	41.2	17.2	13.1	21.5	18.8	43.2	32.7	50.6	60.0
Ammonia	6.9	35.4	0.4	0.0	4.7	7.9	0.3	6.8	0.1
Ammonium phosphate	4.2	5.9	0.0	0.5	4.0	19.2	3.4	6.9	4.5
NPs	1.8	0.3	2.1	5.1	8.0	6.3	0.8	0.2	1.6
NPKs	5.1	7.2	13.8	2.7	1.3	8.5	11.6	4.4	2.4
Other N	12.5	0.9	1.3	0.0	1.2	0.0	1.2	2.3	21.7
Nitrate Based	**24.9**	**31.4**	**66.7**	**66.4**	**57.5**	**13.2**	**46.2**	**14.6**	**7.0**
Ammonium nitrate	9.1	5.4	17.5	43.5	43.1	2.4	27.4	7.1	2.0
CAN	5.2	0.1	28.2	14.5	2.4	0.6	7.7	1.5	1.7
N solutions	5.2	20.4	9.3	3.2	4.7	0.2	09.0	0.0	0.1
NPs	1.2	0.2	1.4	3.4	5.3	4.2	0.5	0.1	1.1
NPKs	3.4	4.8	9.2	1.8	0.8	5.7	7.8	2.9	1.6
NKs	0.0	0.0	0.0	0.0	0.0	0.2	0.6	0.4	0.0
Other N	0.8	0.5	1.1	0.0	1.2	0.0	2.2	2.6	0.5
Total N	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Note: Due to rounding, totals may not add.
Source: Derived from IFA data, 1994 [7].

Table 3. U.S. Consumption of Nitrogen

	1980	1985	1990	1991	1992	1993	1994	1995	1996
United States	(million nutrient mt)								
Total N	10.3	10.4	10.0	10.2	10.4	10.3	11.5	10.6	11.1
Anhydrous ammonia	4.1	4.0	3.4	3.8	3.7	3.2	4.1	3.2	3.6
UAN	1.7	2.2	2.1	2.0	2.1	2.3	2.4	2.5	2.6
Urea	0.9	1.1	1.6	1.4	1.5	1.6	1.7	1.7	1.6
Ammonium nitrate	0.8	0.7	0.5	0.6	0.6	0.6	0.6	0.6	0.6
Ammonium sulfate	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Other straight and mixed N	2.7	2.3	2.3	2.3	2.3	2.4	2.5	2.4	2.5

Source: Commercial Fertilizers, various annual issues.

Table 4. Estimates of Nitrogen Use in the United States

Product	Fiscal year 1991	1992	1993	1994	1995	1996
	(million mt of N)					
Ammonium nitrate (high density)[a,b]	0.826	0.851	0.888	0.862	0.920	0.890
Urea-ammonium nitrate solution[a]	2.465	2.522	2.808	2.746	2.828	2.992
Other nitrates[c,d]	0.023	0.024	0.028	0.026	0.028	0.045
Total nitrates (includes urea of UAN)	3.314	3.397	3.724	3.684	3.776	3.927
Anhydrous ammonia (gas)[d]	3.769	3.723	3.260	4.121	3.237	3.593
Urea[d]	2.537	2.415	2.797	3.226	3.027	2.955
Ammonium sulfate[d]	0.294	0.349	0.327	0.431	0.434	0.423
Total ammonium-based N	6.600	6.489	6.384	7.778	6.698	7.020
Total N[d,e]	10.239	10.384	10.335	11.469	10.631	11.110

a. Estimates based on U.S. Dept. of Commerce annual production and trade data, adjusted by discussion with industry analysts.
b. High-density AN is assumed for fertilizer; low-density AN is assumed for explosives and is not included here.
c. Other nitrates include $CaNO_3$ (15% N), KNO_3 (14% N), $NaNO_3$ (16% N), and $KNaNO_3$ (15% N).
d. Estimates taken from annual issues of Commercial Fertilizers, 1991-96.
e. Total nitrogen estimates include all of the above plus N in other nitrogen products, ammonium phosphates, homogeneous mixtures, and other.

Table 5. U.S. Fertilizer Consumption

	1991	1992	1993	1994	1995	1996[b]
	(million mt N)					
Consumption						
Ammonium nitrate (low density)[a]	0.00	0.00	0.00	0.00	0.00	0.00
Ammonium nitrate (high density)[b]	0.83	0.85	0.89	0.86	0.92	0.90
Urea-ammonium nitrate solution[b]	2.46	2.52	2.81	2.75	2.83	2.99
Calcium nitrate[c]	0.00	0.00	0.00	0.00	0.00	0.00
Sodium nitrate[c]	0.01	0.02	0.02	0.02	0.02	0.01
Potassium nitrate[c]	0.01	0.01	0.02	0.01	0.01	0.02
Sodium potassium nitrate[c]	0.01	0.01	0.01	0.01	0.00	0.01
Homogeneous compounds (nitrate based)[c]	0.02	0.03	0.03	0.05	0.02	0.02
Total Nitrate-Based N (Includes Urea of UAN)	**3.33**	**3.44**	**3.77**	**3.70**	**3.81**	**3.93**
Anhydrous ammonia direct application[d]	3.88	3.78	3.26	4.20	3.30	3.66
Urea[d]	2.54	2.42	2.80	3.23	3.03	2.96
Ammonium sulfate[d]	0.29	0.35	0.33	0.43	0.43	0.42
Other nitrogen fertilizers[c]	0.01	0.01	0.01	0.01	0.01	0.04
Diammonium phosphate[d]	0.56	0.56	0.61	0.62	0.60	0.60
Monoammonium phosphate[d]	0.10	0.10	0.12	0.12	0.14	0.18
Fluid NP[d]	0.13	0.13	0.14	0.14	0.14	0.14
Homogeneous compounds (ammonia based)[c]	0.11	0.11	0.10	0.08	0.11	0.09
Total Ammonium-Based N	**7.63**	**7.45**	**7.36**	**8.83**	**7.76**	**8.09**
Total Fertilizer N Consumption[e]	**10.96**	**10.89**	**11.13**	**12.53**	**11.57**	**12.02**

a. Data not researched.

b. Derived from Commercial Fertilizers, 1991-96, and industry analysts data.

c. Apparent consumption (Production + Imports - Exports).

d. Source: Commercial Fertilizers, 1991-96.

e. Estimate 6% to 8% higher than reported in Commercial Fertilizers, 1996 due to differing data sources and reporting periods.

Table 6. U.S. Development of Conservation Tillage

Year	Total Cultivation	Conservation Tillage	No Till	Ridge Till	Mulch Till	% Conservation Tillage
	(million acres)					
1970	297.4	10.0				3%
1971	312.5	11.0				4%
1972	301.7	12.0				4%
1973	323.7	15.0				5%
1974	331.5	17.0				5%
1975	337.1	18.0				5%
1976	345.1	20.0				6%
1977	353.0	24.0				7%
1978	346.6	31.0				9%
1979	355.1	33.0				9%
1980	362.8	39.0				11%
1981	371.4	43.0				12%
1982	367.5	45.8				12%
1983	325.1	48.9				15%
1984	358.3	52.1				15%
1985	353.0	55.5				16%
1986	338.2	59.2				18%
1987	315.3	63.1				20%
1988	318.0	67.3				21%
1989	331.2	71.7	14.1	2.7	54.9	22%
1990	326.3	73.2	16.9	3.0	53.3	22%
1991	325.4	79.2	20.6	3.3	55.3	24%
1992	326.5	88.7	28.1	3.3	57.3	27%
1993	319.6	97.2	34.8	3.5	58.9	30%
1994	324.0	99.3	39.0	3.5	56.8	31%
1995	318.5	98.9	40.9	3.4	54.6	31%
1996	334.4	103.8	42.9	3.4	57.5	31%

Table 7. IFDC Estimates of Global and North America Nitrogen Product Mix

	IFA Data		IFDC Estimate		Author Estimate	
	World	North America	World	North America	World	North America
Year	1994/95		2020		2020	
Total Nitrogen (million mt N)	73.6	11.94	163	16.6	163	16.6
Products	(% in total)					
Ammonia Based	**75.1**	**68.6**	**75.0**	**69.0**	**75.0**	**66.0**
Ammonium sulfate	3.3	1.8	4.0	2.0	4.0	2.0
Urea	41.2	17.2	46.0	15.0	15.0	15.0
Ammonia	6.9	35.4	7.0	38.0	7.0	35.0
Ammonium phosphates	4.2	5.9	8.0	7.0	8.0	7.0
Others	19.4	8.4	10.0	7.0	10.0	7.0
Nitrate Based	**24.9**	**31.4**	**25.0**	**31.0**	**25.0**	**34.1**
Ammonium nitrate	9.1	5.4	10.0	5.0	10.0	6.0
Calcium ammonium nitrate	5.2	0.1	5.0	0.1	5.0	0.1
N solutions	5.2	20.4	5.0	22.0	5.0	24.0
Others	5.4	5.5	5.0	4.0	5.0	4.0

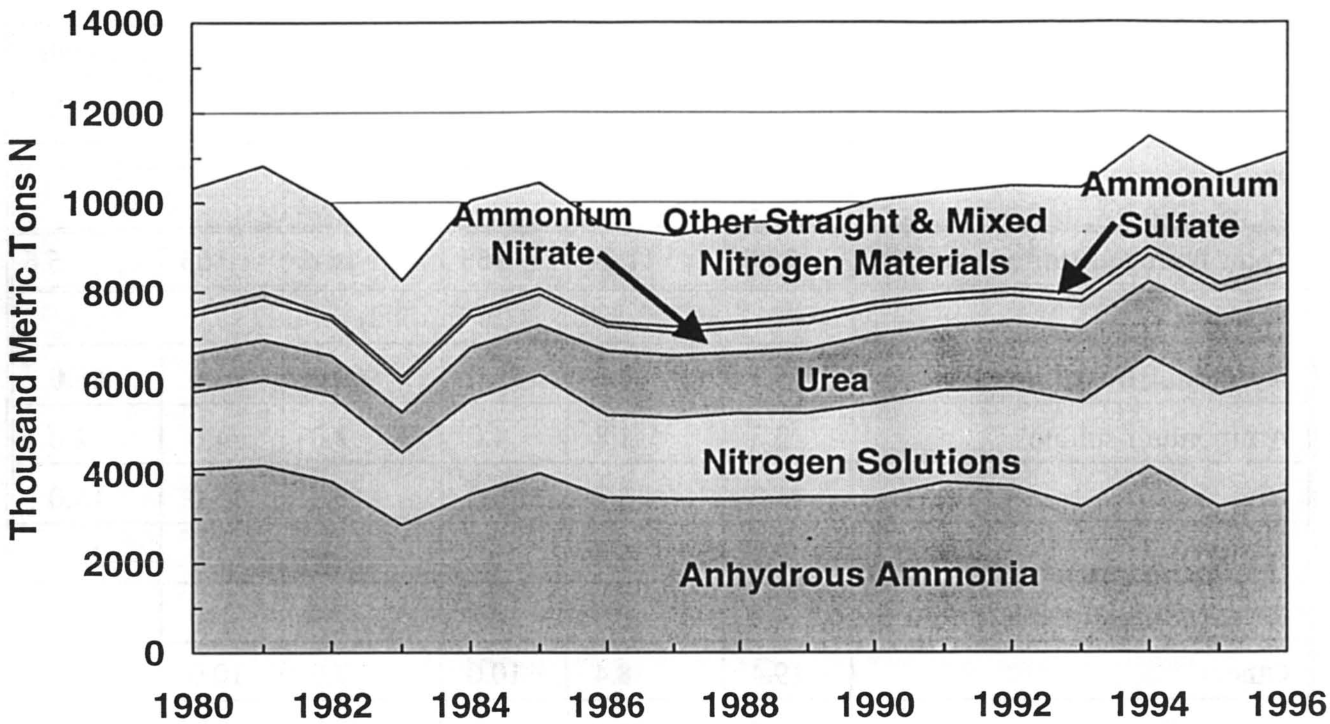


Figure 1. U.S. Nitrogen Consumption by Product

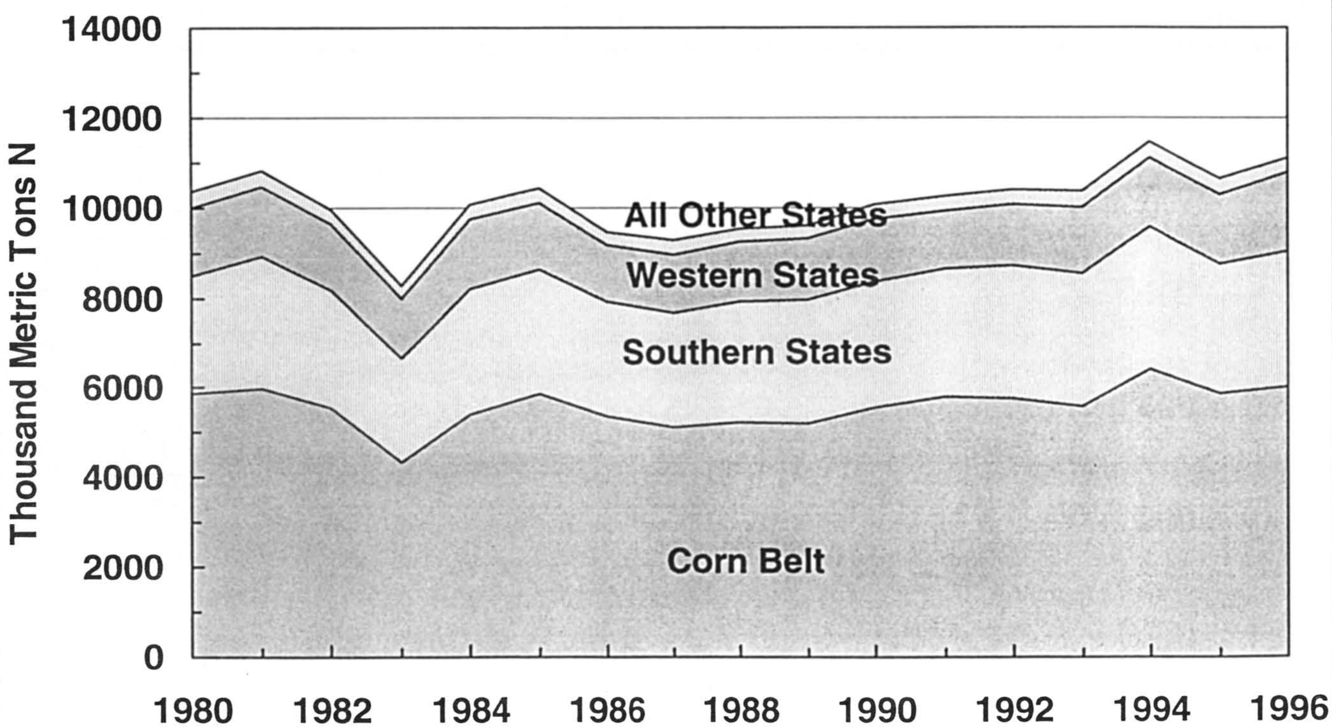


Figure 2. U.S. Nitrogen Consumption by Region

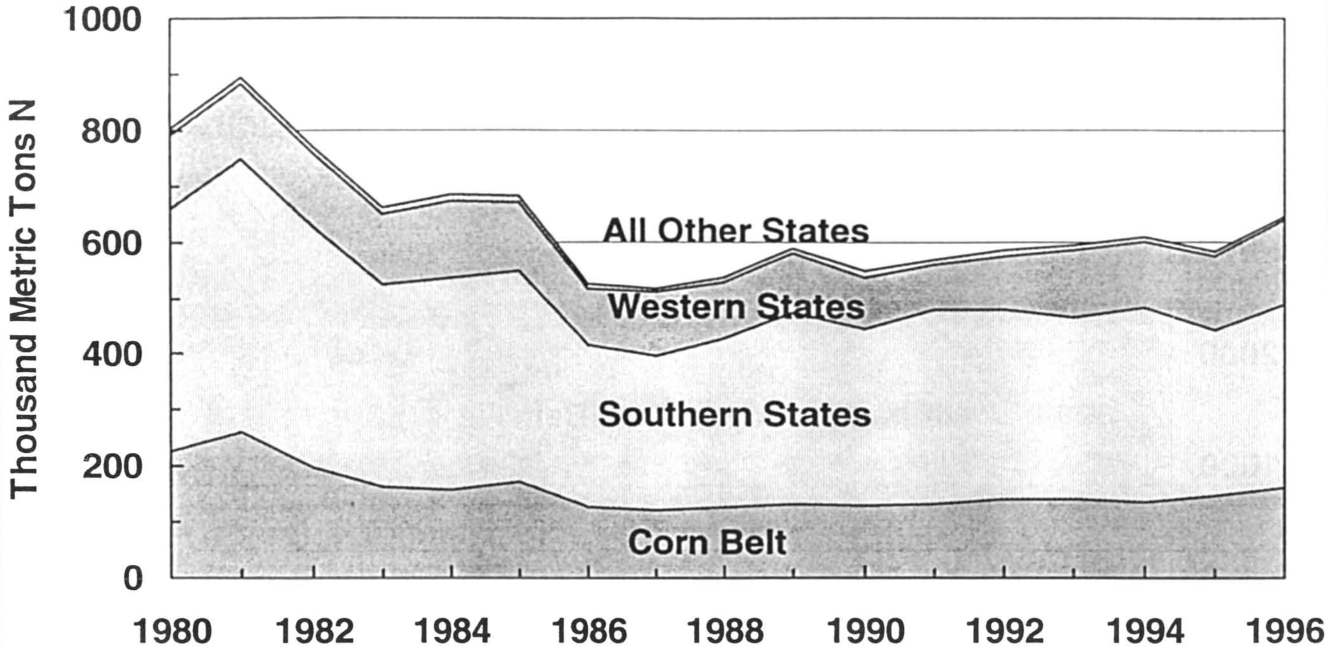


Figure 3. U.S. Consumption of Ammonium Nitrate by Region

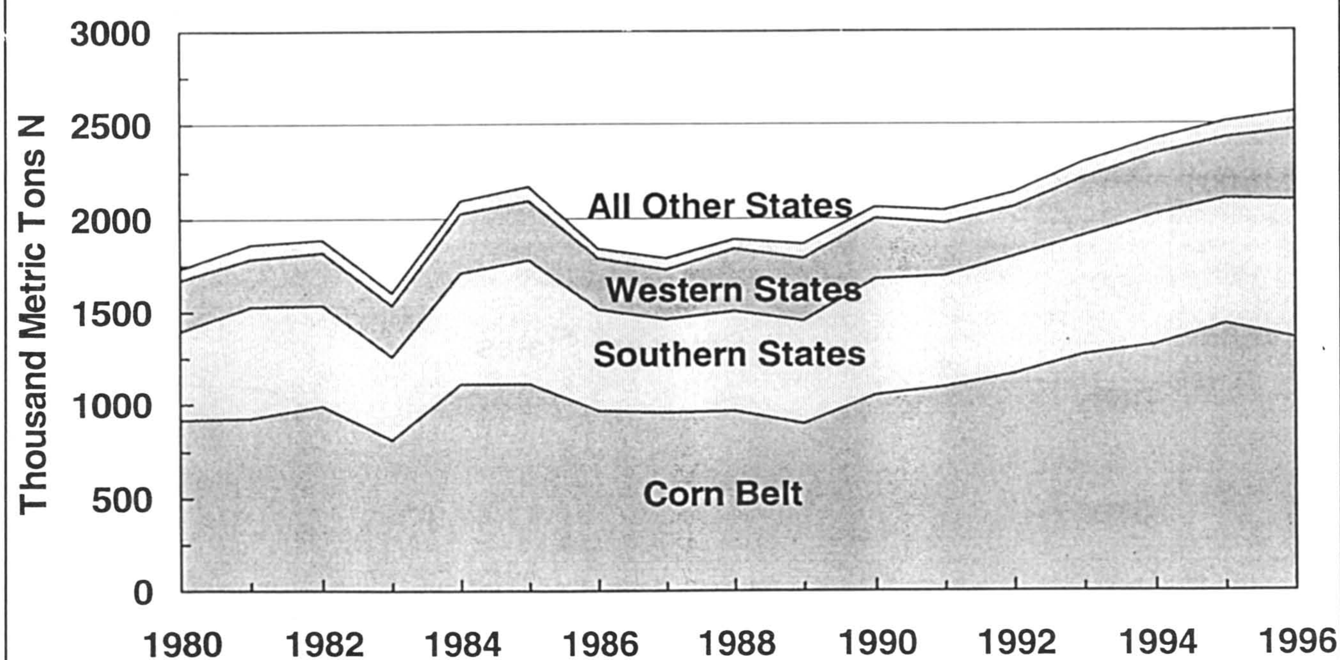


Figure 4. U.S. Consumption of UAN Solution by Region

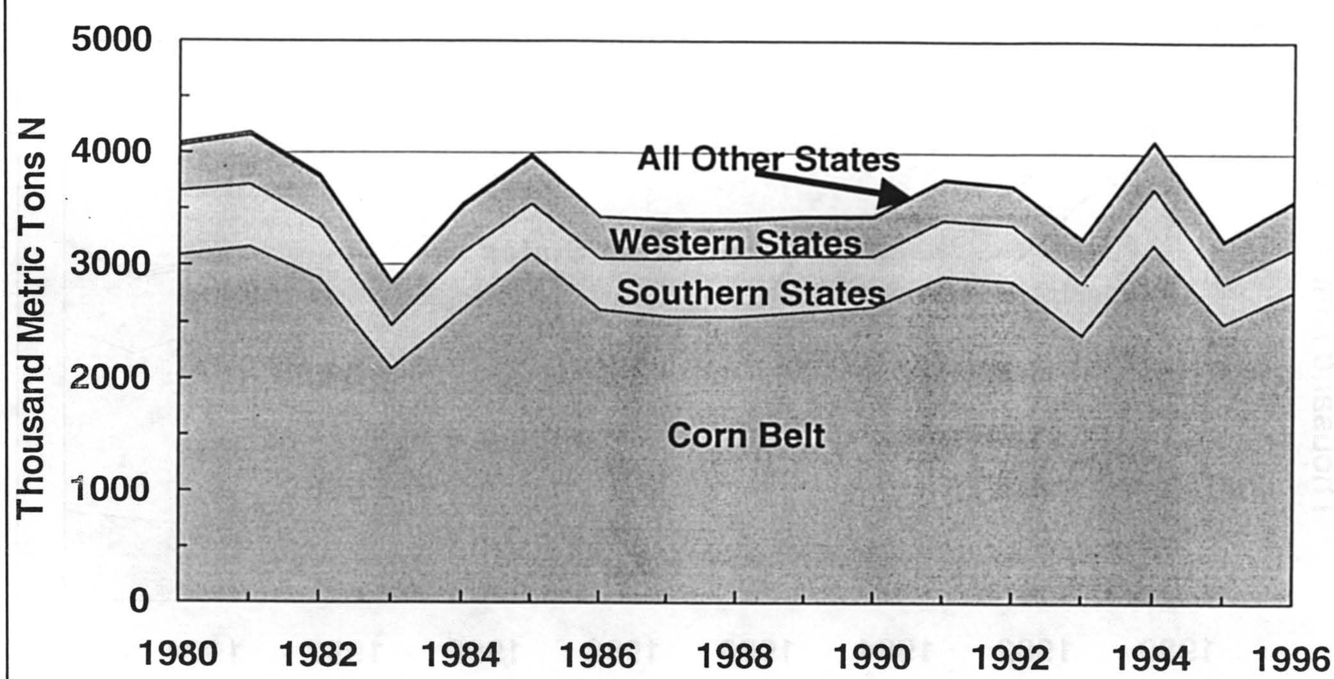


Figure 5. U.S. Consumption of Anhydrous Ammonia by Region

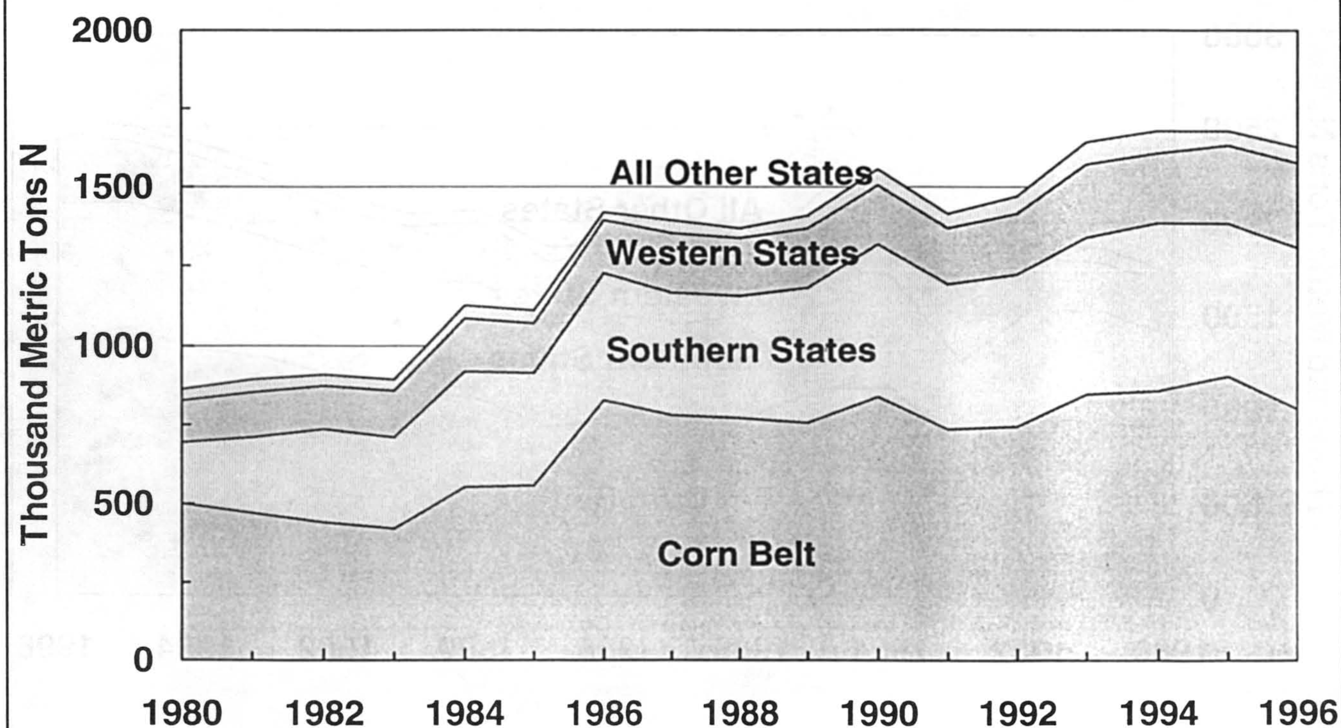


Figure 6. U.S.Consumption of Urea by Region

Who Questions the Effect of Micro-Nutrients

Fred T. "Skip" Heasley

Sims Ag-Products

There has been considerable discussion and serious debate over the effect of micronutrients on crop yields and reflections on yield enhancement. The discussion and reflection centers around types of sales approaches, those that are familiar with the use of micronutrients in a balanced fertility program and those that lack the knowledge to address micronutrient use. This lack of knowledge is most apparent in technical areas such as formulations, plant needs, timing of application, soil test interpretation and the failure to recognize yield enhancement through balanced nutrition concepts.

Historical Nutrient Usage

Soil and plant nutrition demands are ever changing due to the constant influence of new genetics on today's production agriculture. To understand these changes, let us review a short history of the use of nutrients.

Fertility actually began on a large scale in the 1930's with the use of limestone and low analysis fertilizers. Many row spacings were forty two inches wide, the width needed for horses to travel. The planting population was still in the 10,000 plants per acre range, though hybrids were making thier introduction into production. Today the rows are 30 inches wide and the plant population can exceed 30,000 plants per acre. Multiple crop rotations were used to facilitate nitrogen needs and to allow for manure applications on support crops. In the Cornbelt, cereal grains and legumes no longer have economic influence in the market. Today's crop rotation is either Corn-Corn-Soybeans or Corn-Soybeans.

More modern methods of tillage have changed the soil environment of elements. Notill, and Minimum tillage practices have created a need for a balanced fertility environment in the top three to four inches of the soil. Ninety-six percent of a plant's growth is determined in the top three to four inches. With increased plant population and accuracy of spacing, the soil environment has changed from a 6"-10" plow layer profile to a shallower, 4" median that supports three times the plants than in the past. (See Schematic 1.)

Planting dates with new hybrid vigor has created a challenge to growers to plant earlier than ever before. The Cornbelt date for planting in the early years was May 10 th . Planting dates now are three weeks earlier. Hybrids must be adjusted in vigor to compensate for cool soils and the 1800 diseases and insects that can infest a plant put under early environmental stress. A balanced median between growth and nutrient availability is critical at the seedling stage, and for extended availability during the completion of the growth cycle.

Biogenetics is rapidly gaining a foothold in the United States, with 22 million seed acres in 1997. This total includes corn, cotton, alfalfa and soybeans. Many more crops are in the testing stage and will be introduced in the next two years. Fertility support of the biogenetic crops is essential to insure plant health and soil health. Many questions are being asked about yield drag, lack of vigor, slow root development, etc. Balanced fertility becomes ever more important to support such genetically enhanced material.

Elemental Review

Crop fertility has stagnated in the last decade. Recommendations have been based on charts developed in the 40's and 50's, which have only been modified by plants per acre. Most charts are based on averages, rather than high yield or high fertility environments. Also, micronutrients have been overlooked because of the limited amount of research on specific elements. Much of this data was generated in the 1960's and has not been scientifically investigated since. This means the soil environment and genetics have changed but fertility has failed to follow the same path. Is it time for new nutrient strategies in fertility? The answer is, "Yes!" and a total bundling concept needs to be put together.

Companies and dealers must recognize and become educated to the fact that there are 16 essential elements that play a role in production agriculture. Three of these are gases: Carbon, Hydrogen and Oxygen, which are controlled and regulated by soil texture and tilth of the soil. Compacted soils will have a huge limiting factor for production because of the lack of Carbon, Hydrogen and Oxygen. (See Table 1.)

The remaining thirteen elements are either mined for application to the soil, or recycled for use. These are categorized by the amounts a plant will need in the growing season. These factors were determined by per cent dry matter in the plant when harvested, and do not reflect growing season need.

Soil nutrition must have the elements in the available form for diffusion, mass flow or root interception to function with the plants physiological growth pattern. Availability throughout the growing season is critical for maximum economic yield.

Why Have Micronutrients Begun to Appear as Deficient?

New testing procedures for micronutrients, both in the soil and through tissue analysis,have become available in the past ten years. In the past, such tests were a lengthy process, and somewhat unreliable. Today, modern laboratories test for micronutrients with an assortment of machines which give up to 98 percent accuracy of results. The cost of the tests are considerably less when taken for analysis in volume.

Yields of all crops in the last twenty years have doubled, thus creating a need two times greater than what was previously recommended. Micronutrient removal, however, is not in direct proportion to the macro and secondary elements. Each micronutrient has a specific behavior in the plant and the soil. For example, Manganese levels are difficult to manage when the element is testing as deficient in the soil. The element is highly mobile and would be very difficult to build, while the element Zinc is highly immobile in the soil, and can be built to an acceptable soil test level. Crops removing high amounts of elements due to yield or fodder removal quickly deplete the productivity of soil over a short period of time. The first forty years of fertility have not focused on micronutrient testing, leading to the recent appearance of deficiencies.

Soil texture and organic matter are native soil formation characteristics that cannot be manipulated. Soils containing a higher content of organic matter can tie-up micronutrients in the soil colloids, while sand-textured soils cannot hold micronutrients. The same is true for other elements.

We must also be aware that farming practices that slow root growth and development can affect availability to the plant. Early planting into cool damp soils has inhibited timely nutrient uptake. Although planting dates become earlier with new hybrid vigors, the soil microorganisms are not readily active until the soil temperature reaches 55 to 60 degrees Fahrenheit . Many corn plants are planted at a soil temperature of 48-50 degrees Fahrenheit. Nutrient availability by the process of diffusion and mass flow will be severely limited if a pool of the element is not present.

Tillage practices have actually created a stratification of the elements due to a lack of soil agitation or mixing of the top six inches. Elements which are classified as highly mobile saturate a soil profile over a period of time. Elements of immobile chemistry remain where they are applied until moved by erosion, water or mechanical means. Because of this, notill and repeated shallow tillage can affect the availability of elements.

Weather-related factors affect all elements in the soil. Deficiency can occur in a drought as easily as in a flooded crop environment. Lack of soil moisture creates high degrees of tenacity for elements held by soil colloids, making removal of elements from the soil difficult, while flooded micro and macro pores prevent oxidation, often creating an iron shortage.

Soil pH has long been associated with the availability of all elements. A very high pH of 7 or above limits the amount of elements available to the plant. The same is for a pH of 6.0 or less. Soils with native pH's that are economically non-correctable need balanced nutrition more readily that soils with a pH of 6.0 to 7.0. Michigan growers have long recognized the need for balanced nutrition of all the elements because of their native pH's. Many soils pose problems because they have been overlimed, and have a wide range of pH during the growing season. (See Table 2.)

The number of exchange sites on the clay colloids is very important to the availability of the element itself. Soils with textures high in montmorrillinite clays have twice the number of exchange sites as soils high in kalinite clays. The number of exchange sites determines the amount of the elements needed to grow a crop in a normal weather environment. Micronutrients are needed at all sites like the macro elements. New data is surfacing showing that the addition of pelleted lime and micronutrients make an excellent bundling package.

Data Supports New Philosophies in Intense Cropping Environments

(See Schematic 2.) We at Sims Ag Company began an intense research evaluation into micronutrient formulations and usages in various cropping situations in 1993. Four years of replicated data from across the United States is giving new focus to formulation use and elemental status. Mix formulations bundled with racehorse genetics and the macro elements are producing economical advantages to field corn, soybeans, wheat, barley, rye, triticale, green beans, strawberries, sweet corn, popcorn, grain sorghum, sunflowers, tomatoes, potatoes, lima beans, alfalfa, pasture mixes, cucumbers, edible beans and bell peppers.

Plant health is being achieved by focusing on the soil test, along with plant growth physiology, light units for photosynthesis and pH. These achievements produce more fruit per plant. All testing was conducted in a replicated randomized complete block under good laboratory field practices. Crop varieties were kept the same each year in order not to vary the genetics, which could reflect a variable into the experiments. Crops were specifically selected for the area to enhance the environmental effect upon the crop itself. The year 1994 produced record corn and soybean yields at some of the test sites. Years 1995 and 1996 produced average yields in a very late growing season. 1997 has been a year of above average growing conditions with a slight shortage of growing degree days in the months of June and July. All sites were irrigated as needed.

The following is a consolidation of the results achieved with a number of crops under test. (See Tables 3 – 5.)

Summary

Nutrient management planning is a major component of any agronomy program. The past decade has seen added focus on the use of a bundled program of elements, rather than the basics of N, P, and K. Taking the grower to the next step in such a program requires careful planning and management. Agronomic data must be present for economic decisions to be made concerning a fertility program that will maintain a soil test, enhance yield and not pollute the environment.

The impact of Biogenetics is bringing a focus to developing more yield management strategies rather than herbicide and pesticide application revenues. Data generated in the past four years from across the United States are giving indications of the economic advantages of using bundling concepts.

The investigation of formulations has shed new light on the release of microelements in the soil. The early adopter stage is being tested now . The use of micronutrients is gaining a new emphasis for the fertilizer industry. With the development of new testing procedures and new abilities to analyze soil tests in 1-acre grids, the need for a more research in the bundling of elements, will lead to a new era of soil and plant fertility.

Schematic 1.

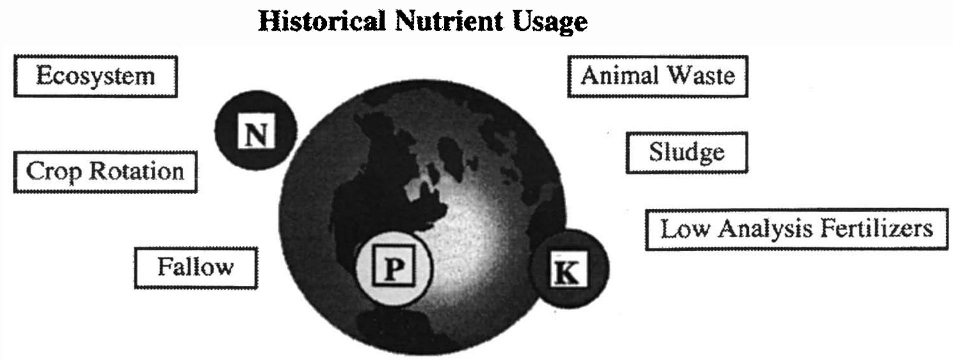
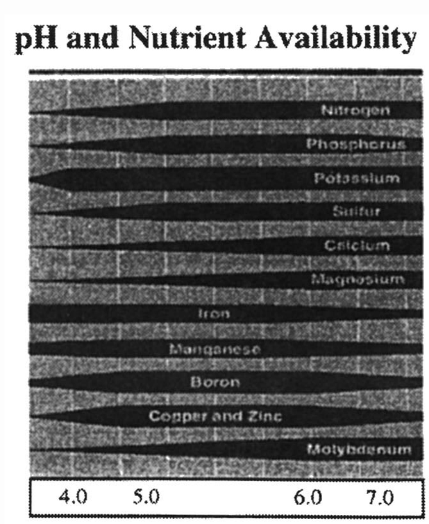


Table 1. Elements required for normal growth of crop plants and their typical levels as percent of dry matter.

Element	Chemical Symbol	Percent of dry matter
Oxygen	O	45
Carbon	C	45
Hydrogen	H	6
Nitrogen	N	1.5
Potassium	K	1.0
Calcium	Ca	0.5
Magnesium	Mg	0.2
Phosphorus	P	0.2
Sulfur	S	0.1
Chlorine	Cl	0.01
Iron	Fe	0.01
Manganese	Mn	0.005
Boron	B	0.002
Zinc	Zn	0.002
Copper	Cu	0.0005
Molybdenum	Mo	0.00001

Source: NFSA

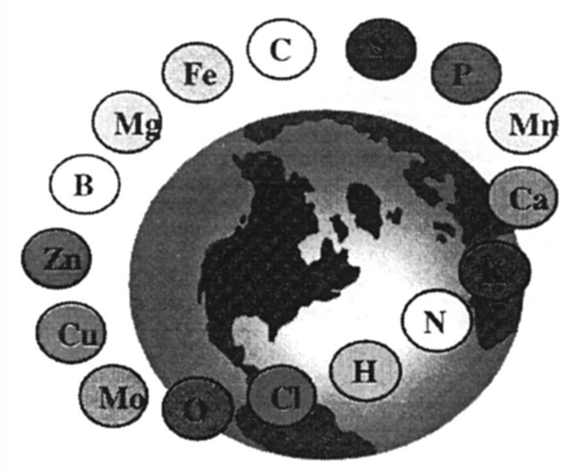
Table 2. Available Nutrients in Relation to pH.



Source: Phosphate & Potash Institute

Schematic 2.

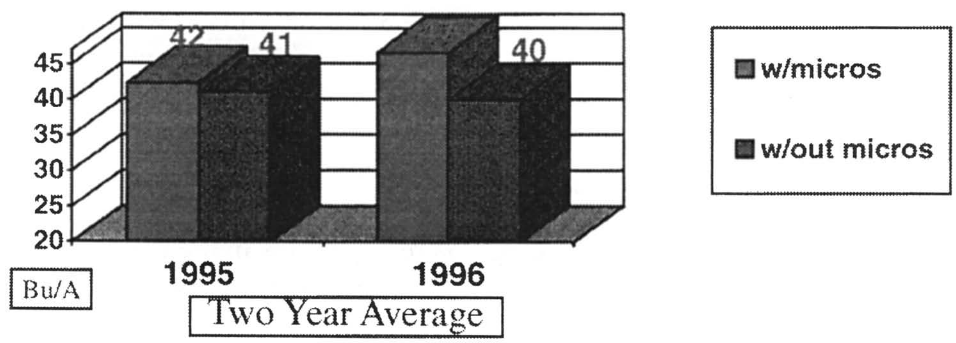
16 Essential Elements



Source: Global Micronutrient Institute

Table 3.

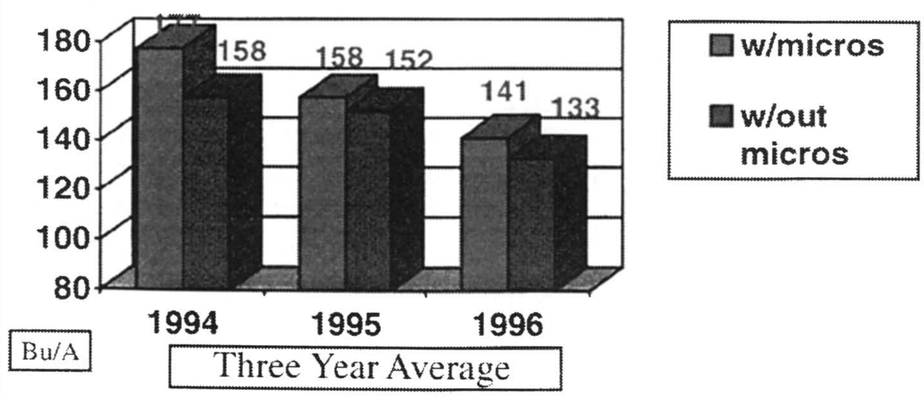
Soybeans



Source: Arise Research & Discovery, Inc.

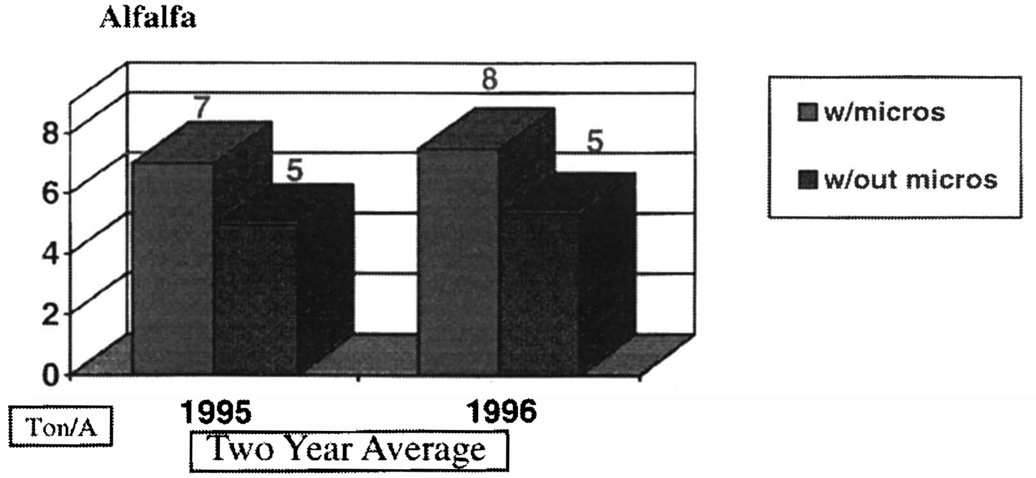
Table 4.

Field Corn



Source: Arise Research & Discovery, Inc.

Table 5.



Source: Arise Research & Discovery, Inc.

Environmental Aspects of Fertilizer Use in Agriculture

David W. Dibb and Bob C. Darst

Potash and Phosphate Institute

An adequate food supply is fundamental to human survival; therefore, maintaining...and improving...per capita food production is a continuing challenge facing world agriculture. How imposing is this challenge? According to former Secretary of the U.S. Department of Agriculture (USDA), Orville Freeman, "In the next two to four generations, world agriculture will be called upon to produce as much food as has been produced in its 12,000 year history."

That observation, even if Secretary Freeman was a few million tons off in his assessment, means that agriculture must continue to increase food production per unit of land if it is to feed a growing world population. Further, that production must be managed so that it can be sustained from one generation to the next as world population finally begins to stabilize and as the land base available for agricultural production continues to decline worldwide. And, it must be done in the face of growing environmental concerns with agriculture—whether real or imagined.

Although the rate of increase in world population is showing signs of slowing down, the number of people inhabiting the earth is still increasing at the rate of about 80 million people per year or about 220,000 per day. The current population of 5.8 billion will grow to more than 6.0 billion before the end of this century. Projecting to the year 2025, world population could well exceed 8 billion people. Some projections suggest that population will stabilize at around 10 billion people by the end of the next century...or, if the slowdown is real, perhaps in the eight to nine billion range.

There are those who believe the world cannot sustain the demands placed upon it by 10 billion people. One of the reasons is that about 90 percent of the population growth is occurring in those countries where food shortages already exist and where more than a billion people already live in poverty.

Further complicating the challenge world agriculture faces are the demands for more calories and more diverse diets as economies improve. For instance, in China meat consumption has tripled in the last 15 years. Each person in that country ate 58 percent more pork last year than in 1990. In greater Asia, consumption of beef, chicken and pork jumped by 59 percent in the last 10 years. Such trends are expected to continue into the next century and will place increasingly greater demands on the world's grain farmers. Why? Because it takes about 2 pounds of cereal grain to produce

1 pound of poultry, 3 pounds of grain per pound of pork and 7 pounds of grain per pound of beef.

In some of the developing world, the pressures of industrialization and urbanization are placing additional pressures on agriculture because of competition for land. China again is a high profile example. With about 22 percent of the world's population, nearly 1.2 billion people, China has only about eight percent of the world's arable land... recently increased to 320 million acres. That figures out to about 0.25 acres per person. And, it is estimated that China has been losing more than 850,000 acres of arable land per year to industrial and urban invasion.

Land loss to urbanization and industrialization is of major concern in the U.S. as well. According to a report from American Farmland Trust, during the period 1982-1992, approximately 4.3 million acres of farmland classified as 'prime' and 'unique' were displaced by development in this country (land used for urban development grew by 26 percent).That is about 50 acres lost every hour of every day. Most of the loss was scattered urban development near major metropolitan areas.

The report also notes that high quality farmland is projected to shrink by 13 percent by the middle of the next century and, within that period of time, the nation could become a net importer of some foods where we are now a net exporter. For instance, 79 percent of this nation's fruit, 69 percent of its vegetables and 52 percent of its dairy goods are now produced on high quality farmland threatened by sprawling growth.

We all know that population growth and arable land are on a collision course, as shown in the table below. Between 1965 and 1990, arable land per person shrank from 1.14 acres to 0.74 acres and is projected to drop to 0.49 acres by the year 2025. If world farmers are to continue to feed the people, they must grow more crops per acre and do it in a sustainable way. Proper crop fertilization is a key to that happening.

The relationship between optimum fertilization and increased crop yields has been documented many times through research. Some contend that higher yields and "modern agriculture" inevitably put our environment at greater risk. The fact is, however, that when properly managed, those higher yields result in increased fertilizer efficiency and greater environmental protection as well. Let's just cite a few examples. In a 1997 Maryland study involving intensive wheat production, the highest yield, 151 bushels per acre, was produced with the highest nitrogen (N) rate. It was also the yield at which N efficiency was highest, 1.07 bushels of wheat per pound of N applied. That compared to the next best intensively managed treatment, with an N efficiency of 0.77 bushel of wheat per pound of N.

In sub-Saharan Africa, 60 percent of the population lives below the poverty level. During the past 30 years, Africa's population has been growing at a rate of more than 3 percent per year while food production is growing at only 2 percent. On average, a child dies every 3 seconds from hunger. Soil erosion and degradation from nutrient mining and other non-sustainable management practices can violently...and permanently...scar the landscape in a matter of four or five years. The outlook is not bright without significant changes in the methods used to produce food.

Traditional agriculture in Africa has been slash and burn...use the land until it no longer produces, then move on to other locations. Livestock overgrazing exposes the topsoil to erosion. Because of a scarcity of land, farmers are now being forced to stay put...farm land that has been depleted of its nutrients, is now infertile and easily eroded. Still others are moving back to even more marginal land, sloping land that is low in fertility and where destructive erosion is a problem. This example, perhaps one of the most graphic indicators of environmental damage, shows the rapid devastation that can occur when modern farming methods and needed nutrient inputs are not applied. It has been shown, by work sponsored by the Sasakawa Foundation in eight sub-Saharan African countries over the last 10 years and led by Norman Borlaug, that proper fertilizer use along with hybrid seed could double, triple or even quadruple grain yields while stabilizing the soil against erosion. Yet, even with this possibility, Dr. Borlaug expresses pessimism for this area of the world because of political barriers that exist. He says, "I doubt that I will live to see a Green Revolution in sub-Saharan Africa, even though the ingredients that are required for such a revolution are already available. The ingredient that is most lacking now to trigger a revolution in agricultural production is the political will of several African leaders to make it happen.

Togo is an African country that mines and exports about 3 million tons of phosphate rock annually. There are vast deposits of phosphate in that country. Many of the adjacent African countries have soils that either naturally or through decades of nutrient mining are severely deficient in P. Yet, phosphate 'fines' from 'P production' are often disposed of by dumping them into the ocean rather than applying them to deficient agricultural land. Government policy and economics can have a tremendous effect on nutrient use and thus on the environment. In Ghana, currency devaluation and removal of subsidies make fertilizers too expensive for most farmers to buy. Less than one-fourth of the fertilizer used in the 1980s is being applied today. At one time, fertilizer subsidies were about 45 percent in Ghana and 75 percent in Tanzania.

In August of 1992, the government of India, for various reasons, decontrolled and removed subsidies on phosphorus (P) and potassium (K) fertilizers, while lowering the controlled price of urea by 10 percent. That action was taken in spite of the fact that soil test surveys had shown tremendous needs for additional P and K use in India. (For example, about 98 percent of India's agricultural soils test low to medium in P fertility; 66 percent low to medium in K fertility.) The result of the policy change was a drastic reduction in the consumption of P and K, which further restricted Indian farmers from growing food efficiently. It reduced nitrogen use efficiency and increased the potential for nitrate pollution of ground water...a negative for the environment. Part of this mistake has since been partially corrected but some of the damage continues.

China is another country where there has been tremendous imbalance between N and P and K fertilization. The result was a declining response to N fertilization and lost yield potential. Fortunately, the Chinese government recognized the problem and recently made a policy decision to achieve improved NPK balance to increase crop production per unit of land and, at the same time, increase the efficiency of input use, namely N in this case. This is positive for the environment and for more efficient food production.

Environmental groups around the world, including those in North America, continue to push for more influence in the development of agricultural policy and the use of land for food production. Changes in the way the U.S. Farm Bill has been formulated during the past 50 years illustrate the point well. In 1940, only a dozen or so groups were involved in writing the Bill; in 1990 more than 250 organizations had input. Much of the outside interest has been spurred by concerns for nutrient management and its possible impact on the environment; more specifically, nitrogen and phosphorus being applied in commercially produced fertilizers.

While appropriate concerns for and protection of the environment are critical to the proper use of fertilizer, world farmers should not be encumbered with restrictions and regulations which are unfounded and undercut sound crop production management practices. Beyond such constraints as these, however, are those instances when persons with a specific agenda say or infer things that are misleading or simply not true. Let me cite you an example.

In the Winter, 1997, issue of the *WSAA NEWSLETTER*, J. Patrick Madden, President of WSAA (World Sustainable Agriculture Association), said, "Healthy soil is the foundation of a healthy society. Just like a healthy person who rarely if ever needs medicine, healthy soil rarely if ever needs synthetic chemical pesticides and fertilizers." Such statements from those in positions of influence, such as Dr. Madden, are not responsible and, indeed, will result in further world hunger if believed.

In fact, more appropriately stated, healthy soils...those capable of producing a sufficient food supply for the world's population...just like healthy people...cannot exist without proper nutrition. Mineral fertilizers are food for soils. Does Dr. Madden believe a person can be healthy without proper nutrition? Of course not. He also should know that soils cannot continue to support economic crop production without the replacement of plant nutrients that are harvested in food crops.

Great progress has been made in growing food for an expanding world population during the last half-century. In the U.S., for example, production of major crops in 1940 totaled about 275 million tons on 320 million acres of land. By the 1990s, American farmers were annually harvesting 660 million tons on 25 million fewer acres. If U.S. farmers had attempted to produce the 1990 crop with 1940 technology, an additional 470 million acres of land of similar productivity potential would have been required.

Before corn hybridization, farm mechanization, and the widespread use of commercially produced fertilizers and pesticides, farming in the U.S. was characterized by heavy...often backbreaking...labor requirements, low crop yields, and disease and pest infested grains, fruits and vegetables. A large segment of the population was, out of necessity, involved in food and fiber production. In 1940, there was one farm for every 15 people. The average farm produced enough food for only about 20 people, compared to producing enough food for more than 120 today.

The sustainability of U.S. agriculture is demonstrated in the record of increasing per-acre crop yields, the adoption of agronomic and conservation best management practices (BMPs), and the increasing crop use efficiency of fertilizers and pesticides that have taken place during the past 50 years, as shown below.

- Corn and peanut yields have almost quadrupled. Data in the figures below show corn and soybean yield trends, taken as 3-year averages to smooth out the effects of climate, 1950 through 1996.
- Wheat and soybean yields have doubled.
- Cotton yields have tripled.

There is no reason to assume that yields in the U.S. will not increase in the future. Scientists continue to develop new technology that will support more intensive production. Genetic materials are being improved. We are utilizing conservation and agronomic practices that are greatly reducing runoff and erosion, protecting the soil and conserving water. In fact...though the war on erosion is not yet won...the U.S. has done an outstanding job of conserving its soils during the past 60 years or so, while producing the yield increases noted.

Prior to 1930, topsoil in this country eroded at the rate of 30 to 40 tons per acre per year. After the Dust Bowl of the 1930s, with contouring and terracing, erosion was slowed to 9 to 13 tons. On the average today, erosion losses are slightly above three tons per acre per year. With conservation tillage, and including the appropriate use of herbicides, average loss is about one ton. As little as 30 percent residue cover can reduce erosion by as much as 65 percent.

For all the above reasons and more, The USDA has projected that yields of major crops grown in the U.S. could double again in the next 35 to 40 years. If that happens, our farmers can continue to exclude the most fragile land from production and still produce sufficient food for consumption here at home plus supply a significant amount for export to our world neighbors.

To those who believe the Green Revolution has run its course, let me say that it has yet to reach some parts of the world. The African example has already been presented; where, with improved seed and appropriate use of mineral...and available organic...fertilizers, yields can be doubled, tripled or quadrupled, but there are other parts of the world where the "green revolution" may be more appropriately described as a "slow evolution". For instance, about 40 percent of the world corn acres are still planted to open pollinated varieties not yet having the advantage of hybrid vigor. Fully one-third of that land lies in Asia, where yields could be increased by 25 to 50 percent just by changing to hybrid corn.

As mentioned earlier, food production has been more of a political issue in many areas of the world than a sustainability question. As a result, the potential negative or positive effects of the type of farming that existed on the environment was not considered. Mexico and Northern Latin America are areas where government and farmer attitudes are changing. That is positive for both the environment and food production. In the past government policies were related only to political objectives. Food production was controlled by the government and used to further political agendas. Today, politicians are beginning to understand the importance of a strong and profitable free market agriculture for a sustainable economic growth.

Growers are also becoming more conscious of the damage that poor agronomic and conservation practices have brought to their farms and their economies. Action is being taken to change those practices and sustain productivity. Currently in the south of Mexico, growers are investing in aglime, new hybrids and fertilizers to increase corn yields. The region already produces one third of the corn consumed in Mexico, but yields are still very low. Government and grower have formed an alliance to increase yields, because they both know higher yields are essential if farmers are to be competitive with their world neighbors. That higher, more profitable yields are possible has already been proven in research and demonstration. The focus is on growing more food, while maintaining and enhancing the productivity of the soils.

Despite recent economic problems in Mexico, food production is becoming more intensive, expansive and efficient. In the past four years broccoli hectarage has doubled, increasing from 17,000 to 35,000 hectares. Nearly two and one-half crops are grown each year, representing one of the most intensive agricultural systems in the world. Yields are improved, but can still be doubled...based on research.

Population growth in Latin America has intensified the search for innovative methods of producing higher, sustainable yields. Plantain is a staple and inexpensive food crop adapted to the tropical and subtropical climates of the region. Its consumption has been steadily increasing. Colombia has the greatest cultivated area...about 100,000 acres. It has been proven by research that by tripling plant density and improving nutrient supply, yields of plantain can be increased by 300 percent. Such yields are compatible with sustainability and offer greater profit potential to growers.

Between 1995 and 2010, Southeast Asia's population is expected to increase by 133 million people. With the potential for irrigated areas diminishing and increasing demands placed on lowlands for urbanization and industrialization, rainfed uplands will become increasingly important for domestic and export oriented agricultural production. Though the uplands will require improved management, including the use of sufficient fertilizers, they have the potential to provide food and fiber for another 700 million people. This area is a focus of current research and innovative methods to enhance productivity, protect the environment, and limit further slash and burn incursions into diminishing rain forest areas.

Three different government agency studies in China indicate that more than 900 million tons of food can be produced on the arable soils of that country. Current production is less than two-thirds that level.

Other new studies in China are showing that appropriate fertilizer use and environmental well being go hand-in-hand. At one location, sediment loss was reduced from 19 tons per acre with no fertilizer to 5.6 ton per acre with balanced NPK. Further, nutrient losses in runoff sediment were reduced to one-half or one-third or less when fertilizer was applied to the crop.

The cerrado region of Brazil is still a largely untapped frontier of potential crop production. At the present time, about twenty-five and one-half million acres of grain crops produce 21 million metric tonnes of grain. If technology available in 1995 was applied to these acres 94 million tonnes could be produced. And, if the additional 121 million acres estimated to be available were brought into production with 1995 technology, 252 million tonnes of grain are possible. Of course, there are economic and infrastructure constraints, and most of the soils are highly weathered with serious limitations for crop production in terms of their low natural soil fertility. However, research is showing that these levels of productivity are attainable with adequate nutrient inputs and proper management on these soils.

There is little question in my mind that world agriculture can continue to feed the growing population...and feed it better than in the past. Appropriate fertilization and protection of the farmed acres will be essential to that end. In the long term, people will have to come to realize the essential relationship between proper nutrient management, including fertilization, food sufficiency, and environmental protection. In the short term, though, we will continue to deal with challenges that society...and our industry...create. In the U.S. we are facing several of them at the present time.

- Hypoxia – The zone of hypoxia in the Gulf of Mexico is of great concern, as well it should be. Some blame it on agriculture, specifically N and P fertilization. We still have much to learn about its origin, what feeds it and what can be done to diminish its effect.
- Nitrous emissions – The condition of the atmosphere is a widespread topic of discussion in the U.S. and around the world. Fertilizers contribute to atmospheric emissions and, possibly, to global warming. We do not know what the significance of the contribution from N fertilizers is as compared to its benefit in CO2 sequestration..
- Byproducts – The fertilizer industry has used byproducts in manufacturing some of its products for years. The practice has proven to be a safe, efficient method of disposing of some byproducts from various other manufacturing processes. It is now a front-burner issue in regard to human health and soil and water conservation.
- Animal manures – Those of us in the fertilizer industry cannot ignore the significance of the debate now going on regarding the proper disposal of animal manures. How will it impact our business?
- Heavy metals – Cadmium in phosphatic fertilizers has been an issue for several years. With the concern being expressed over the use of byproducts in fertilizer manufacture which contain cadmium and other heavy metals, there is sentiment for more complete labeling of fertilizer materials.

In summary, there is a very close relationship among food production, environmental protection and appropriate use of commercially produced fertilizers. Those of us in this room know that. We must do a better job of telling the folks outside about it. Otherwise, we will continue to struggle with image problems that take away from the vital role our products play in the sustainability of mankind and this planet.

Regulatory Update of AAPFCO Activities

Janet Bessey-Paulson

Arizona Department of Agriculture
Environmental Services Division

As President of the Association of American Plant Food Control Officials I appreciate the opportunity to address this 47th annual meeting of The Fertilizer Industry Round Table here in St. Petersburg, Florida. I will take this occasion to make you aware of some of the activities with which the Association is currently engaged. But first I would like to acquaint you with the Association of American Plant Food Control Officials as an organization.

This association has its roots dating back to the mid 1800's. The state of Massachusetts has the distinction of enacting the first fertilizer control law in the United States in 1869. It took several decades, but by 1947 all but one of the existing 48 states had enacted laws to regulate the distribution and use of fertilizer products. My own state of Arizona enacted its Fertilizer Materials Act in 1937.

Many of the original laws were narrow in scope and were extremely non-uniform, which lead to confusion and chaos for producers marketing products in more than one state. Most of these laws did not have the regulatory authority over labeling or inspection of products which allowed for the possible dissemination of misleading information and questionable products. Over the years it became apparent that the need for uniformity was particularly vital.

Another area of difficulty arose when agricultural chemists having the responsibility of analyzing fertilizer products, found methodology to be unreliable in providing consistent results. The first attempts to provide uniformity in legislative areas were tried by members of the Association of Official Agricultural Chemists or AOAC, many of whom were charged with regulating fertilizer products within their own states. These individuals were AOAC members who found vast differences in state laws and in laboratory methods. One of the original objectives of the AOAC was to "secure as far as possible uniformity of legislation." These differences lead chemists to organize for the purpose of developing and promoting uniform state fertilizer legislation. In October of 1946, following the AOAC meeting, the Association of American Fertilizer Control Officials was born. Since the acronym was the same as that of the Association of American Feed Control Officials and caused confusion, the fertilizer association changed its name to the Association of American Plant Food Control Officials or AAPFCO in 1965.

Each state, territory, dominion, province, federal or governmental entity on the North American continent, Hawaii and Puerto Rico is entitled to membership in the Association. It is governed by a Board of Directors made up of the President, President-elect, three directors, Secretary, Treasurer and Past President. The board meets twice a year, once at the mid year meeting, usually held in February in conjunction with the fertilizer industry and again in August at the annual meeting. This board handles the daily activities of the association and makes recommendations to the membership on the disposition of various suggested additions and changes to the officially adopted documents of the Association.

Most of the real work of the association is accomplished through committees. The majority of the committee work is done at the February mid year meeting. Changes or recommendations come before various committees and task forces where there is discussion on the issues between members (who come from the association membership and industry liaisons) and other interested industry and regulatory people. Most committee meetings are open to participation by interested individuals as well as "official" members. After discussion, recommendations are made to the board of directors, usually at the next mid year meeting. The board then decides to accept or reject the recommendations. If the board feels that a suggested change warrants more research by the submitting committee or needs to be looked at by another committee, they can return the proposal to the committee or pass it along to another committee. If accepted, the board passes the recommendations along to the general membership for a vote. This generally occurs during the business meeting held at the annual meeting in August. The association membership usually accepts the board recommendation on most issues. However, it has on occasion rejected a recommendation.

One of the primary purposes of the association is to develop and encourage state regulatory programs to adopt recommended **uniform** laws and rules, as well as **uniform** terms, definitions, labeling requirements, and laboratory methodologies. I emphasize uniform because it is extremely important in a free market economy for industry to be able to distribute their products in multiple states without worrying about maintaining separate labels to comply with specific and unique state requirements. A good regulatory program is in place to provide adequate and appropriate consumer protection without causing undo regulatory burdens. More importantly it is significant that the association is continually striving to address current and future concerns affecting the industry.

There are four areas that I would like to touch on that are impacting the association this year. I will spend a few minutes on each and inform you of the activities that the association is currently engaged in and where we may need to go from here.

- **Environmental Issues**
- **Use of ammonium nitrate**
- **Precision Agriculture Issues**
- **Laboratory Issues**

Environmental Issues

In most states in the United States, environmental issues are not regulated by the agency that regulates fertilizers. Most state fertilizer laws are based on the model Uniform State Fertilizer Bill that has been developed and adopted by the association. Until recently, the Model Bill did not cover areas relating to storage and use of fertilizer materials. The original bill only looked at sales and distribution. With the addition of these areas in the model bill, the state fertilizer control officials who have incorporated the changes in their own laws, can consider and address several environmental issues.

With the passage of the Clean Water Act, maintaining water quality plays a large role in most states. The potential of leakage of bulk fertilizer material that may contaminate ground and surface drinking water sources poses a real threat. Bulk fertilizer storage facilities are one concern. I am not a proponent of additional unnecessary governmental regulations, however if storage facilities could be an area of concern, I would rather see the agency that regulates the products also regulate the storage. In 1993 the AAPFCO made official the "Primary and Secondary Containment of Fertilizer Rules" which are supplemental to the Uniform State Fertilizer Bill. A great deal of work went into the development of these rules by the Environmental Affairs Committee and any state using them would have a good basis for oversight.

Another concern relates to the levels of nitrates added to the land and the movement of the nitrates as they might affect the quality of groundwater. Additionally, the nitrate issue includes the levels accumulated in large animal feeding operations, such as feedlots or dairies. If the levels of nitrates added to the land through input sources or concentrated feeding operations are not regulated by the individual states, the U.S. Environmental Protection Agency will step in and dictate allowable levels and may even get to the point of determining how many animals any individual operator may own at a particular site.

Adulteration is another area for environmental concern. Previously the definition accepted by the Association stated that adulteration was limited to whether a fertilizer product was harmful to plant life. The Association expanded this in the last two years to include harmful effects to animals, humans, aquatic life, soil or water. In August the entire membership of the association approved this provision. In the states where they have enacted these provisions, regulators have a good tool to use in dealing with potential contamination issues. In recent news articles and television "news" programs, they have suggested that American fertilizer products contain "added" hazardous waste materials from industrial and manufacturing processes that are in fact poisoning our crop land. AAPFCO's Environmental Affairs Committee is working diligently to develop model legislation relating to the use of these products as fertilizer materials. They are also looking to create standards under which they may compare these products relative to their potential levels of heavy metals. The California Department of Food and Agriculture has undertaken an extensive survey of various by-products in fertilizer materials and the results of that survey should be available soon. These results will be helpful to the Environmental Affairs committee in its development of standards or guidelines for the maximum levels of heavy metals in fertilizer products.

At the annual meeting held in August of this year in Providence, Rhode Island, the AAPFCO membership passed a resolution declaring that the recycling of industrial and municipal wastes can be beneficial in maintaining a quality environment. The resolution also acknowledged that concerns exist and that there is a need for the regulation of by-products and recycled materials used in fertilizers. They resolved that "the Association of American Plant Food Control Officials maintains a desire to continue to work with consumers of fertilizers and the fertilizer industry in establishing appropriate labeling and testing of wastes used directly as fertilizers, of wastes to be incorporated in fertilizers and of fertilizers containing wastes to ensure that those products are not injurious to beneficial plant, animal or aquatic life, to humans, to the soil or to water when used as directed." Several years ago the Association requested the appropriate committees establish guidelines by 1998 for the use of biosolids and industrial by-products and co-products as fertilizers. This and the adoption in 1997 of the changed definition of adulteration, address a wide variety of environmental concerns.

Use of Ammonium Nitrate

Another area of concern to the Association and an area that we wish was not an issue, is the continued news media portrayal of fertilizer products as explosives. We are all aware that certain formulations of ammonium nitrate can be used for their explosive properties. Used in the right setting and in the correct manner this is appropriate. However, because of the bombing that occurred in Oklahoma City three years ago, people in this country are apprehensive when they hear of stashes of fertilizer being "found" in someone's shed. The government then has to react. The unfortunate problem will always be that some people will intentionally misuse the material.

It is important that the members of AAPFCO and industry continue to cooperate with any authorities making inquiries and to continue to provide correct information to the public. Only by doing this can we continue to protect the legitimate use of fertilizer products.

Precision Agriculture Issues

I would like to now turn my attention to an area that we will hear a great deal more about in the next few days. That is, "precision agriculture," or the exact placement of fertilizer, pesticide products or even water to crops based on specific needs of that crop or the soil that crop is being grown in. In this age of advanced technology, delivering specific requirements is now possible based on unique localized needs. With geographic information systems and global positioning systems available and becoming more sophisticated, it is likely that the farmer of the future can sit in his tractor cab making applications of agricultural chemicals to his crops specific to each square meter of land that he is farming. Gone will be the days of having a soil fertility test taken and assuming that single test will meet the entire field's needs.

It will be the role of the regulatory community to help the farmer in determining if he is getting what he is paying for. The Association has been looking at this issue of precision delivery of fertilizer for the last year with the formation of the Precision Agriculture Task Force. This group has met several times and is educating themselves as to the capabilities of equipment and exactly what form of consumer protection is needed. There have been discussions of labeling needs; sampling of materials, (either what goes into the machines or what is delivered); calibration of the equipment and training of the equipment operator. Each of these areas poses interesting points of continued learning and discussion. The direction of the task force continues to evolve as it strives to develop necessary and equitable guidelines which will allow for fair competition and consumer protection.

Laboratory Issues

Most regulatory sampling programs rely heavily on their laboratories for reliable and accurate analysis of the samples that their inspectors have taken in the field. Whether these samples are for surveillance or compliance purposes, the results from the laboratory are critical in determining the quality of the products being distributed. In recent years there have been many issues relating to laboratory accreditation and requiring quality control measures be in place. The U. S. Environmental Protection Agency requires any laboratory that performs analysis for regulatory programs or is doing contract work for the Agency have in place very stringent written procedures for quality assurance and quality control as it relates to the analysis of pesticide products. Similarly most laboratories doing analysis for fertilizer programs have quality guidelines in place; however the guidelines are not necessarily formalized nor are they uniform from laboratory to laboratory. There are some state legislatures that for purposes of fair competition are looking to require programs to send their samples to private laboratories. This would work if the laboratories all followed the same quality control measures. With these issues in mind, it is my intention as President, to appoint a new laboratory committee within the Association with instructions to develop uniform guidelines for fertilizer laboratories. I will also ask that this committee determine methodology needs and where feasible, help develop new methods of analysis.

Summary

Our roles are continually changing and will continue to do so, as technology expands and the environmental concerns continue to increase. We must keep looking ahead and expanding our knowledge and awareness of changes that are occurring in sampling, application and analysis methods. Last year's AAPFCO President, Lance Hester stated "that while our roles are changing and will continue to do so, we must be able to anticipate changes and look ahead to develop policies that will carry us into the future."

Meetings such as this allow each of us the opportunity to reflect on the past and look to the future. I thank you for the chance to discuss some of the issues that the Association of American Plant Food Control Officials are dealing with.

Risk Assessment of Fertilizer Materials

Phillip "Whit" Yelverton

The Fertilizer Institute

Introduction

I find that I am the final speaker on a program which has been both very informative and very full since early this morning. I suspect that many of us are a bit tired, and perhaps already thinking ahead to this evening's R&R. In order to capture your attention, I would like to pass along to you some wisdom from the United States Congress.

A document now circulating in Washington entitled "Washington Rules" has been developed for anyone who wishes to be effective in dealing with the Congress. I have selected a few of these rules to pass on to you:

- If it's worth fighting for, it's worth fighting dirty for.
- Don't lie, cheat or steal unnecessarily.
- There is always one more son of a bitch than you counted on.
- An honest answer can get you into a lot of trouble.
- The facts, although interesting, are irrelevant.
- Chicken Little only has to be right once.
- "No" is only an interim response.
- You can't kill a bad idea.
- If at first you don't succeed, destroy all evidence that you ever tried.
- The truth is variable.
- A porcupine with his quills down is just another fat rodent.
- A promise is not a guarantee.

The Fertilizer Institute is an organization which, for more than one hundred years, has been involved in the formation of public policy, primarily at the Federal level. My assignment today is to discuss with you several issues, all related to the potential risks to human health from inorganic fertilizer products. I will attempt to make clear how the process of public policy development is now being played out in relation to these issues.

A. Issue Summary

Environmental regulation has been characterized by a reliance on the capability of existing technology to control discharges and emissions of pollutants into the environment. This technology-based approach is being supplanted by a risk-based approach. Under this approach, regulations and standards are developed to minimize or eliminate risks to human health and/or the environment resulting from a particular activity.

The emphasis on risk-based regulation has resulted in the emergence of a new scientific discipline – risk assessment and risk management. The discipline is undergoing rapid development, giving rise to uncertainties regarding the integrity of its methodologies and basic precepts. Nevertheless, use of risk assessment principles is a growing trend, which must be addressed by regulated industries.

As a result of its adoption by regulatory agencies, risk analysis and risk management concepts are also appearing in important non-regulatory contexts. Also, reports in the media are now often in terms of "risks" associated with a particular activity. The remainder of this paper will attempt to demonstrate why and how the fertilizer industry should participate in the arena of risk assessment and policy development for risk management.

B. Background

In April, 1996 following a report to the Executive Committee on the rising issues of risk assessment and risk management affecting public policy formation relating to fertilizer, TFI staff was directed by Resolution 15-96 to gather information on the issue and report in June 1996.

At its June, 1996 meeting, the Board affirmed its concern for risk issues, authorized money for study preparation, and formed a task force to advise the Board.

The Executive Committee met in September, 1996 and heard reports on how risk-based concepts were already impacting formation of regulations. Resolution 22-96 repeated the need for a Risk Assessment Task Force to address the potential impacts on the fertilizer industry, and to bring proposals to the Board.

In February, 1997 the Risk Assessment Task Force met and began developing a project proposal. The proposal was presented to the Executive Committee in April 1997. It outlined a 13-step strategy of assessing the potential risks and benefits of fertilizer, allowing for several stages and key decision points for the Board. A cost of up to $1 million was projected, over a period of 3 years. The project was recommended to the Board for approval.

C. Definition

Some basic definitions will be helpful to establish a context for the discussion of how risk-related issues are affecting the fertilizer industry.

Risk – The probability of occurrence of adverse health effects.

Risk Assessment – The systematic process of characterizing the nature and likelihood of adverse effects based on exposure and hazards.

Risk Management – The process of evaluating policy alternatives by considering or weighing information from risk assessment, economic analysis, feasibility, and social and political values.

Risk Communication – The practice of communicating to various affected audiences the risk of products or practices and how those risks are managed. Affected audiences may include employees, government officials, investors, customers and the public. An effective risk communications program is the result of the knowledge built through the risk assessment and risk management combined with the principles of communicating those risks.

By this definition, of course, any particular activity can be identified as a "risk", with some probability of causing adverse health effects. Our focus is on risk assessment where, as noted earlier, a new discipline has arisen. Our participation ultimately extends, also, into "risk management" which broadly describes the process of public policy development in our society.

D. Risk Assessment Current Concerns

A number of examples will be given below which serve to illustrate the current presence of risk terminology and concepts in public and regulatory discourse. The examples are interrelated by: the inclusion of fertilizer; the use of or reference to risk assessment concepts; and by their identifiable impact on development of public policy (regulatory programs) governing the fertilizer industry.

1. California Heavy Metals Study

A study was commissioned by the California Department of Agriculture in June 1996 to examine possible compliance issues under Proposition 65 relating to the presence of lead, cadmium and arsenic in fertilizers. A risk assessment has been conducted which analyzed various fertilizers in California and the probabilities of certain exposure levels of these metals occurring.

Some points for consideration about this study: (a) It was limited in scope – only three minor elements were examined and the "receptors" included only farm family, farm worker, and fertilizer applicator. It did not extend to food chain analysis. (b) It does establish some precedents for the application of risk concepts, e.g. exposure pathways and scenarios. These precedents are now a part of a fertilizer risk assessment model. (c) The study included no field validations – it was entirely based on probabilistic modeling. (d) Opportunities for input and review were severely limited during the completion of the study.

2. Seattle Times Articles

A series of articles in the Seattle Times, published on July 3, 4, and 13, 1997 were collectively titled "Fear in the Fields: How Hazardous Waste Becomes Fertilizer". A local story in Quincy, Washington, involving a clean-up of an old rinsate pond, several disgruntled farmers, and the mayor was merged with an "investigation" of permitted industrial by-products being used in fertilizer. Add to this mix the involvement of the "Washington Toxics Coalition" and a national story emerged

This episode has engaged the general public in a discussion of the risks of using industrial by-products as a source of beneficial minor elements for agriculture. It has also raised the issue of risks associated with indigenous minor elements in fertilizer such as cadmium.

The Environmental Protection Agency has also responded by creating a work group to review these issues.

3. Environmental Defense Fund

A major study was released on July 29, 1997 titled "Toxic Ignorance". EDF says in the study that 71% of the 3000 highest-volume chemicals in the U.S. economy have not been subjected to "health-effects screening tests". According to EDF, this means that the public cannot tell whether these chemicals pose health hazards or not.

Fertilizer materials are included in the high-volume list. Several industry CEOs have now received letters from EDF requesting "basic safety information" about specific products.

This initiative has reinforced the presence of "Community Right to Know" as a potent force in public policy formation, referred to as a "national policy" by EDF. It has also served to establish a testing benchmark for human health hazards, based on 1990 standards from the Screening Information Data Set (SIDS) created by the Organization for Economic Cooperation and Development (OECD), referred to as an "international consensus".

The additional issues listed below have been discussed previously, or will be covered later. They are also related to the risk issue. A summary is also included at Attachment A.

1 – Reconsideration of Phosphogypsum Use Ban (Radon)

2 – Bevill Amendment – possible reconsideration

3 – National Cancer Institute study of agricultural health

4 – Ammonia exposure thresholds

E. Existing Standards

A number of related sets of standards are currently in force, and may provide some guidance to us in the current discussion.

1. Canadian Standards

Agriculture Canada has promulgated the "Standards for Metals in Fertilizer and Supplements". The standard was first introduced in 1979, and was re-evaluated between 1993 and 1995. These standards establish maximum acceptable cumulative metal additions to soil for all fertilizers and supplements including processed sewage, composts and other by-products.

2. EPA 503 Rules

The Environmental Protection Agency established standards for the use or disposal of sewage sludge in 1993. Regulations were established for sludge applied to the land for a beneficial purpose, i.e. as a nutrient source or as a soil conditioner. An evaluation of the risks posed by pollutants which may be in sludge included potential risks to human health through direct human exposures, consumption of crops by humans, consumption of exposed crops by animals as well as contamination of drinking water sources.

3. European Standards

The European Community, as well as several of the individual member states, has adopted standards for cadmium content in fertilizer.

4. Food and Drug Administration

FDA establishes safe background levels for foods.

F. Existing Information

Some information on these topics is already available, such as the data developed by EPA on plant uptake as a part of the sludge risk assessment. The California Study will undoubtedly provide large amounts of information on the limited metals and receptors specified in that study. Specific studies on human toxicity of certain elements, such as lead, are also available. All of these should be analyzed and correlated for consistency, as well as reviewed in the context of identifying missing data sets.

The academic community has also begun to speak out, and two recent quotes are given as examples:

1. "Historical trends in dietary intake show that exposure to arsenic, cadmium, and lead have decreased since the mid-1970's...the downward trend in metal intake suggests that soil amendments have not had a measurable impact on residues in food nor on dietary intake."
   - from Dr. Allan S. Felsot of Washington State University, based on U.S. Food and Drug Administration studies.

2. "The chance of the health of any person being threatened as a result of the land application of fertilizer at agronomic application rates is very, very, very small (nonexistent, if fertilizers are used properly). The potential amount of heavy metals added at the recommended fertilizer application rates is just not enough to significantly influence the concentration of plant-available toxic metal in the soil or the potential for uptake by plants."
   - from Dr. Richard Loeppert, Professor of Soil Chemistry, Texas A & M University

G. TFI Responses

Risk Assessment may be described in three simple parts:

(1) What is in my products?
(2) How do exposures occur?
(3) What are the consequences of those exposures?

Each part can be determined by a study of existing information, or by generating new information. Most often, a combination of these is required.

1. Risk Assessment Study

TFI has proposed a risk assessment study which will help to answer these questions. The project is divided into 13 steps, with multiple "decision points" to provide for on-going evaluation of the project by the Board. (Attachment B)

The goal of completing the risk assessment is to provide a technically rigorous basis for the evaluation and prioritization of potential risks of fertilizer materials in commerce. We anticipate that completion of the project will allow the industry to better manage issues such as those presented in this paper, over the long term.

2. Phase I Proposal

Proposals have been developed and reviewed by the Risk Assessment Task Force to complete the "product analysis" part of the study. Several facilities were considered for appropriate sampling and analytical capabilities. We anticipate the continued involvement of multiple contractors, with coordination by TFI staff.

3. Benefits Study

The most comprehensive and useful risk management strategy for fertilizer materials is one which has both risk assessment and benefits analysis components. The goal of a benefits analysis is to provide a technically rigorous basis for describing and quantifying the societal benefits of fertilizers.

The development of the risk study and the benefits study should proceed in parallel. A proposal has also been developed for this segment of the risk assessment project. It consists of a literature search, followed by assimilation of the information into a comprehensive paper describing the benefits of fertilizers, and demonstrating the risks associated with not using fertilizer. The positive roles that fertilizers have in relation to global environmental concerns will be a focal point. In addition, issues related to nutrition, food security, population, etc. will be expounded in the context of the positive roles of fertilizers.

4. Structural Issues

TFI's Counsel has reviewed several structural issues related to the Risk Assessment Project. The issues reviewed included: (a) confidentiality of data, (b) potential liability, (c) potential affirmative reporting requirements, e.g. to EPA and (d) contributions of resources from parties outside TFI membership.

In general, counsel has recommended continuation of the current structure, including a task force with Board oversight. Confidentiality concerns can be addressed by use of third party aggregation, as with our current programs. If additional issues arise in the future, such as data compensation from other parties, copyright protection of study results, etc., these can be addressed separately.

A copy of the legal review referred to above is available directly from McKenna and Cuneo, L.L.P.

5. Comparison of Toxicity Tests

Toxicity testing has been referred to with some frequency throughout this discussion. In fact, there is no simple definition of or limitation on the concept of toxicity testing.

Two sets of toxicology tests are often referred to; some discussion of the extent and costs associated with these "sets" may be useful.

First, the "OECD SIDS" was referred to above in reference to the Environmental Defense Fund letter. The SIDS toxicity tests are comprehensive in nature and include repeated oral testing (in rats), plus tests of genetic toxicity in vitro and in viro, reproductive toxicity testing and developmental toxicity/teratogenicity testing. This set of tests costs approximately $200,000 per chemical, and can require more than a year to complete.

Second, is the familiar "six-pack" testing used to support EPA labeling for acute toxicology to workers of pesticides. This includes rat testing of acute oral, acute inhalation, acute dermal and dermal irritation, plus testing of rabbit eye irritation and guinea pig skin sensitization. This "set" costs $50,000 per chemical and can be completed in several weeks.

It is unlikely that either of these established "sets" will meet our needs exactly, for completion of the fertilizer risk assessment. For this reason, the step-wise process of the study proposal, which allows for evaluation of the project at several critical decision points, is crucial to its success.

Obviously, if we learn that a comprehensive testing set is necessary to complete the assessment to a scientifically rigorous and defensible conclusion, and the Board agrees to this testing, then additional funding will be required above the $1 million. Also, additional issues of potential liability and data ownership may be raised.

However, we may also discover and recommend that a limited set of studies, perhaps similar to the "six-pack" will serve our needs to rigorously complete the risk assessment. If this is the recommendation, and the Board agrees, the total costs may be somewhat less, and remain within the $1 million total for the project.

6. Labeling Proposals

TFI has had discussions with the Association of American Plant Food Control Officials (AAPFCO) concerning expanded labeling of fertilizers. AAPFCO is made up of officials from each state who are charged with regulating the content and sale of fertilizers. Proposals made by AAPFCO are usually adopted quickly into state law.

A new label is likely to require that all ingredients in bulk or packaged fertilizer be listed in order of predominance. Currently, only recognized plant nutrients, which are guaranteed to the customer, must be listed. We also expect some move to develop a statement of maxima for certain elements including cadmium, lead, arsenic, and mercury. Current standards, discussed previously in this paper, will be considered if appropriate.

At this point, expanded labeling of some kind seems likely. In addition to the AAPFCO discussion, several states are considering action, plus there is increasing interest from EPA. Our best option at this time is to work with AAPFCO to design expanded labeling which does not impose unreasonable burdens on the industry; AAPFCO is willing to allow for industry input into the process.

The AAPFCO strategy allows us more input than other options, plus the opportunity to maintain uniformity of regulations at the state level. Additional disclosures, through labeling, may be an effective method of beginning to dispel anyone's belief that we are "hiding" something, and to continue our efforts towards better understanding of fertilizer products.

Attachment A

Risk Assessment/Management Issue Matrix

Risk Determined Issues	Toxicity Thresholds	Risk Assessment	TFI Response/ Action Initiated
(1) EDF Letter	Fertilizers	Chronic/Cancer	1997
(2) Minor Element Composition Hazardous Waste	Micronutrients/ Fertilizers	Chronic/Cancer	?1997
(3) NH3 Exposure (AEGL) Ammonia exposure thresholds	NH3	Acute	1996
(4) California Heavy Metals Study Health risk of metals in fertilizer	Cd/Pb/As	Cancer (Prop 65)	?1997
(5) Phosphogypsum Land Application Ban Set precedents for cumulative exposure risk	Radionuclides	Cancer	1994
(6) Sludge Application Regs Application/Exposure thresholds For contaminants in sludge	Metals/Other	Chronic/Cancer	1993
(7) Pesticide/Fertilizer Combinations Testing of fertilizer components not required at this time	(1) End Use Product (2) Fertilizer Warning	Cancer/Acute/Chronic	1996
(8) Farm Worker Safety Issues Study of cancer risks from various exposures, incl. Fertilizers	Fertilizers	Cancer	?1998
(9) Ammonia Rfc Reference dose for NH3	NH3	Chronic	1993

August 27, 1997

Attachment B

Steps and Decision Points for the Risk Assessment

Step 1. Prepare a list of what types of information (e.g. composition, acute toxicity, uses [both type and location]) is needed and design a survey to obtain from Members their already existing product information on fertilizer materials.

Step 2. Use the survey to poll Members to collect available information including composition to the smallest quantity known. Where key information is lacking, conduct adequate chemical or physical analysis of appropriate materials.

Step 3. [Concurrent with Step 2] Conduct literature search of prior risk assessment studies of fertilizer materials or closely related compounds to identify methodologies, input factors and other key model information. Also review interim results of the California Study.

Decision Point Review all available information (from Members and from literature). Adjust approach and fill gaps, as warranted, before proceeding.

Step 4. Develop a "typical analysis range" for each material. This would include both the variability in the composition of a particular type of material, e.g. as a result of different raw materials, and the variability in composition within a given production point as a result of batch-to-batch differences.

Step 5. [Concurrent with Step 4] Develop a list of constituents within the fertilizer materials that represent potential health concerns for typical targets.

Step 6. Prepare a matrix of constituents for each material to get a representative composition profile (avoids using an identifiable material in risk assessment).

Decision Point Review and approval of the analysis range, constituents and composition profile.

Step 7. Choose representative (conservative) material compositions from the matrix for each scenario (e.g. edible crops, crops for livestock, non-crop plants). Establish a generic "prototype" material or product for each use scenario based on this aggregated information. These generic compositions provide a construct for eventual risk evaluations. [In applying the prototype, Producers could determine how similar their material is to the generic prototypes and whether some adjustment is warranted]

Step 8. Conduct a literature search to identify relationships between dosage and incidence of adverse effects from constituents chosen in the matrix. Collect and examine the range of available toxicological values and standards (including any uncertainty factors that have been applied). Choose appropriate threshold or benchmark values for each endpoint (e.g. cancer, reproductive toxicity, acute toxicity).

Step 9. Identify toxicological data gaps and establish procedures/standards for conducting toxicological studies. Recommend studies as warranted.

Decision Point Reach agreement on conducting any toxicology studies.

Step 10. Complete any necessary toxicology studies.

Step 11. [Concurrent with Step 8] Conduct a literature search to identify environmental fate and transport characteristics of the constituents chosen in the matrix. Identify and evaluate existing fate and transport models for appropriateness. Conduct additional experimental work, field analysis and model development as needed to complete adequate fate and transport models. Establish an approach for assessing exposure to prototype materials (consider dermal contact, indirect ingestion, inhalation, and dietary intake as appropriate for each of the typical targets). Estimate exposure levels to the constituents for each scenario.

Step 12. Evaluate potential risks on the basis of comparing dose-response information to exposure information for each of the prototype materials and use scenarios.

Decision Point Consider the need for any further evaluation and/or refinement of risks in Step 12. [Also, as part of secondary priority under "Scope/Goals" above, consider the need for any evaluation of risks in groundwater, water quality, ecological, etc. as a result of post-use environmental fate of fertilizer materials]

Step 13. Enter risk management phase incorporating results of the benefits analysis.

Tuesday, October 28, 1997

Session III
Moderator:

Patrick Peterson

The Safety Aspects of Handling, Storage and Transportation of Ammonia

Brian R. Spencer

CF Industries

CF Industries, Inc. (CF) Distribution Facilities group operates 21 company owned ammonia terminals, located in 10 states. Each facility is operated by a Site Superintendent and, typically, four full-time operators. This staff is assisted by one or two part-time operators and a part-time office clerk. Management of our distribution system is based in our corporate headquarters in Long Grove, Illinois, a Chicago suburb.

The Distribution Facilities group supports these terminals, along with our 5 dry fertilizer warehouses, with a staff consisting of Operations Management, Engineering and Technical Service, Administrative Support, and a Environmental, Health and Safety (EHS) group. The Engineering group for Distribution Facilities is based in Long Grove, providing both project and process engineering expertise. The Technical Service Group, based in Terre Haute, Indiana, provides mechanical equipment maintenance assistance, as well as instrument and electrical support. This group also runs our vessel inspection program. Our EHS group is composed of 7 people, 3 of whom are based in the field

Successfully supporting our terminals to insure the safety of our employees, neighbors and the environment is, of course, a continuous challenge due to the competing demands on CF's personnel and the distance between our 21 terminals and their support groups. Several components of our safety programs have been tailored to reflect that challenge.

While I do not have the time to specifically review the regulations that cover our business, I am sure you will notice that several of the items I will discuss are required components of 29 CFR 1910.119, OSHA's Process Safety Management (PSM) standard. May 26th marked the fifth anniversary of the effective date of this Standard. While CF has always maintained high safety standards, completing the work required to comply with this Standard has improved our overall level of performance and ability to safely operate our facilities.

CF has always worked to maintain compliance with the regulations that apply to our operations. There are certain areas where CF has decided to develop internal standards and requirements that go beyond what is required by regulation, to enhance our safety performance. These are items that we believe are reasonable for our facilities. They might not, of course, be applicable or useful for every operation.

One of these requirements calls for internal inspections of our refrigerated, or low pressure, ammonia storage tanks, at 15 year intervals. During the inspection, our Technical Services group completes both a visual and a wet magnetic fluorescent particle inspection of all floor and tank wall welds. All floor welds are also vacuum box tested. Magnetic Flux Exclusion tests were run on the floor plates to check for underside corrosion. Since no evidence of bottom side corrosion was found, this test is no longer a routine part of our inspection protocol.

Several other inspections are also completed while each tank is out of service, such as foundation level surveys, anchor bolt inspections and expansion joint, valve and pipe checks and repairs.

We also internally inspect our ammonia bullets on a 5 year interval. Other refrigeration process vessels, such as receivers and intercoolers, are internally inspected on 15 year intervals. We also use the wet magnetic fluorescent inspection method on these vessels, using the same inspection procedure we use on our large storage tanks. To insure that we can internally inspect every pressure vessel in our system, we have spent $560,000 over the past 5 years to replace every vessel that did not have a manway port that allowed access for internal inspection.

We have also initiated the practice of internally shot-peening every pressure vessel. The reasoning is that by internally shot-peening the vessels, the surface would be placed in compression, thus reducing the potential for the formation or propagation of surface cracks caused by tensile stress corrosion cracking. This past summer we completed internal inspections of the first set of vessels that were shot-peened. A significant reduction in the number of surface indications was noted in these shot-peened vessels. This reduction in indications is being evaluated as we consider adjusting our inspection interval for pressure vessels.

Our Technical Services group also completes additional system inspections during the pressure vessel inspections — on the relief valves, control instrumentation and excess flow valves.

Storage and process tanks and vessels should be built and maintained to applicable codes, API 620 for low pressure storage tanks, the ASME codes for pressure vessels. Solution storage tanks should be built to the API 650 code. We have always believed that the small additional cost of building code tanks is more than "worth the money."

I noted that we complete a variety of inspections to related systems and equipment during the inspections of our tanks and process vessels. We have specific requirements designed to insure the integrity of our piping systems. We perform random thickness tests on piping systems to detect both external and internal corrosion. Pipe supports and expansion joints are also inspected using specific protocols. We have found construction problems with pipe supports and expansion joints that have been "covered up" with insulation since the facility was built. During the outages we remove and send major process and control valves off-site for inspection and overhaul by authorized vendors. These tank and vessel inspections might be the only opportunity to look at these valves without taking a major process shut-down, which makes it a opportunity we don't miss.

Since I have been discussing major equipment inspections, now might be a good time to discuss our use of contractors for this work. Contractor safety reviews and training documentation are required by the Process Safety Management standard. Prior to implementation of the PSM standard, we gave contractors site specific safety orientations when they first came on a site and required that all contractors maintain specific insurance coverage. We also completed periodic safe work practice inspections, to insure they were following our site specific safety rules and applicable regulations. To comply with PSM requirements, we implemented an expanded program to review contractors' safety performance, using OSHA 200 records, to evaluate the number and severity of injuries over a three year period. We also continue to check contractors while they are on our sites for compliance with requirements such as hot work, fall protection, lock and tag and confined space programs.

With our ammonia terminals spread out over 10 states, we have developed specific relationships with several contractors that are used to minimize the challenge posed by this "geographic handicap." We currently use two firms to complete all of our major process and vessel welding work. We have always qualified individual welders by having them submit monitored weld specimens to testing. Only welders who passed this qualification test are used by our Technical Services group. The two firms have the capability to supply crews and equipment to any of our facilities. Since our ability to take equipment out of service for inspections and maintenance is limited by the need to have the equipment in service for the Spring and Fall fertilizer seasons, utilizing these large contractors also enables us to schedule several inspections for the same time period. Utilizing annual blanket purchase orders reduces the burden of qualifying and contracting with a larger number of firms. Since the same individuals can be scheduled into our sites, the need to check PSM qualifications repeatedly is also eliminated. Site specific safety orientations are, however, always completed.

We use the same plan for the companies that complete our tank and vessel inspection work, utilizing a small number of large companies for all of our work. All major outages are planned and scheduled early in the year with each contractor, minimizing potential timing conflicts.

We use one company for all of our tank construction and major repair work, again benefiting from reduced contracting, qualification and training requirements. We have been very successful in contracting several major projects on a turn-key basis, reducing the demands on Engineering and Technical Services personnel while reducing our costs and, I believe, improving the quality of equipment we have in service. All of these companies have become very familiar with our standards and quality requirements.

So far, I have discussed things we do to try to prevent ammonia releases. What can we do if there is a release? We have decided to respond to any ammonia release on our site that is within our capabilities. While regulations allow employees to call for help in the event of a release and then evacuate the facility, we believe that the consequences of a release can be minimized if we are trained and equipped to respond ourselves. After all, no one is more familiar with ammonia and our site than we are. We have made the investment in both equipment and training to enable our terminal personnel to take offensive action in response to a release of ammonia. Every Superintendent and Operator at our terminals has received Hazardous Materials (HAZMAT) training. Every terminal has totally encapsulating enclosure suits and self-contained breathing apparatus. In addition to these very important pieces of personal protective equipment, the terminals have all the other emergency response equipment that we believe would be required to address an Emergency Response. We have developed a comprehensive training facility on the grounds of our terminal near Peoria, Illinois, and hold refresher training for all of our HAZMAT employees. We schedule every employee into one of four annual sessions that run for three days every year. We also complete "live" confined space rescue and retrieval training at these sessions.

If you have an emergency response plan that relies on outside help, you should consider determining the level of help that is available. Typical first responders at our terminals would be a local fire department. The level of training and equipment available to these departments will likely vary widely. We have worked with our first responders to improve their expertise and abilities by donating equipment and sponsoring ammonia response drills on our sites. We plan to continue these efforts.

When equipping your emergency response teams, or purchasing any other safety equipment, don't assume that it is suitable for your specific application. Take a hard look at it. When we purchased our first totally encapsulating suits, we tested the entire "system" to insure that it was suitable for our application — exposure to anhydrous ammonia. During this evaluation, we immersed the gloves in liquid ammonia. They fell apart when we took them out. Working with the manufacturer, we obtained gloves that passed the same test. We asked the manufacturer to add reinforcing to the suit's knees and elbows, and reverse the direction of the zipper, so it "zips down." We also added wider belt loops, which make it much easier to attach the life lines to the suits. The manufacturer has since added these features to a suit and now sells it as a standard model.

There are two lessons here: don't take the applicability of safety equipment for granted, and you can work with a manufacturer to get the equipment you need.

I don't want to give you the impression that our focus is on equipment alone. Knowledgeable and well trained personnel are essential to the safe operation of our facilities. I noted that our EHS Group has three supervisors who are based in the field. One of the primary responsibilities of these supervisors is to visit every one of our facilities to complete a wide range of site reviews and operator training. To maintain consistency across our facilities, the EHS Group has developed a EHS Group Protocol. The three EHS supervisors use this protocol as the outline for work to be completed during their facility visits. The protocol contains detailed guidelines for items to be completed at every facility, such as walk around inspections, site auditing and record reviews. One of the most comprehensive components of the protocol is 33 specific training programs that each employee receives. Each training program contains a course outline and a test to document that every employee has received and understood the training. They also have employees "prove" that they truly know how to "work safe" by having them demonstrate the correct way to carry out specific programs, such as Lock Out/Tag Out and Confined Space Entry

Our EHS reviews also have one more very important component. CF has a corporate EHS audit group that independently audits each of our sites. This group performs a complete audit of a facility every other year. On the off years, they visit each site to do a follow-up inspection, designed to confirm progress towards addressing any past findings. This group is designed to function as an additional set of eyes for our facilities. The intention is to maintain our operations at the highest level of safety we can.

I would like you leave you with one thought. When you write programs for your employees and facilities, don't write them with the sole intent of meeting a regulation. While your programs certainly need to do that, the primary goal must be to assist your employees in working safely.

Latest Fluid Drum Granulator Applications

Patrick Bouilloud

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Abstract

This paper presents the FLUID DRUM GRANULATOR and its latest applications, mainly for the manufacturing of COMPOSITE GRANULES.

Composite Granules are particles having a core and an external layer of different NPK composition. They are manufactured by coating a PK Granule with a melt or a solution (ammonium nitrate, urea, nitrophosphate) in the FDG, leaving an end product with the desired NPK composition.

The main advantages of this kind of Granules are:

- nitrate and potash content isolated in different zones of the particle reducing reaction between them,
- external layer of the Granule rich in nitrogen that can be rapidly assimilated by the plant,
- PK core that will be delivered in a second step to the crops,
- coating of PK granules with the melt reduces dust formation.

This technique will be applied for the upgrading of NPK plants. The revamping is based on pilot plant trials realized in a small scale FDG at KT in Beauvais (FRANCE). The results of the tests and the characteristics of the granules before and after FDG coating will be presented.

The upgrading of an NPK plant foreseen will be described.

The advantages brought by the FDG implementation are :

- improved end product characteristics (humidity, abrasion resistance and physical shape),
- increased capacity,
- low investment cost.

A second type of Composite Granules, namely ammonium sulphate crystals coated with an ammonium nitrate melt will also be presented. The results of the pilot plant trials for the manufacturing of these granules will be shown.

The main advantage of these Composite Granules is the end product characteristics (size, shape, composition) that improves their fertilizing applications and their handling and storage.

The present applications of the FDG :

- rounding of compacted products,
- granulation of solutions and slurries,
- granulation and fattening of molten salts,

will be reviewed.

A special case of molten salts granulation will be presented with more details. This is the supergranules manufacturing. The supergranules are particles of sizes above 6 mm that are widely used for forest fertilization.

1. Introduction

KALTENBACH THÜRING's (KT) Fluid Drum Granulator (FDG) process has been applied to the granulation of many products (ammonium nitrate, urea etc..) and is still being developed for new applications. The one we are presenting today is the manufacturing of COMPOSITE GRANULES.

The term Composite Granules, represents particles having a core and an external layer of different NPK composition.

This technique was developed in our pilot plant in Beauvais in FRANCE. But first we will present the FDG process.

1.1. FDG Process Description (see figure No. 1.1.):

The heart of the process is a horizontally aligned cylindrical granulating drum which rotates around its axis in the conventional fashion. The interior of the drum is fitted with special anti-clogging lifters. But the main feature distinguishing it from conventional drum granulators is an internal fluidized bed. This comprises a flat perforated plate through which fluidizing air is blown (direct from the atmosphere or after conditioning, according to the product being granulated).

The granulator is supplied with seed material, which can be recycled off-size but might also be prills that it is desirable to enlarge or a compacted product that is desirable to make smoother and rounder or any Granule to be coated with a product of different composition. In the granulator the material is subjected to the dual operation of size enlargement and cooling or drying as the case may be. This occurs progressively in the following cyclic sequence : the lifters raise the seed material to the upper part of the drum, whereupon it falls onto the surface of the fluidized bed. This is where the product is cooled or dried (when feed material is a slurry). The product flows on the bed and falls into the lower part of the drum. As it falls, it is sprayed with the feed melt or slurry. The coated granule is then lifted back to the fluidized bed where the new surface layer solidifies by cooling or evaporation of its moisture content. The same cycle is then repeated as many times as necessary to reach the desired grain size.

Various additives, such as fillers, micronutrients or other specific additives, can be added with the sprayed product.

An external fan draws the air out of the granulator.

1.2. Pilot Plant (shown on pictures)

The pilot plant is composed of a large variety of equipments (FDG, pipe reactor, dryer, cooler, screens, scrubber etc..) that can be interconnected with a great facility.

The Fluid Drum Granulator has a diameter of 1m and a of length 1.2 m. The production capacity of the drum is in the range of 200 to 1000 kg/hr, which is a good basis for the scaling up to the industrial plants.

KT has a team which is in charge of developing new applications for the FDG. The basic engineering of the industrial plants is performed by the engineering team of KT.

2 Present FDG Applications

As said before the FDG has been applied industrially to the granulations of various products.

The main present applications are :

2.1. "Rounding Off" of Compacted Products:

The product leaving the drum will have the edges fairly round and a better resistance to abrasion.

2.2. Granulation of Solutions or Slurries:

The main application is the granulation of ammonium sulphate solutions or slurries. For this case the fluid bed is fed with hot air to ensure the evaporation of the moisture brought by the solution or slurry.

Lately the granulation of biochemicals (such as Lysine which is a product for animal feed) has been realized and an industrial project is under construction. One of the features of this granulation is the small size of the granules which are in the range of 700 μm.

2.3. Fattening of Molten Salts:

The fattening of urea or ammonium nitrate prills refers to the enlargement of the granules in the FDG by coating with the molten solution. This will be clearly explained with the industrial example presented here after.

- CORK fattening unit 1100 TPD :

The prills from the prilling tower are introduced into the fluid drum granulator as seed material and urea melt is sprayed. The granules are enlarged with the succesive layers of product cristallizing over the prills.

The specifications of the prills and product exiting the drum corresponding to the flowsheet are enclosed (table No. 2.3.1. and figure No. 2.3.2.).

The characteristics of the fattened prills to point out are their improved crushing strength and abrasion resistance and of course their size (around 2.7 mm) which is ideal for handling, storage and bulk blending.

For the process we have to point out the reduction of dust emissions from the prilling tower due to its lower capacity, as part of the melt is being cristallized in the FDG.

2.4. Granulation of Molten Salts:

The granulation is the process in which the seeds fed to the FDG are made of crushed on-size product recycled to the drum. As for the fattening, cooling of the fattened prills is needed to solidify the successive layers deposited on the granule surface and is performed on the fluid bed fed with ambient air.

The granulation process versatility allows the manufacture of granules with sizes ranging from 2.5 up to > 10 mm in the same granulation loop.

We are presenting the application of the granulation process to the manufacture of supergranules.

- Supergranules (urea and ammonium nitrate) manufacturing :

Supergranules are particles of size above 6 mm which are extensively used for forest fertilization. This granules have been produced in the pilot plant FDG with great success.

We are enclosing the typical process flowsheet (see figure No. 2.4.1.).

For this case the seed material can be either prills or crushed onsize product that is sent to the FDG. Melt is sprayed in the drum to coat the product with different layers.

The product exiting the FDG is screened. The possible lumps and fines are withdrawn and melted; the onsize product is cooled in a fluid bed cooler and bagged.

The undersize product is recycled to the FDG.
Pilot plant results : UREA SUPERGRANULES

The main operating conditions and granules characteristics are shown on the following table.

Table 2.4.1 : Recycle rate 1 : 1.

UREA	Seed material	FDG	
		melt	Onsize
Flowrates (kg/hr)	2	240	242
Granule diameter (mm)	1.6	–	12.5
Crushing strength (kgf)	0.7	–	>10
Bulk density (kg/l)	0.71	–	0.66

The curve of the crushing strength in relationship with granule diameter is presented on the following figure. We can observe the increase of the crushing strength due to the layering effect of the FDG.

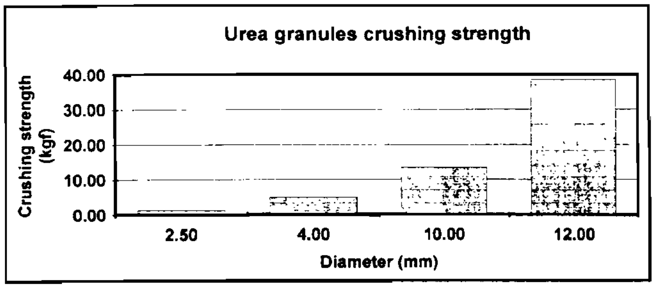


Figure 2.4.2. Crushing strength of urea granules manufactured in the FDG

Other products such as ammonium nitrate supergranules have also been manufactured in the pilot plant.

2.5. Conclusions:

These examples point out the versatility of the fluid drum granulator for the production of granules with mean diameter ranging from:

- 700 µm biochemicals,
- 1.7 to 5 mm for conventional fertilizers,
- up to >6 mm for supergranules.

A list of references for the FDG is enclosed.

3. Latest Applications: Manufacturung of Composite Granules

This section presents the FDG in its application to the manufacturing of COMPOSITE GRANULES.

As defined before Composite Granules, are particles having a core and an external layer of different compositions. One or more layers of different nutrients may be applied on the granule to obtain the desired final composition and structure.

Practically this is performed in the FLUID DRUM GRANULATOR by introducing seeds, which may be granules of a straight or compound fertilizer and spraying a melt or slurry to coat them.

3.1. Application to Upgrading of NPK Plants:

3.1.1. Introduction

Pilot plant trials were performed to confirm the feasability of manufacturing Composite Granules for the upgrading of an NPK plant. The results of these tests and the unit revamping foreseen will be presented.

But first we will compare the different methods used to produce complex fertilizers..

3.1.2. Methods for manufacturing complex fertilizers

Presently two methods are widely used to bring the required nutrients N, P2O5, K2O to the crops :

- Bulk Blending,
- Compound Fertilizers.

Bulk Blended fertilizers

Bulk Blending is performed by mixing dry granules of different nature. The more common materials used are monoammonium and diammonium phosphate, triple superphosphate, potassium chloride, ammonium nitrate, urea and ammonium sulphate.

Characteristics: This method has the advantage of being simple as it is limited to mixing of dry raw granules.

However this technology has some basic problems which require attention. All material has to be strong and in a well dried form specially for long storage periods to avoid caking problems. Moreover the mixing of certain compounds can not be done due the high hygroscopicity of the resulting mixture (urea and ammonium nitrate or compounds containing ammonium nitrate and urea and single or triple superphosphate).

The other main drawback of this method is segregation of the material after being mixed which can lead to a widely different composition. The segregation is caused by difference in particle sizes of the raw materials.

Compound fertilizers

In compound fertilizers each granule has the desired NPK composition. Many processes exist to manufacture these fertilizers :

- granulation of dry mixed material with

steam/water or by addition of materials that react chemically,
• slurry granulation,
• melt granulation, } (drum/pugmill or pan
• and prilling. granulators),

Characteristics: The compound fertilizers present the advantage of having all the required nutrients in each granule.

This method is however fairly expensive as most of the granulations require high recycle rates. This results in large equipment (granulator, dryer, screening section and air scrubber).

Prilling of melt makes it difficult to introduce potash in the formula as it is insoluble and can cause clogging of spraying equipment.

Composite granules

Each granule will have the desired NPK composition, but the manufacturing is extremely simple as for a straight fertilizer, and is less expensive compared with the production of compound fertilizers.

The core of the granule which may be a straight or a compound fertilizer will be coated with one or more melts that can be ammonium nitrate, urea or a nitrophosphate.

This method presents several advantages :

- The granules have an external layer rich in nitrogen that can be rapidly assimilated by the plant.
- The PK core content will be delivered to the plant in a second step.
- Potash and nitrate are isolated in different zones of the granule, and the reaction between them will be limited.
- The coating of the granules with the melt reduces the dust formation of particles made from agglomerated powders.
- The layering effect of the FDG increases the physical characteristics (hardness, friability) of the granules and improves their physical aspect.
- Finally the implementation of the FDG in an existing plant is an excellent way to improve the product quality and increase the capacity of the unit.

An example of the manufacturing of Composite Granules applied to the upgrading of an NPK plant will be presented in the following section.

3.1.3. Practical Applications : Upgrading of NPK Plants

The example we are presenting hereunder is a study for an NPK plant and is based on KT pilot plant trials.

• Original granulation loop (see figure No. 3.1.1.):

The plant has a capacity of around 400 000 T/Y of NPK fertilizers with main grades being 15-15-15 and 17-6-18.

The NPK granules are produced in a pugmill granulation loop starting from solid raw materials (potash, ammonium phosphate and filler) and with an NP melt produced in the wet section of the plant (N/P2O5 ratios varying from 1.9 to 3 depending on the grades to be produced).

The loop consists of the granulator, the drier and the screening section. The oversize granules are crushed and returned with the undersize to the granulator. The onsize product is cooled in a drum with air and sent to storage.

The capacity of the plant has been increased from its nameplate capacity by nearly 30%. This increase has been achieved with a reduction of the main equipment efficiency, namely granulator, drying and screening, leaving the following problems:

- high recycle rates around 5 : 1 with a corresponding higher electricty consumption,
- and poor product characteristics : high humidity and high granulometric dispersion with the corresponding caking problems.

• FDG Upgrading of the plant (see figure No. 3.1.2.) :

The heart of the revamping step will be to install an FDG where the product leaving the granulation loop will be coated with an NP melt.

The original granulation loop will remain without extensive modifications to produce the NPK seeds. These granules, having an intermediate composition (with a low nitrate content) will be called PREGRADE. The granulation of the Pregrade will be realized with steam (and in some cases with a part of the NP melt) in the existing granulator.

The Pregrade granules will be fed to the FDG where the melt (N/P2O5 composition ranging from 1.9 to 3 depending on the grades to be produced) will be sprayed to coat the granules with a uniform layer.

The product exiting the FDG will be screened and cooled in the existing drum and will have the desired NPK composition and granule size.

The final composition can be easily modified by varying the pregrade composition and the melt N/P2O5 ratio. The size of the granules leaving the FDG can be adjusted by changing the ratio of melt to seeds fed to the drum.

The advantages of the Composite Granules have already been quoted in the above section.

The upgrading of the plant with the FDG has several advantages namely :

- improved characteristics of the end product (lower humidity, narrow granulometric dispersion),

- bring back the original granulation loop to its nameplate capacity for optimum operation,

- extra capacity with the FDG implementation,

• and finally low investment cost.

Table no. 3.1.3.1 : Differences between original granulation loop and after FDG revamping.

NPK granulation plant for a 15-15-15 Grade	Original granulation loop		Expected values After FDG revamping	
Humidity (%)	1.0 - 1.5		below 1.0	
PBM (%)	>1.6		< 0.2	
Granulometric dispersion	high	(>4 mm) 6%	narrow	(>4 mm) 2%
		(<1.4 mm) 4%		(<1.4 mm) 1%
Name plate capacity (t/d)	840		1200	
Shape	irregular		very round	

Note : Abrasion resistance test made with the SUDIC method. PBM= Particle breakdown modulus.

• Pilot plant trials results :

As said before, the revamping project has been based on tests performed in KT pilot FDG.

Granules with an intermediate composition (Pregrade) were introduced and sprayed with a melt (NP with a concentration of 96%) in the FDG.

Heated atmospheric air was introduced in the drum to cristallize the melt and evaporate the moisture.

Table no. 3.1.3.2 : Results of the trial for the manufacture of a grade 18-15-11

Pilot plant trials NPK plant upgrading	PREGRADE (FDG Inlet)	FDG	
		Melt (96% conc.)	FDG outlet
Flowrates (kg/hr)	250	210	450
Granules diameter (mm)	2.7	-	3.3
Humidity (%)	1.8	4	1.1
PBM (%)	1.7	-	0.1
%N	9	29	18.0
% P_2O_5	16	14	15.0
% K_2O	20	-	11.0

PBM = Particle breakdown modulus.

The result shows the Pregrade and final compositions of the granules, as well as their size before and after FDG. The fattening factor depends on the ratio of liquid to solid fed to the drum and can be easily modified.

Various grades were obtained in the pilot plant by modifying the Pregrade and melt composition.

We are showing on the enclosed pictures (figure No. 3.1.3.) the structure of the Composite Granules obtained in the pilot FDG corresponding to the above table.

3.2. Application For Coating of Ammonium Sulphate Crystals:

• Interest of coating ammonium sulphate crystals:

Ammonium sulphate solutions have been granulated in the FDG to produce granules with mean diameters ranging from 2-4 mm . The shape of the product is extremely important for its end use and granules present unquestionnable advantages over crystals of small size (around 700 mm) in terms of caking and spreading problems.

KT has developed in the pilot plant the process to manufacture Composite Granules with a core being ammonium sulphate crystals coated with a melt (ammonium nitrate,urea etc..).

The Composite Granules that were produced, present better physical characteristics that sharply improves their handling (roundness, size, hardness) over the ammonium sulphate crystals.

• Pilot plant results:

Test description:

Crystals of ammonium sulphate (mean size 800 µm) are continuously fed (with the recycle) to the FDG and sprayed with a melt of ammonium nitrate of 98 % concentration.

The granules leaving the drum are screened to withdraw the possibly formed fines and lumps, to collect the on-size product (>1.6 mm) and return the undersize product to the FDG.

Table 3.2.1: Test operating conditions and product characteristics

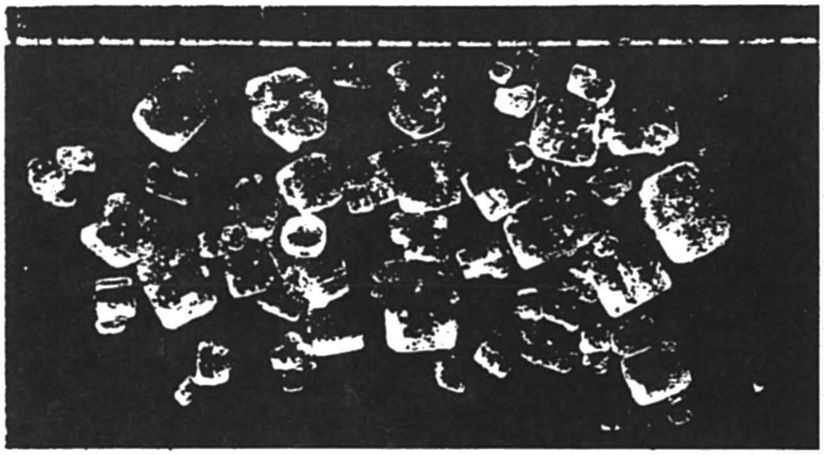
Pilot plant trials	Ammonium sulphate crystals	FDG	
		Melt	On-size product
Flowrates (kg/hr)	25	175	200
mean diameter (mm)	0.8	–	1.6
shape	irregular	–	very round
Bulk density (kg/m^3)	1085	–	947
% N	21.2	35	33.4
% SO_4	72.7	-	9.1

The composition and the size of the final product can be easily controlled depending on the ratios of sulphate to nitrate in the Composite Granules.

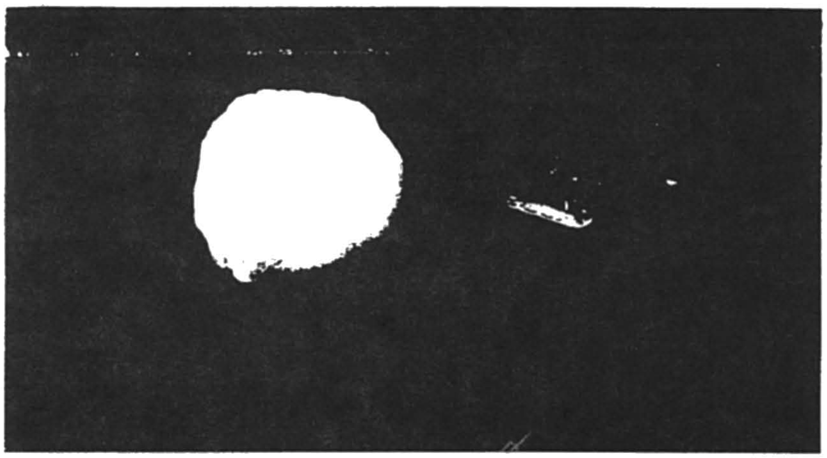
Other coating substances can be sprayed in the FDG. The way is opened to a large variety of compound fertilizers.

The structures of these Composite Granules obtained in the pilot plant are shown on the joined pictures (figure No. 3.2.1.).

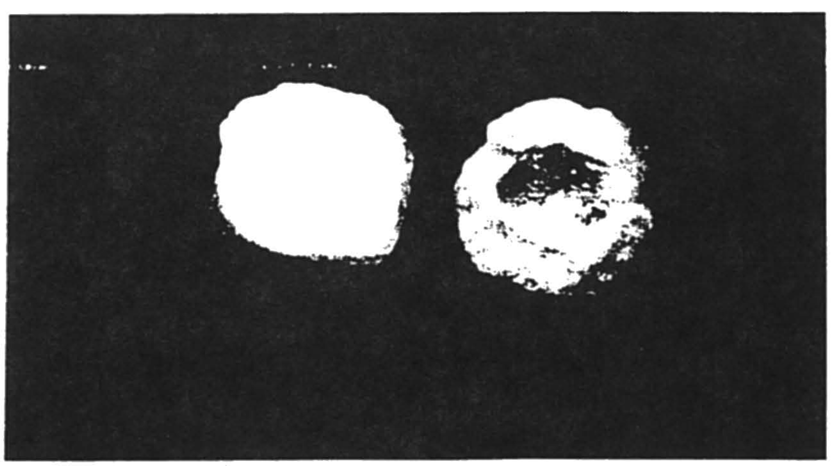
Figure 3.2.1: Ammonium Sulphate – Ammonium Nitrate Composite Granules



A – Ammonium Sulphate Crystals

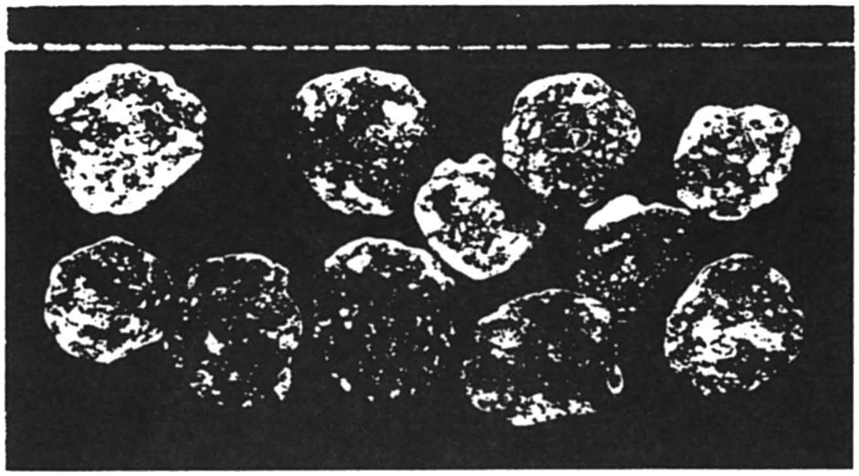


B – Granules before and after FDG Coating

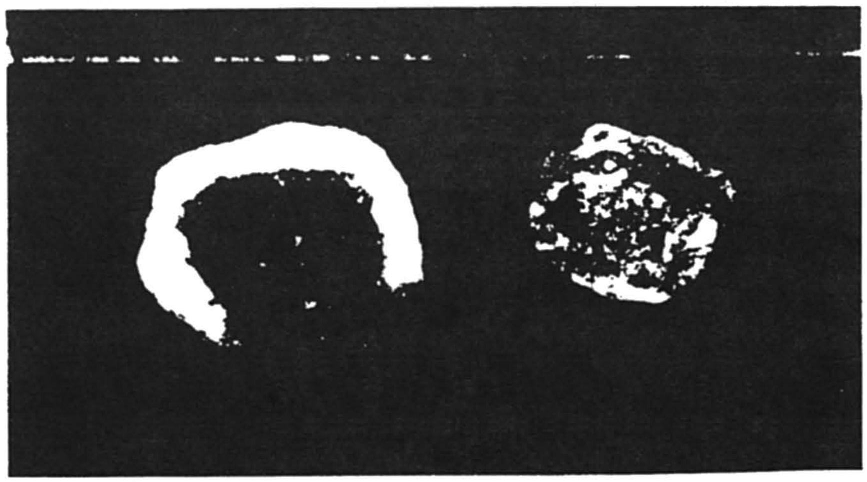


C – Composite Granules : N-SO_4 33.3 - 9.1

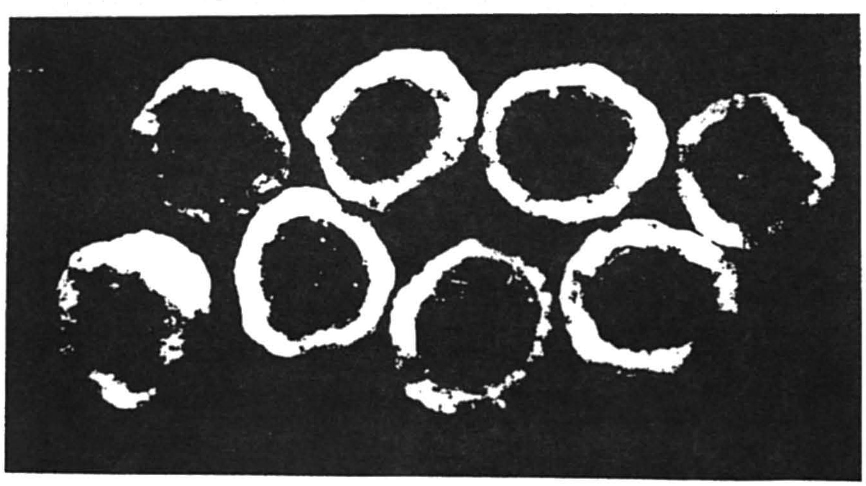
Figure 3.1.3: NPK Composite Granules



A– Pregrade (core of Composite Granule (N – P_2O5 – K_2O) 9-16-20)



B– Granules before and after FDG coating (external layer (N - P_2O_5 - K_2O) 29-14-0)



C – Composite Granules: N - P_2O_5 - K_2O 18-15-11

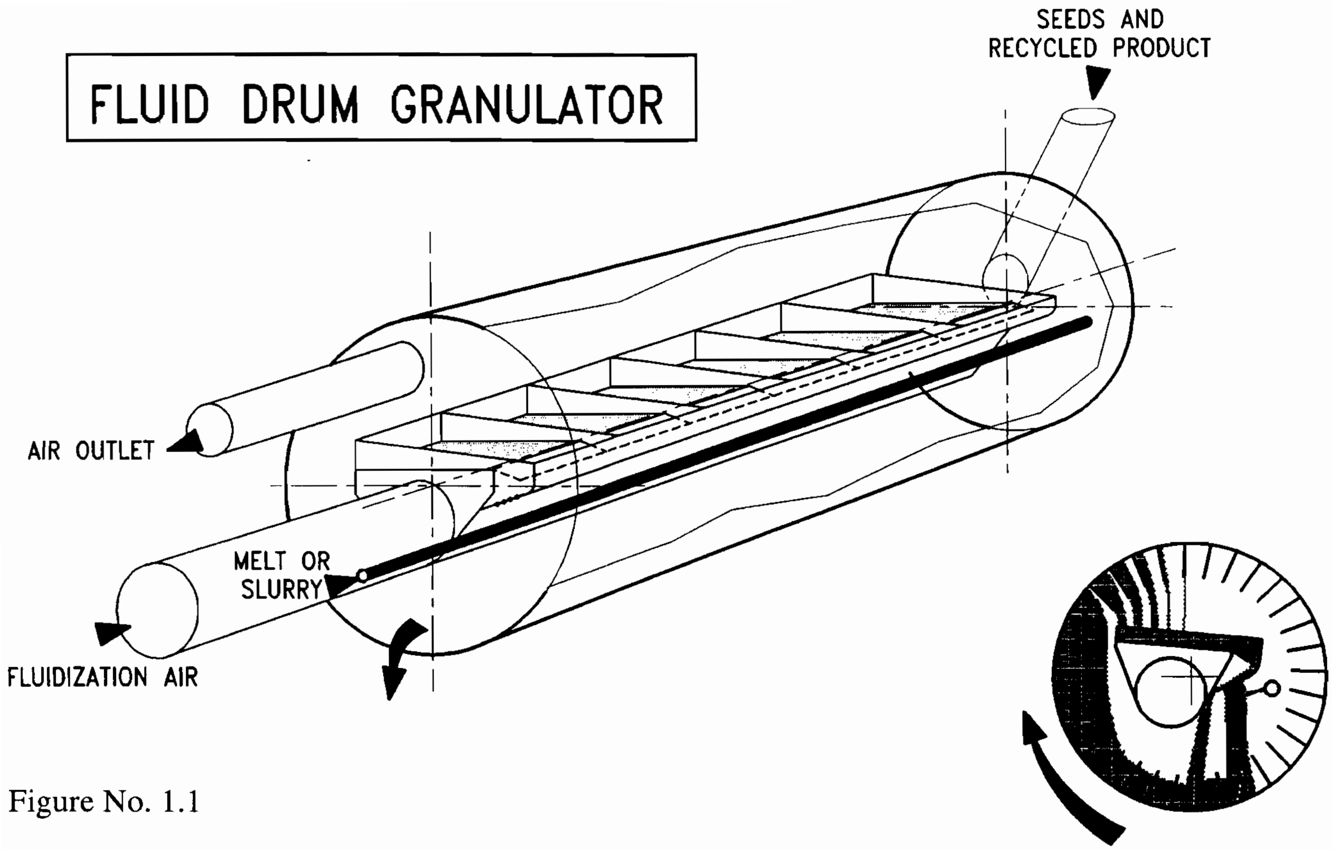


Figure No. 1.1

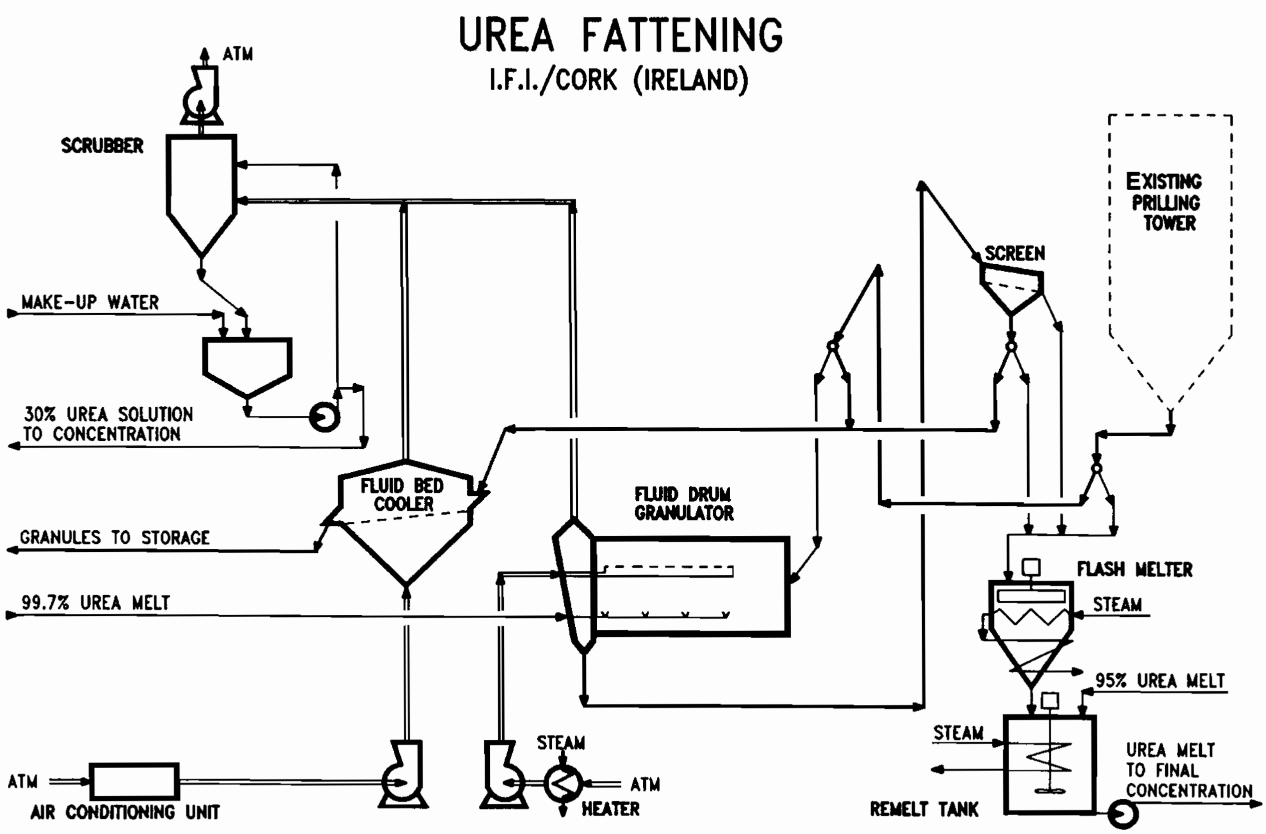


Figure No. 2.3.2

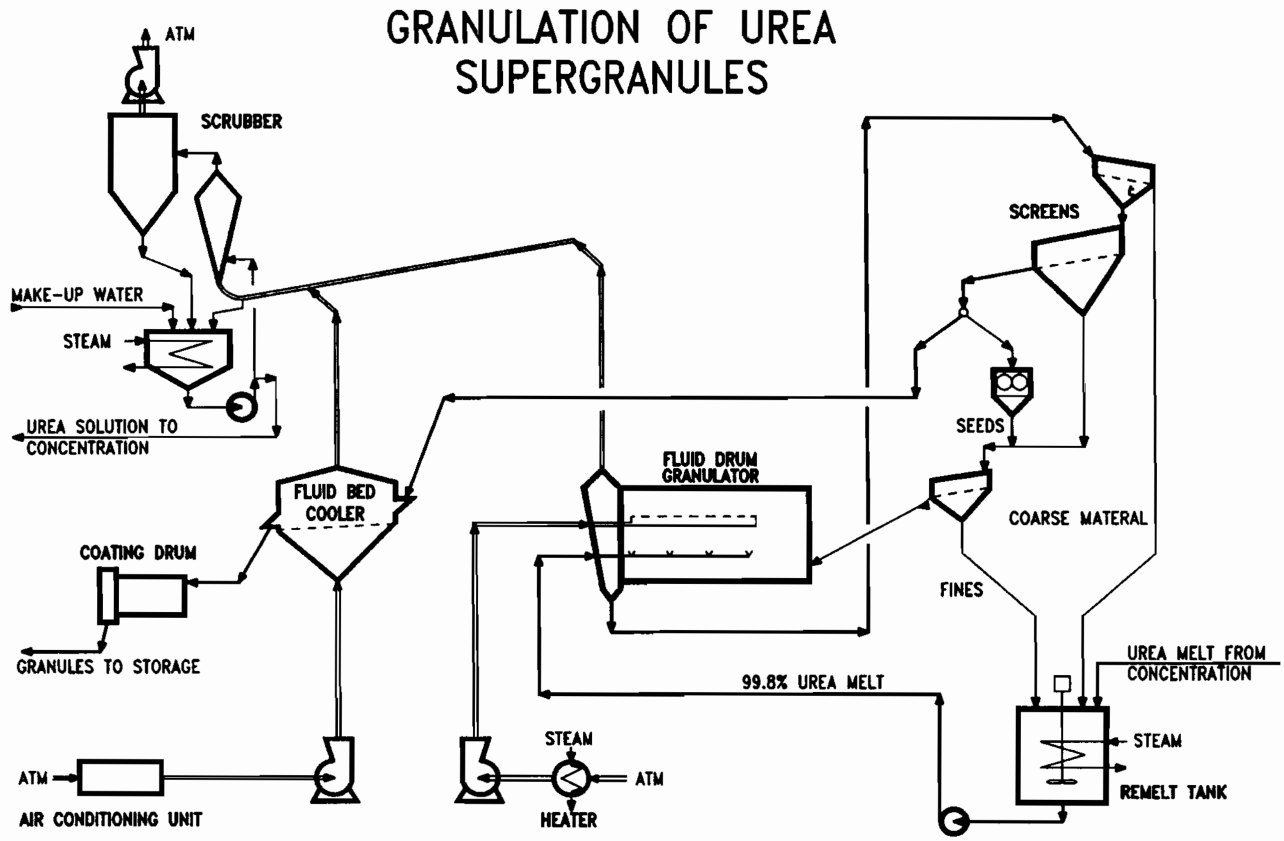


Figure No. 2.4.1

N.P.K. GRANULATION PLANT BEFORE F.D.G. REVAMPING

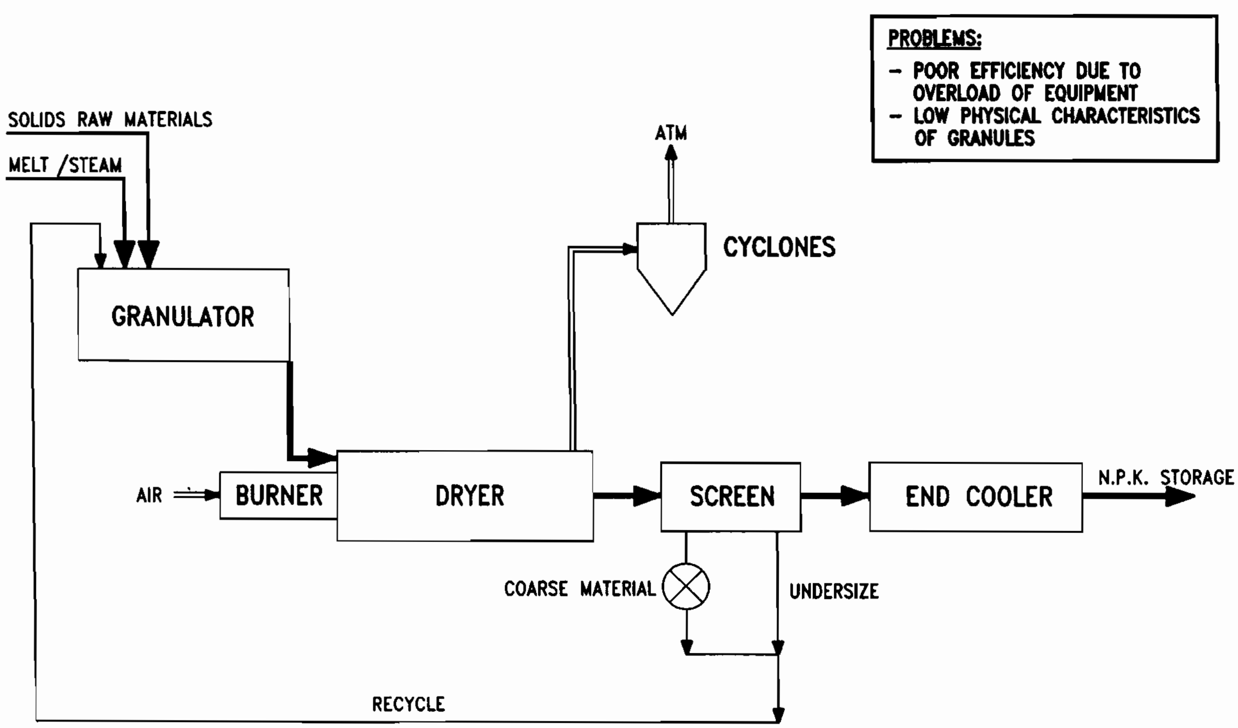


Figure No. 3.1.1

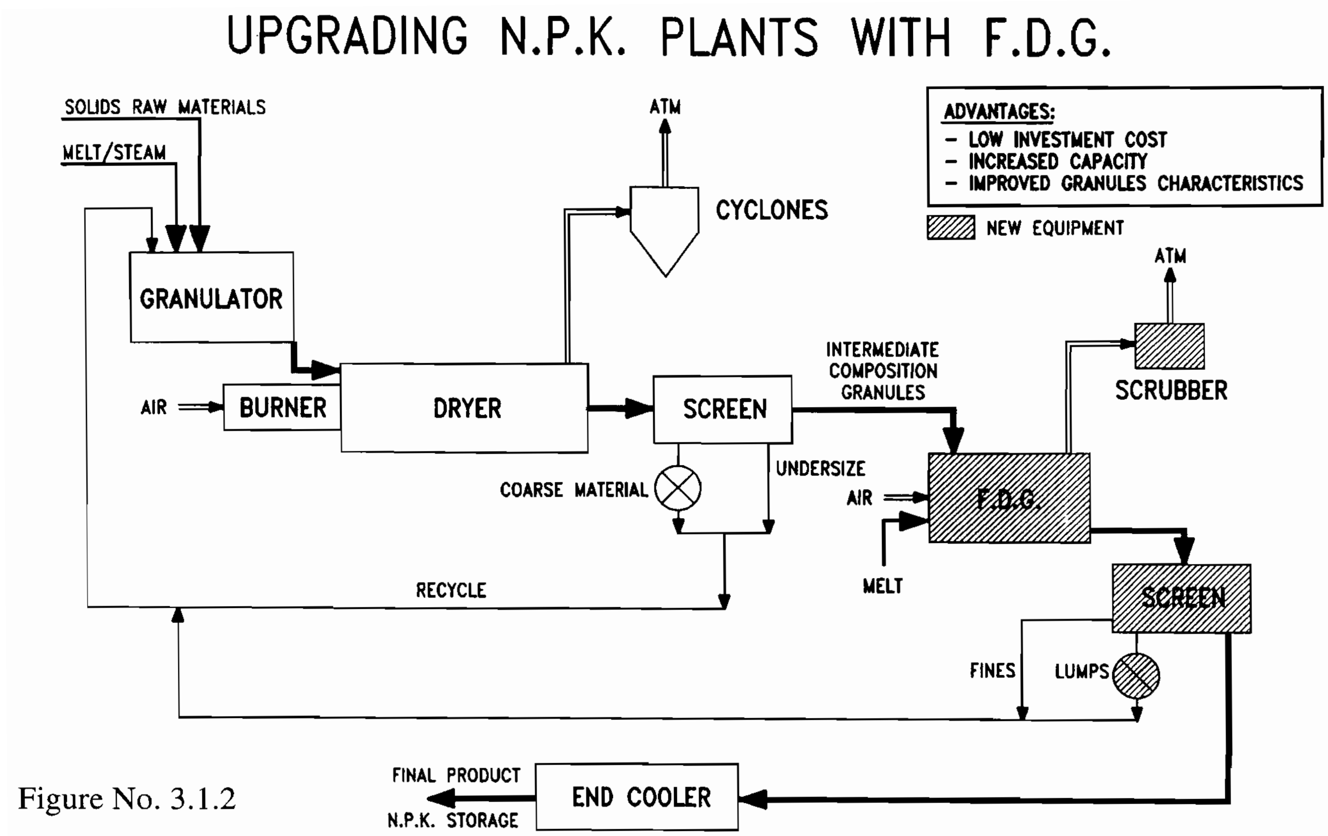


Figure No. 3.1.2

Table No. 2.3.1

Plant owner	:	**I.F.I.**
Location	:	**Cork (Ireland)**
Product	:	**Urea**
Type of process	:	**Fattening**
Specifications of the FDG inlet products		
Solid		
. nature	:	urea prills
. mean particle size	:	2.1 mm
. water content	:	0.3 %
. temperature	:	75°C to 85°C
. biuret content	:	1%
. crushing strength	:	0.75 kg
. resistance to abrasion (% breakdown)	:	5 %
. flowrate	:	22 t/h
Liquid		
. nature	:	urea melt
. concentration	:	99.7 %
. temperature	:	140°C
. flowrate	:	23 t/h
Specifications of the final product		
. nature	:	"fattened" prills
. particle size / mean diameter	:	2.7 mm
. water content	:	0.2 %
. biuret content	:	1 %
. crushing strength	:	2 kg
. resistance to abrasion (% breakdown)	:	0.3 %
. temperature (to storage)	:	45°C to 50°C
. flow	:	45 t/h
Recycle		
Solid		
. nature	:	nil
. ratio	:	nil
Liquid		
nature	:	Urea solution
. ratio	:	0.025 / 1 to 0.050 / 1
Emissions		
. Prill tower to atmosphere		
– before installation of FDG	.	38 kg/h
– after installation of FDG	:	18 kg/h
. Scrubber of FDG to atmosphere	:	1 kg/h

Molecular Responses of Plants to Phosphate Deficiency

K.G. Ragothama, PHD.

Purdue University

Our research at Purdue University is focused on understanding how plants respond and adapt to limiting levels of P in nature. The long term goal of this research is to understand fundamental processes leading to the survival of the plants under limiting nutrient conditions and to genetically modify plants to enhance the acquisition of applied fertilizer.

Phosphorus is one of the least available of all essential nutrients in the soil (Barber 1980). This deficiency can result in retarded plant growth and severe reduction in yield. Phosphate interacts strongly with soil particles and remains relatively immobile in the rhizosphere. Because of the unique nature of phosphate interaction with soil particles and slow movement by diffusion, up to 75% of applied P may be unavailable for plants, forcing farmers to apply 4 -5 times more phosphorus than needed for crop production. Phosphorus deficiency in nature is not new to plants. In response to limiting levels of P they have developed several adaptive mechanisms. Table 1 outlines some of changes occurring in plants growing under P deficiency. Plants under P limiting conditions exhibit multiple responses (Marschner, 1995), including enhanced root growth, altered root morphology, enhanced uptake of P, production of phosphatases and RNases, acidification of growth media, and synthesis of new proteins. Phosphate starvation also results in altered gene expression in plants (Liu and Raghothama 1995, 1996, Liu et al. 1997, Muchhal et al. 1996), and presumably the regulation of some of these genes facilitates P acquisition and utilization. Altered gene expression is a component of plant responses to phosphate starvation (Liu and Raghothama, 1995; 1996; Liu et al., 1997). Our knowledge about genes expressed during phosphate deficiency is increasing (Table 2).

Phosphate Uptake and Transporters

One particular adaptation that plants undergo in response to P deficiency is the development of enhanced ability to absorb phosphorus. Many studies using whole plants and cell cultures have clearly demonstrated that plants starved for P for a short time exhibit enhanced ability for phosphorus uptake. Phosphate is acquired by plants in an energy mediated cotransport process, driven by a proton gradient generated by the plasma membrane H+-ATPases (Figure 1). Our laboratory was the first to report the cloning and characterization of high-affinity phosphate transporter genes from plants (Muchhal et al., 1996). Subsequently, several laboratories have reported the cloning of similar genes from different plants (Smith et al., 1997, Leggewie et al., 1997, Kai et al., 1997, Liu et al., 1997). A computer generated model of phosphate transporter is presented in Figure 2. This is a membrane bound protein allowing hydrogen and phosphate ions to pass from outside, i.e. soil solution, to inside of the cell. Recently a research group in Japan has shown that constitutive expression of an Arabidopsis plant phosphate transporter gene in tobacco cell cultures resulted in increased fresh weight and uptake of P under low concentration of phosphorus (Mitsukawa et al., 1997). Now, there are at least 8 different research groups around the world working on phosphate transporter genes. This level of research activity in phosphate transporters emphasizes the significance of phosphorus in plant nutrition and sustainability of world agriculture in the future.

Our research has shown that phosphate uptake by plants is regulated, at least in part, at the level of gene expression. Plants monitor the deficiency of phosphorus in the soil, and this information is communicated to the nucleus of root cells to activate the expression of phosphate transporter genes. At present it is not clear how this deficiency signal is communicated in the plant. The sequence of molecular events leading to production of more phosphate transporters is shown in Figure 3. Enhanced gene expression results in increased message for synthesis of phosphate transporters. Increased number of transporters prime the plants to acquire more phosphate when it becomes available. The Figure 3 is a simplistic representation of one of the molecular events occurring under phosphate deficiency. The regulation of each step outlined in Figure 3, may involve a complex interaction between several protein factors.

Expression of phosphate transporter genes is regulated by changing levels of phosphorus in the growing media. Northern analysis of RNA was used to examine changes in gene expression under altered P concentrations. In this technique, RNA was isolated from roots of aeroponically grown tomato plants misted with nutrient solutions containing 250 micromolar P or no P. The RNA was separated on a denaturing formaldehyde gel, and transferred to a nitrocellulose membrane. The membranes were used for detecting the levels of phosphate transporter message with ^{32}P labeled gene probes. The Phosphate transporter gene is expressed strongly in roots under phosphate deficiency conditions (Figure. 4) . Further studies have revealed the following information on phosphate transporters in plants:

1) Plants have a family of phosphate transporter genes.
2) These genes may be functioning in different tissues or cell types.
3) Phosphate transporters are induced as a specific response to phosphate starvation.
4) Induction of phosphate transporter genes by phosphorus deficiency is rapid and reversible.
5) Tomato phosphate transporter message accumulates in epidermis of roots under phosphate deficiency.

Future prospectus in phosphate uptake research

Most phosphate fertilizers produced today come from non-renewable sources of phosphate rocks. Expanding world population will put enormous pressure on food production and fertilizer usage, and there is need to develop alternate strategies to enhance the uptake and utilization of applied fertilizers. Biotechnological modification of plants with efficient nutrient uptake and utilization traits should alleviate some of these problems.

The nineties have been a most productive time for plant nutrition research. In the last few years, significant breakthroughs in isolation and characterization of several potassium channels and transporters, NO_3 and ammonia transporters, Fe and S transporters and phosphate transporter genes have been accomplished. We now, have the capability to develop technologies to enhance nutrient acquisition and utilization by plants. The recent cloning and characterization of phosphate transporter genes in our laboratory and elsewhere have provided an opportunity to create phosphate uptake-efficient plants in the future. Input-efficient plants are essential to enhance fertilizer usage by plants and to extend production to low fertility lands to meet a growing demand for food by an increasing world population. Reduced application of phosphate fertilizers in combination with plants that are efficient in uptake and utilization of applied phosphorus is an ideal situation for growers and industry. Furthermore, nutrient efficient plants may play a crucial role in the success of the newly emerging technology of precision farming.

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Table 1: Examples of Plant Adaptations to Phosphate Deficiency

Physiological	Nutrient recycling, altered uptake of nutrients.
Morphological	Changes in root architecture, formation of root hairs, proteoid root formation. Association with mycorrhizal fungi.
Biochemical	Increased carbohydrate transfer to roots. Enhanced secretion of organic acids, protons and other specialized organic compounds to enhance the solubility of phosphorus. Secretion of enzymes such as RNases and phosphatases
Molecular	Altered gene expression.

Table 2: List of Genes Expressed Under Phosphate Deficiency

Phosphate transporters
TPSI1 (tomato phosphate starvation induced gene)
Calcium ATPase
RNases
Phosphatases
Vegetative storage protien gene
Beta Glucosidase
Mt4 (A novel gene from *Medicago*)

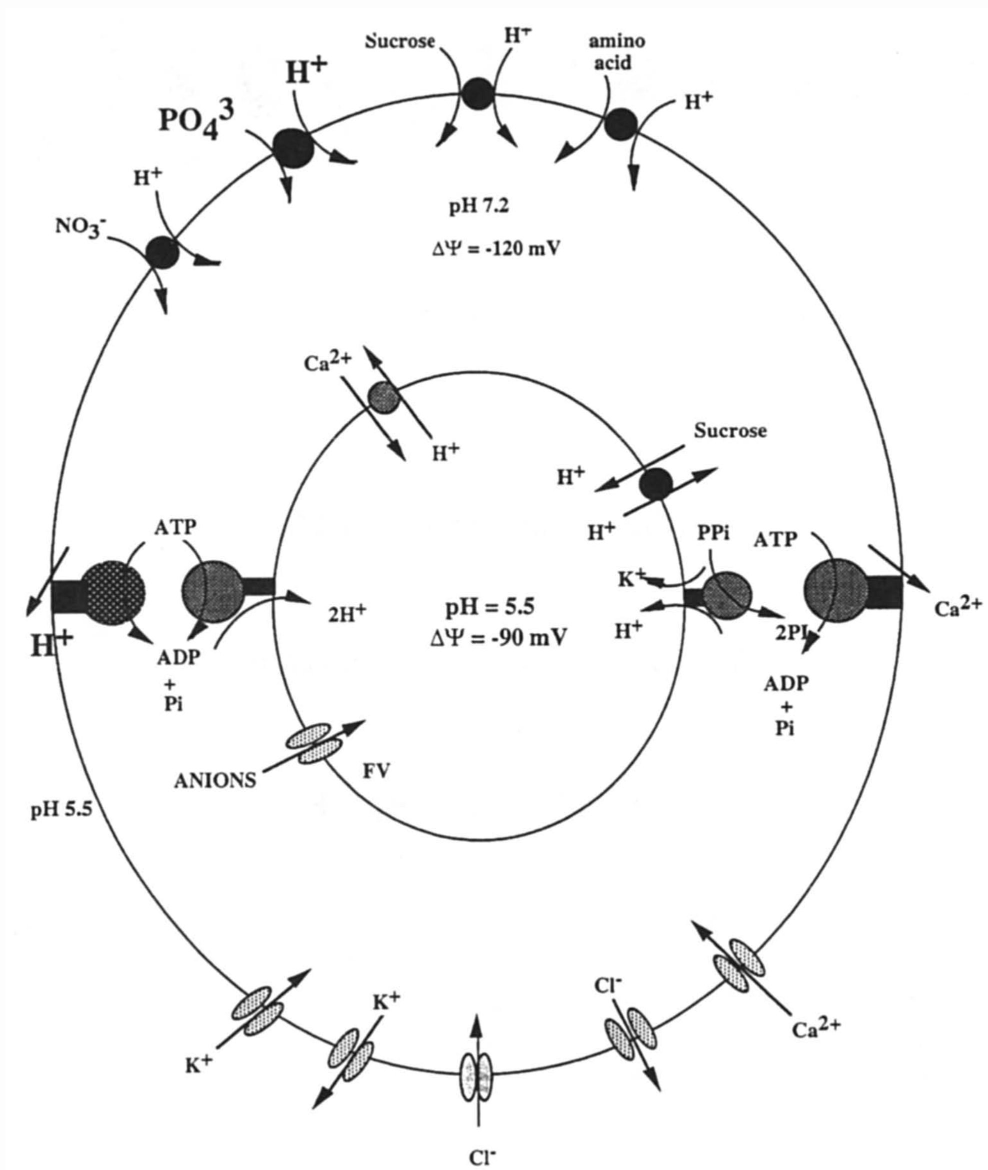


Fig. 1: Mechanism of phosphate uptake by plant root cell

The phosphate transporter is a membrane associated symporter of protons (H+) and Phosphate. This membrane associated protein uses the hydrogen gradient generated by the plasmamembrane H+-ATPase to facilitate the transport of phosphorus and other nutrients.

Fig. 2: Computer generated model of a plant phosphate transporter.
The roman numerals refer to putative membrane spanning domain.

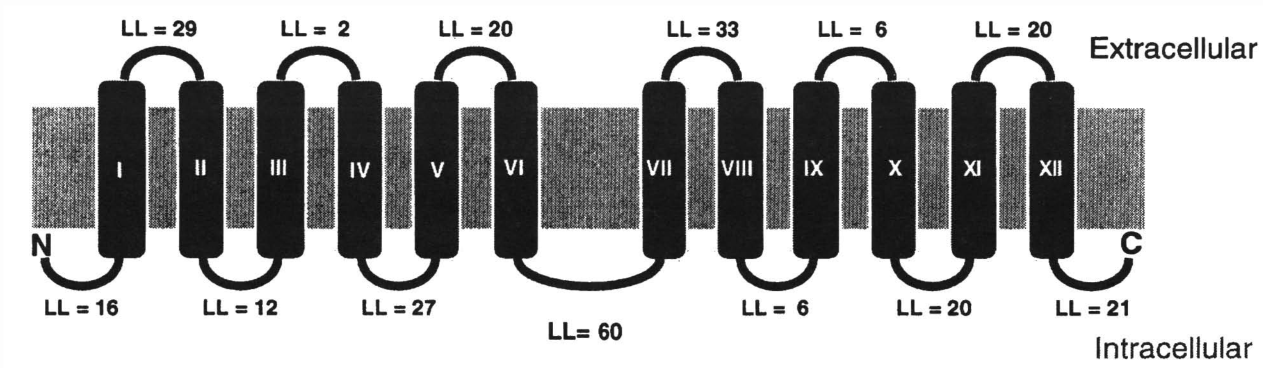


Fig. 3: Molecular regulation of phosphate uptake in plants.

Phosphate transporter gene

↓

Phosphate transporter mRNA

↓

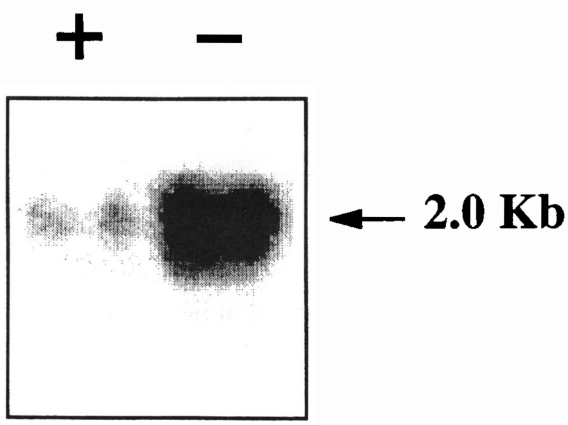
Phosphate transporter protein

↓

Increased phosphate uptake

Fig. 4: Tomato phosphate transporter gene is expressed in response to phosphate starvation.

Northern blot analysis of the expression of tomato phosphate transporter gene. Total RNA from roots of tomato plants grown aeroponically and misted with a solution containing 250 µM (+) or no (-) phosphate was hybridized with ^{32}P labeled phosphate transporter probe. The nitrocellulose filter was exposed to a X-ray film to obtain the autoradiograph depicted below.



Tuesday, October 28, 1997

Session IV

Coordinator:

David Leyshon

The Port of Tampa ships over 10 million tons of fertilizer products, mostly DAP, MAP and TSP annually. About 8 million tons of phosphate rock is also moved through the port. These products are shipped to the far corners of the earth and also barged to the lower Mississippi.

CF Industries maintains an ammonia terminal where the 120 tph pipeline to Central Florida begins. CF's bulk storage for DAP is 75,000 tons which is received by rail and trucked from their Zephyrhills plant.

IMC Agrico's Port Sutton facility includes a 75,000 ton DAP warehouse and 10,000 ton animal feed storage in silos. An ammonia receiving facility with 50,000 t of refrigerated storage feeds the same ammonia pipeline. Ammonia comes from Russia and Trinidad primarily.

Big Bend handles IMC-Agrico's wet phosphate (10%-12% moisture) for shipment to the chemical plants in Louisiana. TSP and phosphoric acid are also shipped out of Big Bend.

Between Port Sutton and Big Bend is the Cargill complex, which was viewed from the road. It produces about 2800 stpd P2O5, DAP, TSP and Map. Their 200-foot high gypsum stack containing the waste of over 70 years of operation was recently capped with a 60-mil plastic cover and a layer of soil. The stack now looks like a big green hill with profuse vegetation - animal and bird life.

About 50 of the Round Table registrants participated in the tour.

Wednesday, October 29, 1997

Session V

Moderator:

Michael Hancock

Precision Agriculture — Industry Point of View

Jeff Keiser

Terra International

Slide Presentation

Precision Agriculture

Precision agriculture is …

…applying generally accepted and environmentally sound agronomic principles and practices to relatively small units of land to maximize returns.

Precision Farming Process

- Collect data to identify variability of soil, environment, and crop characteristics
- Collect yields site-specifically across fields
- Analyze the data to determine appropriate actions
- Manage the within-field variability with DGPS and variable rate input controllers or site specific crop production techniques

Precision In Agriculture™

For customers of Terra, it's the help we offer to:

- understand technology
- profitably apply it to the decision process
- provide services the producers need

Precision In Agriculture™

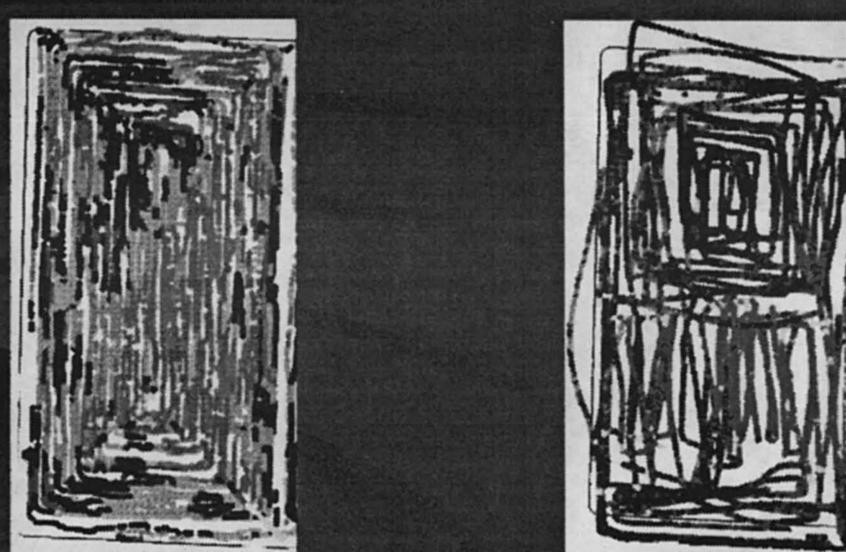
Help from Terra comes in the form of:

- Provisions
- People
- Processes

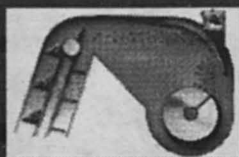
Provisions

- Global Positioning Systems (GPS)
- Differential GPS (DGPS)
- Yield and moisture monitors
- Grid or other intensive soil sampling
- Geographic Information Systems (GIS)
- Variable Rate Technology (VRT)
- Database Management

DGPS Vs. GPS - Examples of Each

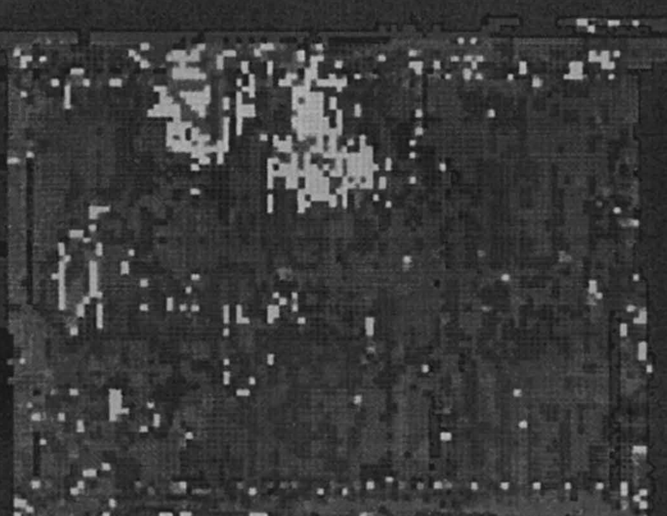


Electronic Equipment



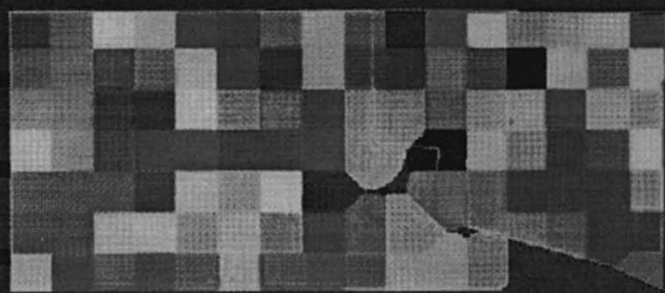
- Yield Monitors
- Laptop Computers
- Weather Stations
- Hand-held sensors and data-loggers
- PCMCIA cards
- Modems
- Radio equipment

Yield Map



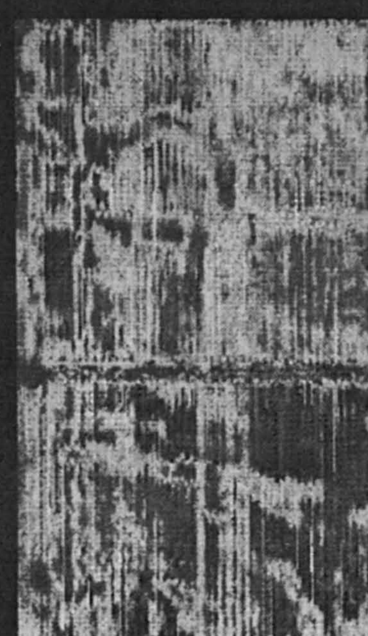
- Quantify variations in yield
- Provoke curiosity and the desire to "fix it"
- Archive data visually

Intensive Soil Testing



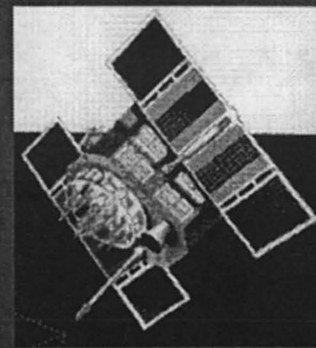
- ➢Grid
- ➢Soil Type
- ➢Management Zone

Geographic Information Systems (GIS)



- Manage, analyze, and present visual images of geo-referenced data
- Present data as layers of field information
- •Mathematically build new layers (mapping programs cannot do this)
- •Can incorporate digitized map features

VRT



Controllers connect the:

- ➢ Variable recommendation
- ➢Product
- ➢Location

Database Management

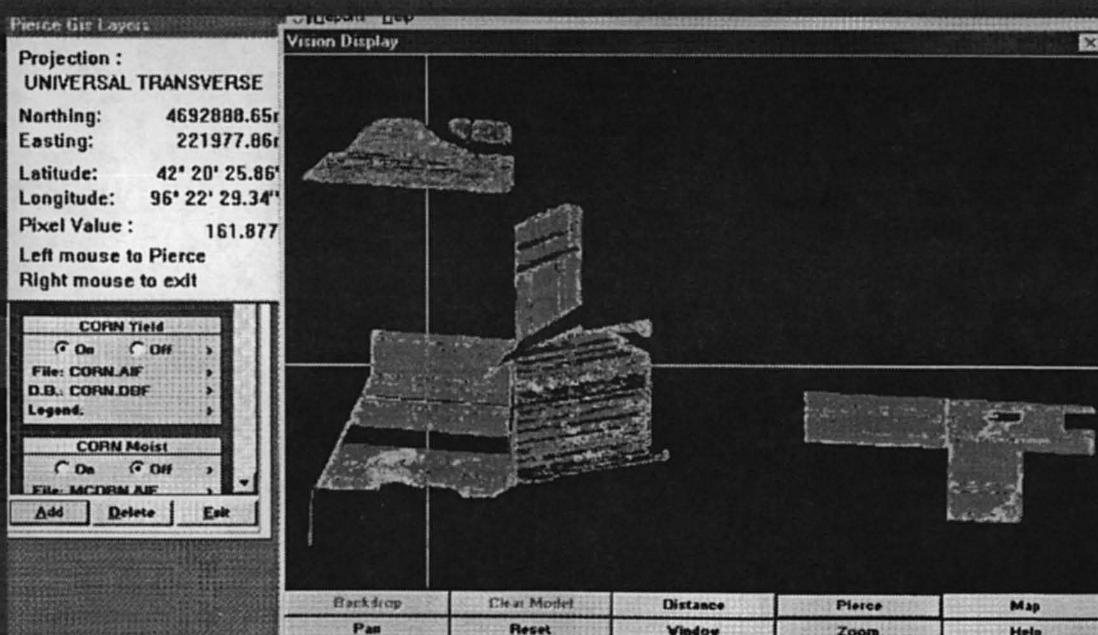
- Data Security
- Data Confidentiality
- Data Accessibility
- Data Accumulation
- Data Analysis

- Decision Support System

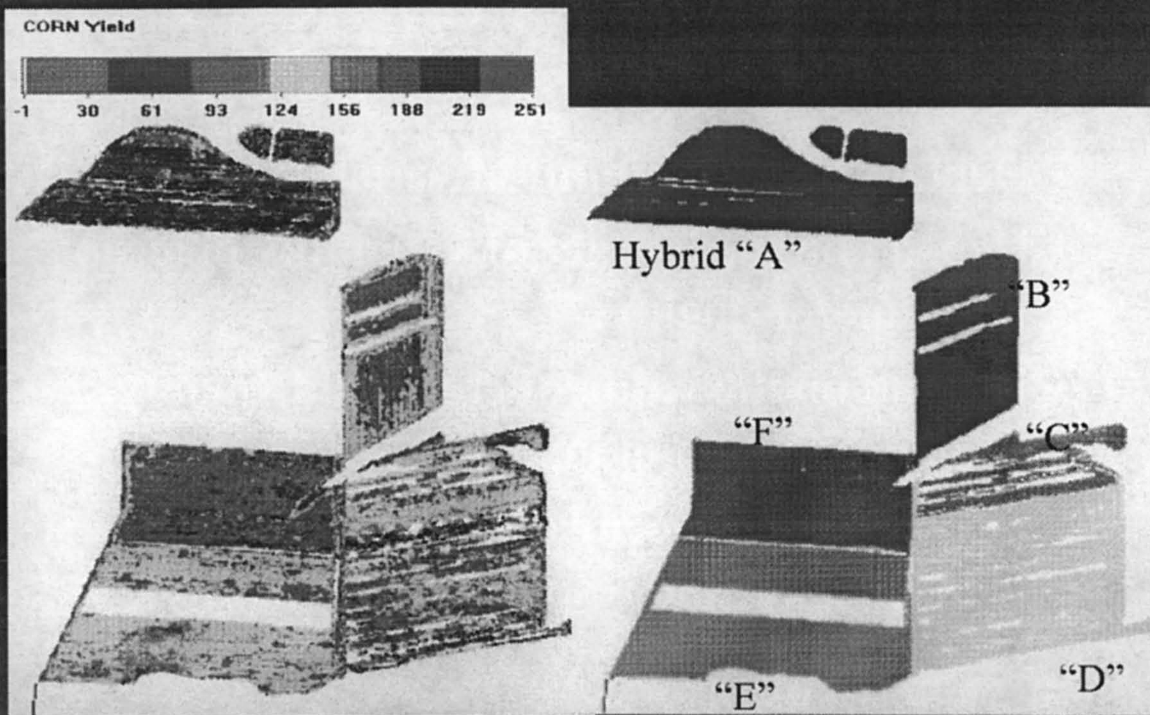
People

Cropping Systems Advisors (CSA) are Terra's experts. They bring the technology out of the laboratory and out into the field. They are agronomists, computer technicians, crop scouts, researchers, and GIS practitioners.

Analyzing Crop Yield

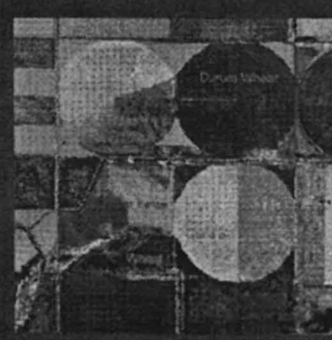


Corn Yield Vs. Hybrid



Under Development

- Crop yield diagnostics and evaluation of alternative management practices
- A database of recommendations (DSS)
- Hyper-spectral remote sensing
- Ground-based sensors



Benefits of Precision Agriculture

- Depend on the **amount** of variability.
- Depend on the **impact** of variability on crop yield and/or quality.
- Depend on the **value** of crop yield, quality, and/or reduction in inputs.
- Depend on the **accuracy** of your identification and response to variability.

Precision Agriculture — Research Point of View

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Introduction

As we prepare to enter into the twenty-first century, a new way of thinking about agronomic crop production is gaining popularity across the United States, Europe, and the rest of the world. This new way of thinking about agricultural production is referred to as Precision Agriculture at this conference. It is important to note that the terms Precision Farming, Prescription Farming, Advanced Farming, Farming by the Foot, Variable Rate Technology, Site Specific Management, and others all relate to the same basic process. This process enters the agricultural industry unlike many other advancements from the past in that it encompasses all phases of production agriculture and does not enter the industry with a strong, scientific, research based foundation. Instead, it enters the industry based on common sense, relationships to scientific fact, and technology incorporated from other industries. It enters the industry with information, both unimaginable in the past decade and of a quantity to boggle the most diligent producer. It is agriculture's entrance into the information age. Its entrance, though gaining wide spread popularity, is challenging existing agricultural institutions as they attempt to incorporate its information, principles, and practices.

What is Precision Agriculture

Precision Agriculture has been defined as "a management concept which recognizes variability within the soil and crop environment and maximizes economic production while minimizing environmental impact for a specific location (Krill, 1994)". Within this definition lie the several key issues of precision agriculture. First, precision agriculture is management. It is not concerned about reinventing the science of agronomy. It is concerned with the decision making process that occurs throughout the process of agronomic production. It is about collecting information, making decisions based on that information, and implementing those decisions. Precision Agriculture is concerned about making better decisions. Secondly, unlike the current system that operates on field averages and uniformity, Precision Agriculture acknowledges and thrives upon the variability that exists within the field. For Precision Agriculture to exist, variability must also exist. The criterion upon which precision agriculture is judged is also unique. It is not judged on maximum agronomic production but on economic efficiency and environmental stewardship. The goal of Precision Agriculture is to improve the economic and environmental conditions of the production agriculturist. Finally, precision agriculture requires the ability to find a specific position accurately, repeatedly, and efficiently. Precision Agriculture requires location and that location is now available through technology. This location technology is what is commonly referred to as the Global Positioning System (GPS) and agriculture requires a level of accuracy that also requires differential correction (DGPS). The positioning system is now available for Precision Agriculture. (See Figure 1.)

Being a management concept, Precision Agriculture is not accomplished through the purchase of a single piece of agronomic equipment but rather through the implementation of an entire process. This process is cyclic (Figure 1) and accomplished through the acceptance and adoption of a new management system by the agronomic producer. The process involves activities represented by the pointed boxes and the creation of spatial data in the form of maps represented by the rounded boxes. The process will span years and several growing seasons. Each individual growing season of precision agriculture management leads directly into the following growing season by providing data and an increased knowledge of the decision making process upon which to base the following years management decisions. In the center of the cycle is probably the single most important part of the precision agriculture process. A producer involved in Precision Agriculture must be willing to learn. This learning is accomplished by continually evaluating the Precision Agriculture process and learning from the outcomes of previous decisions. Learning can also be accomplished through formal attendance at meetings and seminars or reading literature. Much of this information will come through the agricultural research institutions. The private agricultural industries are also taking more interest in the educational needs of today's agricultural producer. Informally, the learning process can also be enhanced through sharing between individuals involved in the agronomic production process. Through this learning process, the agriculturist will be able to improve his/her decision making process and thus the effectiveness of Precision Agriculture for his/her situation. Precision Agriculture is a management system and therefore continual in nature and cannot be accomplished by implementing a single practice, hiring a single application, attending a single meeting, or purchasing a single piece of equipment. Precision Agriculture is a management for agriculture's future.

This management concept begins with the collection of data as the producer attempts to accurately define the current condition of their agricultural land for each and every specific location. The collection of this data can be done in many manners. These manners include the use of existing data such as NRCS soil surveys, Census TIGER files, and others. Additional data can be collected remotely through the use of aerial and satellite digital imagery. Data can also be collected directly from the field through soil sampling, tissue analysis, and yield monitoring. An often forgotten source of data is through the experience of individuals associated with the agronomic production of the land over time. The collection of this data results in the information base in the form of condition maps upon which the process continues, decision making. The first step of Precision Agriculture is defining the current conditions through the collection of spatially identified data.

Using the data collected, the agriculturist advances to the decision making step of Precision Agriculture by attempting to define the current condition and then based on this current condition makes an application recommendation for every specific location. These recommendations are based off of the best agronomic information currently available to the producer. With Precision Agriculture, the demand for agronomic information does not decrease, but increases as current recommendations must be fine-tuned to better represent the identified conditions. It is also important for the agriculturist to continually learn from past results of their own decisions on their own land to improve their decision making process. The economic pay back of Precision Agriculture comes directly from this decision making process. If a producer makes the same decisions using a Precision Agriculture management system that they made using a traditional management system there will be no economic pay back for Precision Agriculture. The pay back for Precision Agriculture is currently the direct result of improved decision making which results in more efficient agronomic production. In the future, some value may be attributed to an increase in land value as a result of the information collected and available regarding that land. The improved agronomic efficiency must result in the economic return to the producer. Because of this individual phenomena, there will not be a general statement related to the economics of Precision Agriculture as each individual situation will be different because of different potential for improved efficiency of agronomic production. Being capital intensive, Precision Agriculture will probably not be scale neutral but have some advantage to the large producer who can spread those capital costs over a larger land resource. The result of the decision making process is the creation of management maps. The management maps contain, to the best of the agronomic producer's capabilities, the optimum rate of individual crop inputs or land improvements to maximize economic efficiency and minimize environmental impact.

The cycle of Precision Agriculture must continue as it must now select and identify equipment capable of making the variable rate application of crop inputs. It is important to note here that all equipment is not created equally and the producer must select equipment capable of making the changes indicated in the management maps. Equipment needs to be evaluated on its accuracy of location, product, and rate along with its rate of change including time and distance. It is the responsibility of the machine to efficiently deliver the products requested at the rates and locations found on the management maps. Because machines are not one hundred percent accurate, a good application device will also record what the actual application of products and rates were in the form of an input map. It might also be necessary for the producer to make other decisions related to the crop and soil environment for a specific location. These decisions could include the addition or modifications of drainage or irrigation systems or the installation of other soil and water control structures. Like any other decisions made, the plan for implementation would be available in the form of a management map and the actual installation would be recorded in an input map. This step is identified as application control with the result of the application being recorded on input maps.

As the crop season closes the producer again returns to data collection and the evaluation of past decisions as the cyclic process prepares to begin another rotation. The creation of performance maps is the conclusion of a single growing season. These maps are a part of the data collection process and can be seen as the conclusion of one cycle and the beginning of the next cycle. Performance maps are most commonly seen in the form of yield maps. These maps accurately portray the results of the growing season. These maps provide the foundation upon which to evaluate past decisions. Under the conditions identified did the decisions reached produce the outcomes expected? This is the time for the producer to learn in order to improve his/her decision making process for future years. It is also unique that as soon as performance maps are created they become past data upon which to base future decisions, a condition map. The precision agriculture cycle is now complete and posed ready to enter into the process again for the second growing season.

Implications to Research

Precision Agriculture has many implications to agronomic research. Precision Agriculture is a management system and therefore crosses several agricultural disciplines. The communication channels between these disciplines within the research institutions are not well established. Historically, the land grant system was responsible for much of the advancement in the agricultural sector. Precision Agriculture back doors the traditional land grant system with its scientific research base and is being driven by technology commonly being adapted from non-agriculture sources. Much of the agronomic research was founded upon single variable research and control through uniformity. Precision Agriculture requires variability and does not fit well into small plot research designs and statistical analysis. Precision Agriculture also provides the producer with access to information on their own farm with little additional effort like they never had before. With this information the agronomic producer can hold the research community accountable for recommendations and challenged for explanations of many agronomic phenomenon discovered on their farm. The concept, practices, and equipment of Precision Agriculture currently and will continue to challenge the research community.

To effectively examine Precision Agricultural systems, a well-trained team with diverse expertise is necessary. By definition, Precision Agriculture must recognize variability within the crop and soil environment and manage that variability. Precision Agriculture is evaluated on its economic and environmental efficiency. Finally, technology and the adoption of that technology to agricultural equipment are what is currently driving Precision Agriculture. As one can see Precision Agriculture does not fit well into any one singular agricultural discipline. Beyond the traditional agricultural disciplines also lie the disciplines related to spatial analysis, positioning systems, and geographical information systems. A strong research program in Precision Agriculture is going to require a multidisciplinary approach including the traditional disciplines of Agronomy, Agricultural Engineering, and Agricultural Economics and new disciplines, many times outside of the agricultural community, related to the spatial nature of Precision Agriculture. Agricultural research organizations will be challenged to develop teams of highly trained individuals from across many disciplines to work as a single unit to examine the complexities and completeness of Precision Agriculture management systems.

Precision Agriculture enters agriculture through channels unlike many of the past and present agricultural advancements. Traditionally, new agricultural advancements are generally discovered and developed through the scientific process and thus have a solid research based foundation. Since its conception in the early 1900's, the land grant college system with its agricultural research and development centers has had a major role in many of these advancements. This system of colleges and research and development centers along with other governmental agencies was seen as the primary and unbiased research mechanism for agriculture. Precision Agriculture has back doored this traditional system and is being driven by technology. This technology is generally being brought to agriculture through the marketplace by private organizations. This technology is also generally not the result of a long scientific process but the adoption of technology from other non-related industries. The primary industries being the declining defense and space department industry. This technology is also being widely accepted by the agricultural community and therefore has left the traditional agricultural research institutions behind, somewhat isolated from the loop, and now trying to play catch up. In this process of catch up, the traditional agricultural research institutions are being challenged to develop this scientific research based foundation in a time of limited resources in both staff and budget.

Precision Agriculture challenges the current methodologies of traditional agronomic research. Much of the existing research was conducted in small plot research. Using this research methodology, the researcher attempted to maintain consistency across all plots except for the one or two research variables. These results were then expanded to agronomic production by identifying field averages and making application to these entire fields by relating field averages to small plot research results. This form of research has provided agriculture with the solid agronomic foundation upon which agriculture has prospered. This type of research is still important and vital for today's agronomic research to maintain that solid foundation; however, it needs to go further with Precision Agriculture. Traditional agronomic research is founded in the ideas of controlling variability through uniformity. Precision Agriculture by definition requires variability and therefore has a conflict with traditional research methodology. Many a research plot has routinely been examined to determine and insure this uniformity through uniformity trials. To examine Precision Agriculture variability must enter into the process. To find variability agronomic research is going to have to expand its small plots into field size research. To conduct these field size research trials, new research methodologies need to be developed, tried, and tested. These new methodologies will also have to incorporate the tools and equipment found in Precision Agriculture. This concept of field size research challenges the traditional agricultural research institutions in finding the resources necessary. These resources will include both the needs for increased land area and technologically advanced Precision Agricultural equipment. To meet these needs, many agronomic research institutions will need to develop and strengthen relationships with current agronomic producers and industry as research is taken from the research plot to their farm. The challenge to the research community continues, as its analytical methods must incorporate the concept of time and space.

Precision Agriculture brings spatial variation into the process of production agriculture. This spatial variation does not fit well into the traditional statistical analysis tools used by agricultural researchers. In Precision Agriculture, immense quantities of data are collected, maintained, and stored through the use of Geographical Information Systems (GIS). This data contains specific information related to measurable characteristics of the crop and soil environment and is tagged with a precise geographical location and time. The development, maintenance, and storage of this information create the first challenge to this next generation of agricultural researcher. Once collected, maintained, and stored, the second challenge arises for the researcher. This spatial data collected in Precision Agriculture needs to be analyzed using a non-traditional agronomic research analytical tool known as geo-statistics. Through using, developing, and proving geo-statistical procedures in production agriculture, the researcher will attempt to gain valuable insight into the spatial distribution and interaction of the variables related to agronomic crop production. Unlike traditional research, these research procedures will be required to not only understand the spatial distribution of the variables but also the interactions between the variables. Instead of dealing with a relatively small number of research plots, the researcher will now be challenged with the millions of pieces of information collected through the use of Precision Agriculture. Upon entering into this new realm of analysis, the next generation of agricultural researchers will need to look beyond the traditional disciplines of agriculture and expand into disciplines with expertise in Geographical Information Systems and the analysis of their data. The knowledge of agronomic information will need to remain rooted in the sound practices of traditional small plot research but then be expanded into the world of Precision Agriculture with its variability, field size plots, and spatial analysis.

Finally, Precision Agriculture challenges all in the agricultural industry by providing the agronomic producer with information like they have never had before. With this information the agronomic producer has an accountable means to verify the decisions implemented on his or her agronomic land. The information collected will also provide the agronomic producer with data to support many agronomic phenomena that will challenge the agricultural research institutions to explain. This information, when properly collected and used within the capabilities of the Precision Farming equipment collecting the information, has the possibility to provide solid information to enter into the decision making and evaluation processes. Poorly collected information also has the possibility to enter the system and produce the opposite effect having a negative impact on agriculture. To insure the reliability and validity of Precision Agriculture data, only tested and proven equipment should be used without reservation that has been installed, calibrated, and operated within the capabilities of the equipment. Researchers will be challenged as they attempt to incorporate this new data into the system as they are held accountable for recommendations made and must explain deviations from expectation. Only through first understanding the process and practices of Precision Agriculture will the researcher be capable of attempting to meet this challenge.

Conclusion

Just as Precision Agriculture is changing the way production agriculture is thinking about agronomic crop production, the agricultural research institutions must also change their thoughts concerning the study of agronomic crop production. The introduction of Precision Agriculture brings the information age fully into the realm of agriculture. With this information, agriculture will operate differently than before. Just as information has changed the business world, so will information change agriculture. With change comes the need for knowledge and the agricultural research institutions must rise up to meet this need for knowledge. The traditional agronomic research must also change to meet the demands of studying Precision Agriculture. Precision Agriculture will require the known agronomic knowledge base to be elevated to the next level. In reaching that level, research agronomists will have to attempt to understand the existing variability in the crop and soil environment and how that variability affects crop growth and development. Known responses will need to be fine tuned for all the different environmental conditions found in production agriculture. In studying variability, new research methodology and analysis techniques will need to be developed, tested, and proven. Single variable studies conducted on small uniform plots will need to be taken into large scale plots in field conditions where variability exists and the interactions commonly found in production agriculture can be studied. Through studying variability, the quantity of information will be like that never seen before by researchers. In dealing with these vast amounts of spatially reference data, researchers will have to learn how to use the powerful information handling and processing tools found in Geographical Information Systems. Traditional researchers will have to look beyond their traditional colleagues and seek information from experts outside of their discipline that understand and know how to use Geographical Information Systems.

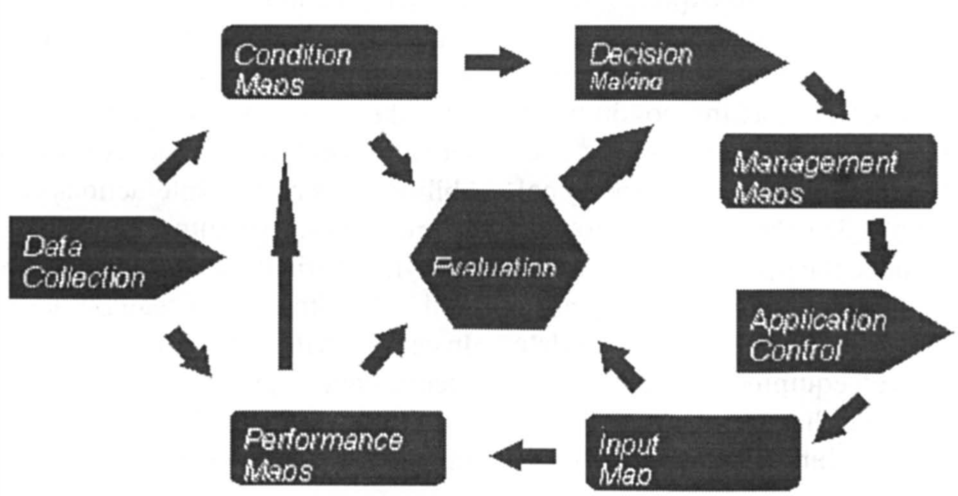
Precision Agriculture is management and being management is concerned with the decision making process. In studying the decision making process, Precision Agriculture will drive the research to be team oriented and involve collectively many different disciplines. Agronomist, Economist, and Engineers from within the agricultural disciplines will need to work together not only between themselves but also outside of the agricultural disciplines to find the expertise necessary to study the spatial data of Precision Agriculture. Precision Agriculture is a complete system, a methodology to manage agronomic crop production. The need to study Precision Agriculture in "real' field conditions will require the researcher to cooperate with actual production agriculture fields to understand their existing variability and crop responses to that variability. With Precision Agriculture being very technology oriented, researchers will also have to cooperate with industry to provide them access to the current technology. This technology will need evaluation to discover what its position is in the system and level of accuracy. The study of Precision Agriculture is truly going to take a team approach to knowledge building.

Finally, the traditional agricultural research institutions enter into the study of Precision Agriculture behind. Precision Agriculture was not the result of a long and scientific research project but the implementation of technology from outside production agriculture into production agriculture. Being driven by technology and private industry, the information knowledge base does not exist as it has traditionally in agriculture. The agronomic research institutions will be challenged to make up this difference. Precision Agriculture also provides the agronomic producer with information. Through this information, questions and challenges to the existing knowledge base will arise from the agronomic producer. The producer will have information about his or her own crop production situations unlike they have never had in the past. The agronomic research institutions will again be challenged to meet these new demands for information and explanation.

The future of research for agronomic production agriculture looks bright. Precision Agriculture will issue in a reevaluation of current knowledge and demands for an entire expanded set of knowledge relating to the management of agronomic crop production. Only through cooperation and intense study of the decision making process can agricultural research meet the challenge. The question is "How and who will lead agriculture into the realm of Precision Agriculture and the twenty-first century".

Precision Agriculture Flowchart

Figure 1



Precision Agriculture — Regulatory Point of View

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Introduction

Precision fertilizer application or site specific soil management, as I prefer to call it, is just one aspect of precision agriculture. My remarks today will concern only precision fertilizer application which is the modern application of the fairly mature agronomic practice of applying inputs to obtain the maximum economic response from some unit of land. My discussion concerns only the fertilizer sold for use in a site specific soil management program and will include four topics: (1) a brief history of fertilizer regulation in the United States, (2) the Association of American Plant Food Control Officials' Uniform State Fertilizer Bill, (3) specific application of the Uniform Bill to site specific soil management, and (4) a summary of two surveys of the states one taken in 1995 and one in 1997 on precision fertilizer application (PFA) considerations.

History of Fertilizer Regulation in the United States

In Kentucky and just about anywhere else in the United States, farmers purchase, agricultural professionals recommend, and lending institutions loan money to purchase fertilizer without any thought given to whether it is anything other than what is guaranteed on the label. It is not this way in many countries in the world today and it was not that way in Kentucky or in the US in the latter part of the nineteenth century when fertilizer use was just beginning. Let me illustrate by quoting a prominent agriculturist from the nineteenth century.

"Let a trustworthy chemist be employed to analyze every year all the various manures that come into the Connecticut market. Let the analysis be made, not on samples forwarded by the dealers or manufacturers for analysis, but on specimens procured by the farmers themselves, such as shall fairly represent the article that is spread upon the fields. These samples should be procured from different places, and the same manure should be repeatedly examined in order to test the uniformity and reliability of its composition. The analysis should be repeated every year, so that all improvements or deteriorations in the manufacture be kept pace with. The results should be published in the organ of the society, so that all its members be informed what are good fertilizers, and what are trash. With this system in skillful operation, an honest dealer would sell his commodities nowhere more gladly than in Connecticut, for he would be sure of finding for them here a full and enlightened appreciation, while the rogues would send their wares to some other market; the risks of detection would be too great for them to encounter." 1

This statement was made by Samuel Johnson who was a chemist, the director of the first agricultural experiment station in the United States (the Connecticut Agricultural Experiment Station), the first president of the Association of Official Agricultural Chemists (now known as AOAC International) and a strong proponent of laws to regulate fertilizers in Connecticut and elsewhere. The two basic and enduring objectives of a fertilizer regulatory program are found within this quotation: protection of the consumer of fertilizers and protection of the honest manufacturer of fertilizers.

This quotation also reflects the commercial fertilizer situation in the latter part of the last century. As the benefits of using nitrogen, phosphorus and potassium fertilizers became established there were unscrupulous persons who were selling worthless or nearly worthless materials as fertilizers. Opportunists confused, misled, and defrauded farmers as they attempted to adopt this new technology of fertilizer use. It was under these conditions that the first state fertilizer laws were enacted with the purpose of preventing fraudulent sales of fertilizer, thereby leveling the commercial fertilizer playing field. There is an interesting relationship between the establishment of the state agricultural experiment stations, which were early proponents of fertilizer use, and the enactment of the early fertilizer laws in the various states. For example, the Kentucky Agricultural Experiment Station was established in 1885 and the General Assembly of Kentucky designated the director of the station as the administrator of the Kentucky fertilizer law in 1886. Five of the first 16 bulletins published by the Station were the results of analyses of official samples of commercial fertilizers. Kentucky was not unique in this, for by 1899, twenty-eight state agricultural experiment stations were required by law to inspect and analyze fertilizers2.

The early non-uniformity of the states' fertilizer laws gave rise to two organizations, AOAC International and the Association of American Plant Food Control Officials (AAPFCO), that have had and are still having a significant impact on the fertilizer regulatory programs throughout North America. AOAC originated among chemists who wanted universally accepted analytical procedures for nitrogen, phosphorus and potassium in fertilizer3 and today AOAC analytical methods are the standards used throughout the world. The AAPFCO, organized in 1946, began within the AOAC as a committee that adopted standard fertilizer terms and definitions. Fertilizer control officials in each state, Canada and Puerto Rico constitute the membership of AAPFCO. The Uniform State Fertilizer Bill written by AAPFCO is the topic of the next section.

AAPFCO'S Uniform State Fertilizer Bill

AAPFCO vigorously promotes uniformity in fertilizer regulation throughout North America through its Uniform State Fertilizer Bill (USFB), which includes model legislation, regulations, terms and definitions. Because each state, Canada, and Puerto Rico have their own fertilizer laws, uniformity is of paramount concern for companies selling in more than one entity. The USFB requires a clear and truthful label around which all other activities revolve. Consumer protection and industry protection flow from this *labeling* law. The document evolved from a few early definitions into its present fairly comprehensive form and it continues to evolve. Administration of the law requires basically the verification and clarification of the fertilizer label. Basic components of the law include (a) labeling, (b) registration and/or licensing, (c) inspection and analysis of official samples, and (d) tonnage reporting.

Labeling includes the *label* (material required to be associated with the fertilizer when sold) plus any other material that is used to promote the sale of the fertilizer such as radio and TV advertisements, brochures, etc. Minimum information for any fertilizer label includes: (a) brand, (b) grade (omitted if N, P2O5 and K2O are not guaranteed), (c) guaranteed analysis, (d) name and address of the manufacturer, and (e) net weight. The format of the guaranteed analysis, the most important of these items, appears below:

Guaranteed Analysis

Total Nitrogen(N)..............______%
Available Phosphate(P2O5)..______%
Soluble Potash(K2O)..........______%
(Secondary Nutrients, Ca, Mg, and S are next)
(Micro nutrients, B, Cu, Fe, Mn, Mo, and Zn are next)

Registration requires each person to receive approval for each fertilizer and its associated labeling prior to it being offered for sale. Licensing requires approval of each retail outlet prior to it offering fertilizer for sale.

Inspection and analysis of official samples offers the opportunity to verify the label and labeling of the fertilizers found for sale in the state. We use sampling and analytical methods approved by the AOAC.

Tonnage reporting provides the control office with information on fertilizer use as well as financial support for the program, if an inspection fee is assessed. The only source of fertilizer-use statistics for the United States comes from the tonnage reports submitted to each control office in the various states.

With this perspective of the fertilizer regulatory programs in the United States, I want to relate AAPFCO's USFB to site specific soil management.

The Uniform State Fertilizer Bill and Site Specific Soil Management

Site specific soil management as it relates to fertilizer inputs requires application of specific fertilizers at specific rates to specific soil areas based on soil test recommendations. Important regulatory considerations are (a) the label of the fertilizers applied to the specific sites within the management area, (b) claims made by the company for the fertilizer applied as part of the site specific management program, and (c) sampling of fertilizers sold as part of a site specific management program.

The USFB requires a label for each fertilizer product sold with the guarantees stated for each of the plant nutrients claimed to be present. The critical question is: Does the company make a guarantee for each fertilizer applied to each specific grid or is the guarantee for the total blend applied to the total area? If the answer is the former, then there must be a label for each blend applied to each area along with the total weight applied. Such a label would be more complicated than the usual bulk blend label but very doable. I visualize an invoice created by the computer where each area is listed along with the guaranteed analysis and net weight of each mixture applied. If the answer is the latter, then the label would be simpler and no different from that of bulk blend labels in use today.

The USFB prohibits use of false or misleading labeling in the distribution of fertilizer. The definition of labeling includes all written, printed, or graphic material upon or accompanying any fertilizer; or, advertisements, brochures, posters or television and radio announcements used in promoting the sale of the fertilizer. The critical question is: Are any statements made by the PFA company in any of their promotional programs misleading or false? Benefits claimed for the fertilizers applied as part of site specific soil management programs would require documentation with scientific research data that are available to the control official.

Sampling of the fertilizers sold as part of a site specific soil management program is the most challenging of the considerations. We could sample the materials used in the equipment but such samples would not represent the mixture applied. We could go to the field and catch the mixture in pans as it is spread but this would be a difficult task because of the personnel time that would be required, although it could be done. We could ask the equipment manufacturers to design into the equipment an automatic sampling device that would take samples of the various mixtures on board after they are mixed. This would be the ideal solution from the regulatory standpoint and it would also provide a quality control tool to the company.

Regulation must not inhibit the implementation of new technology that is beneficial to the farmers and the fertilizer industry. However, we must not allow a situation to develop similar to that when the original fertilizer laws were enacted where farmers were misled and defrauded by opportunists. Site specific soil management is new technology that appears to provide significant benefits to the farmers, industry and environment. We as control officials must be willing to work with the industry to adapt our regulatory programs to meet the needs of site specific soil management and also provide the classic consumer and industry protection.

PFA Survey

In August 1995 I surveyed the lower 48 states with the objective of determining which states have PFA services and how the fertilizer control official in each state was regulating this practice or would regulate it if it were available. The same survey was conducted again this year, 1997, and the results of those surveys are summarized in the following figures.

Fig. 1 (1995)
In 1995 there were 43 responses(90%) to the surveys sent out which is a very good response.

Fig. 1b (1997)
In 1997 we received 41 responses(85%), again a very good response.

Survey Question 1: Are PFA services offered in your state?

Fig. 2 (1995)
In 1995, of the responses received, 22 states or 51% of those responding indicated that PFA services were available in their state.

Fig. 2b (1997)
In 1997 a few more states (25 or 61% of those responding) indicated that PFA services were being offered in their state.

Survey Question 1a: Are label requirements different for PFA fertilizers than for regular bulk fertilizers?

Fig. 3 (1995)

In 1995 in those states with PFA services, 21 or 95% said that the label requirements for fertilizers distributed by PFA equipment were the same as for regular bulk fertilizers.

Fig. 3b (1997)

In 1997 the response from those states with PFA services was about the same as for 1995 with 23 states or 92% reporting that label requirements were the same for PFA fertilizers as they were for other bulk fertilizers.

For the remaining questions the control officials were asked to assume that PFA services were being offered in their state.

Survey Question 2a: Should each fertilizer mixture applied to a specific soil area have a separate label?

Fig. 4 (1995)
In 1995, 27 or 63% of the control officials indicated that they would not require each separate mixture applied to a specific area to be labeled separately. Eleven or 26% said that they would require a separate label.

Fig. 4b (1997)
In 1997 the responses were essentially identical: 27 said 'NO' and 12 said 'YES'. It is important to understand what this means. A 'YES' response means that each soil area is considered to be an entity and equivalent to a 'field'. A 'NO' response means that the whole field is still considered the entity. There is a large difference between these two concepts. This will be addressed in a later question.

Survey Question 2a: Comments when the answer was 'YES'

Fig. 5 (1995)
In 1995 the respondents comments relative to the labeling of the PFA fertilizers were varied. When the respondent said "YES" their comment predominately was that it was required by law(64%).

Fig. 5b (1997)
In 1997 when the answer to question 2a was 'YES" it was unanimous: **It is required by law.** This is a significant change from 1995; however, the number of control officials who said, 'YES', that each PFA fertilizer should be labeled was slightly less than half of those who said 'NO' each PFA fertilizer need not to be labeled.

Survey Question 2a: Comments when the answer was 'NO'

Fig. 6 (1995)
In 1995 when the respondent said "NO" to the labeling question their predominate response was that there would be 'no way to do it!'(41%). The other major response was that each load should be labeled but not each individual mix (26%).

Fig. 6b (1997)
In 1997 the number of officials who said 'NO' there is 'no way' to label each PFA fertilizer was about the same as 1995 at 10 (37%); however, a significant number (13 or 48%) said it was not required under their law or simply that it was not regulated.

Survey Question 2b: Are the claims for the benefits of PFA covered under the definition of 'Labeling'?

Fig. 7 (1995)
In 1995 the overwhelming response was "yes" (63%). Thirty percent (30%) said "no".

Fig. 7b (1997)

The response in 1997 was about the same with 29 or 71% answering 'YES" and 9 or 22% answering 'NO'.

Survey Question 2b: Comments when the answer was 'YES"

Fig 8. (1995)
In 1995 the comments relative to claims and labeling were varied. When the control official said "YES" that PFA labeling was regulated their comment predominately was that labeling was regulated 'By Definition' (70%).

Fig. 8b (1997)
In 1997 the overwhelming response as to why labeling included PFA claims was that it was 'By Definition'. I think this was a significant change in interpretation of the labeling definition by the control officials

Survey Question 2b: Comments when the answer was 'NO'

Fig. 9 (1995)
In 1995 when the respondent said "NO" that labeling was not regulated their comments were quite varied: 'it is a service not a fertilizer'(23%), 'labeling applies to fertilizer only'(15%), and some miscellaneous ideas like 'let the market decide' or 'it is too difficult'.

Fig. 9b (1997)
In 1997 the comments associated with the 'NO' response to the question of claims and labeling were also varied. There was no clear consensus. Some of the comments in 1997 that were not made in 1995 were: 'the law is not applicable' (33%) and 'they are equipment claims not fertilizer claims'(22%).

Survey Question 2c: How would you sample PFA fertilizers

Fig. 10 (1995)
In 1995 this question elicited varied responses: 'sample the materials only' was the most frequent response(42%), followed by 'certify the equipment'(21%), 'catch pans in the field'(9%) and 'on board'(5%).

Fig. 10b (1997)
In 1997 the responses were essentially the same as for 1995. 'Sample the materials' was still the most frequent response (43%) followed by 'certify the equipment' (22%) with 'catch pans' and 'on board' equal at 14%. The idea of on board sampling increased from 2% in 1995 to 14 % in 1997 indicating that this has begun to catch on.

Survey Question 3: Should PFA fertilizers be regulated differently from conventional fertilizers?

Fig. 11 (1995)
In 1995 The majority opinion was "NO" (56%) meaning that the control official would apply existing law to the PFA fertilizers. Sixteen percent (16)% said "YES" meaning that they believed that the existing fertilizer law would require amending to accommodate the new practice.

Fig. 11b (1997)
In 1997 most control officials seemed to be concluding that PFA fertilizers should be regulated differently from the conventional bulk fertilizers. The shift in opinion was significant with 54% now saying that PFA fertilizers should be regulated differently compared to 56% who said 'NO' in 1995. This is almost a complete reversal.

Both surveys revealed that there is still not a consensus among the states on the matter of applying the current fertilizer laws to the PFA fertilizers.

Label requirements would be no different. The 1997 survey showed that 70% of the control officials would not require a different label for PFA fertilizers yet 70% said that 'labeling' associated with PFA fertilizers would be regulated. Presumably, even if a company made claims for the benefits of applying separate fertilizer analyses to specific soil areas and in fact did apply the separate analyses, 70% of the states would not regulate this. Sampling of PFA fertilizers is the major problem associated with the regulation of these fertilizers and was indicated in both surveys. Unless there is some way to assure that the equipment is applying the fertilizers accurately, we are dependent on the goodwill and integrity of the company making the claims.

One major trend noted in comparing the two surveys in that more control officials now are thinking that PFA fertilizers may require a regulatory program different from the conventional one.

Summary

Background information on fertilizer regulatory laws and specifically the Uniform State Fertilizer Bill of AAPFCO provided a springboard for our consideration of the fertilizer regulatory aspects of site specific soil management. The difficulties of applying fertilizer regulatory laws to site specific soil management were discussed. The difficulties cited were labeling the fertilizer applied to each management site, supporting claims made for fertilizers used in site specific soil management programs and the sampling of the fertilizers applied in a site specific soil management program. The results of the survey of the state indicated that there is lack of consensus on how to regulate this practice. Regulatory programs must be tailored to meet the needs of the site specific soil management technology without sacrificing consumer or industry protection.

[1] Johnson, Samuel. As quoted by Harry J. Fisher, Presidential Address, Official Publication No. 17, 1963-64, Association of American Fertilizer Control Officials, Division of Regulatory Services, University of Kentucky, Lexington, Kentucky 40546. p 30.

[2] Kerr, Norwood Allen, 1987, The Legacy-A Centennial History of the State Agricultural Experiment Stations 1887-1987. Missouri Agricultural Experiment Station, University of Missouri-Columbia, Columbia, Missouri 65211. p 31.

[3] Helrich, Kenneth. 1984. The Great Collaboration. The Association of Official Analytical Chemists, Inc. Arlington, Virginia 22209. p 4.

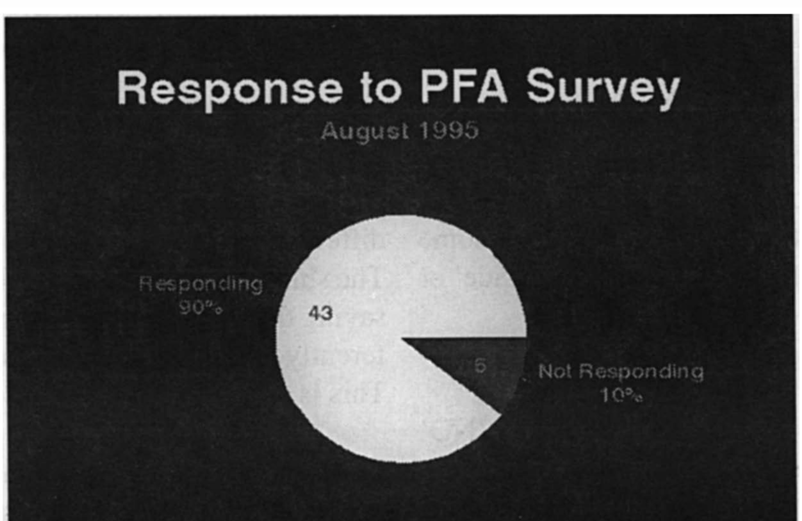


Figure 1. Proportion of States Responding to Survey

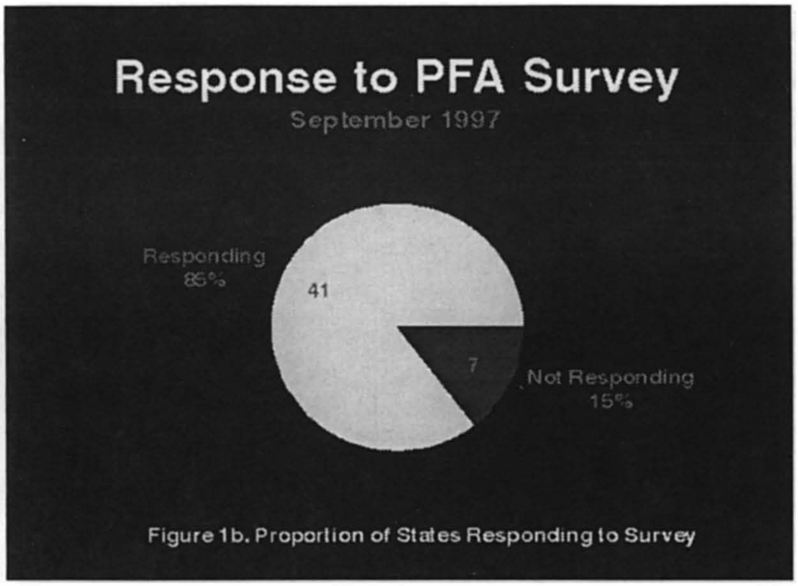


Figure 1b. Proportion of States Responding to Survey

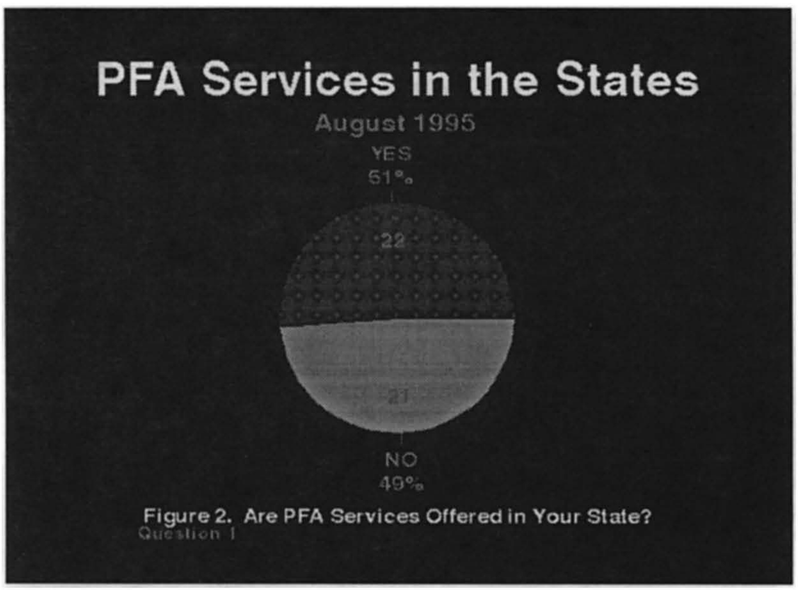


Figure 2. Are PFA Services Offered in Your State?
Question 1

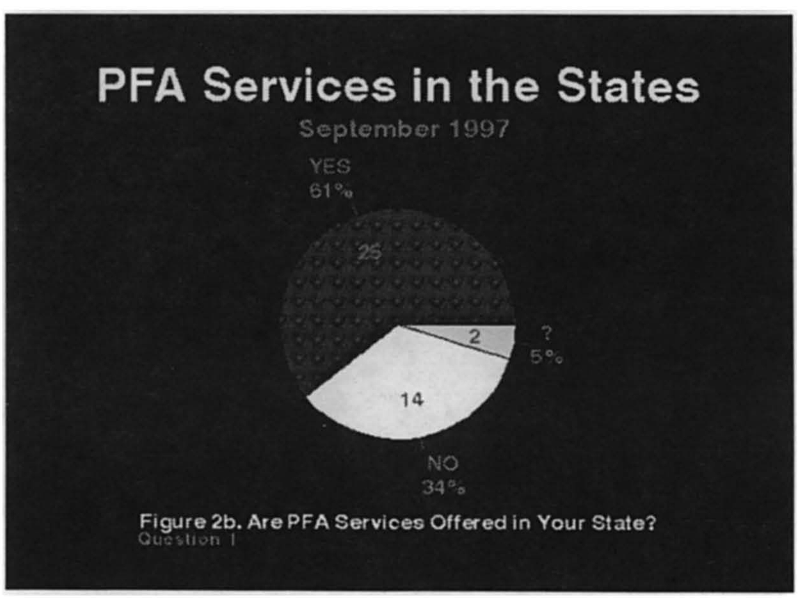


Figure 2b. Are PFA Services Offered in Your State?
Question 1

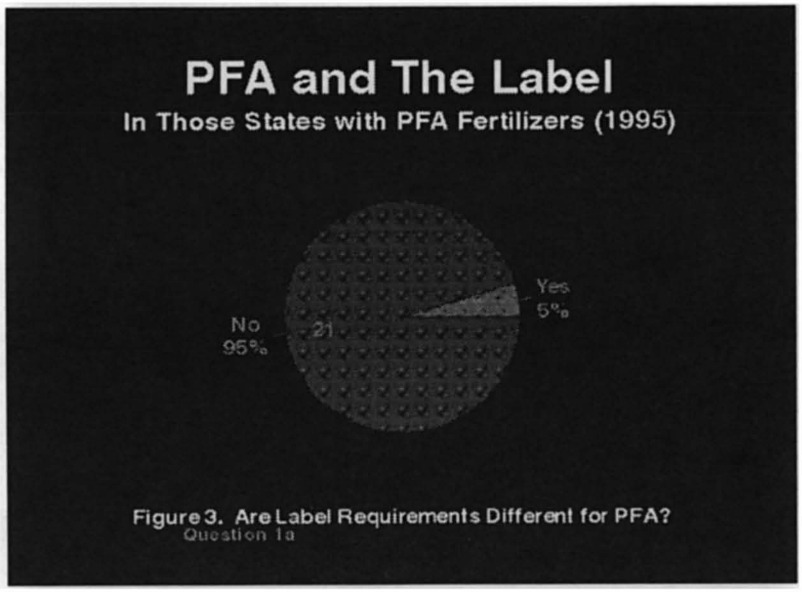


Figure 3. Are Label Requirements Different for PFA?
Question 1a

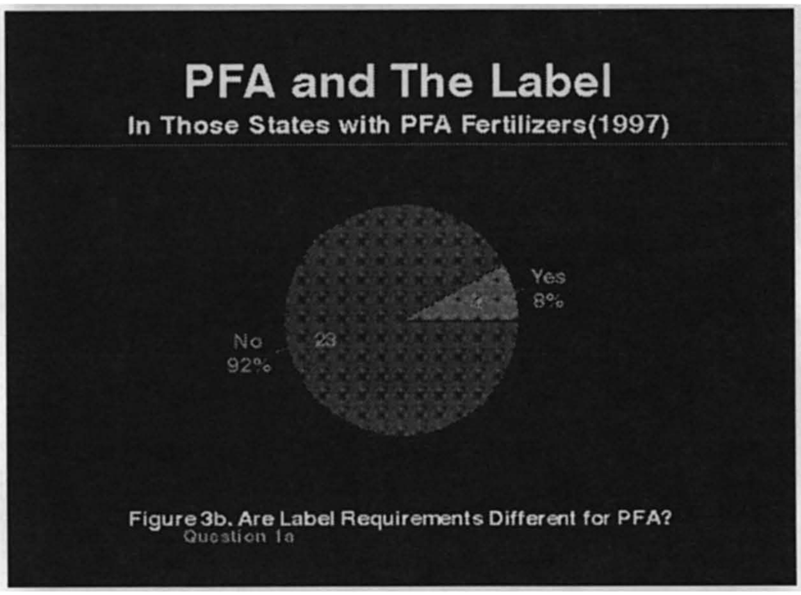


Figure 3b. Are Label Requirements Different for PFA?
Question 1a

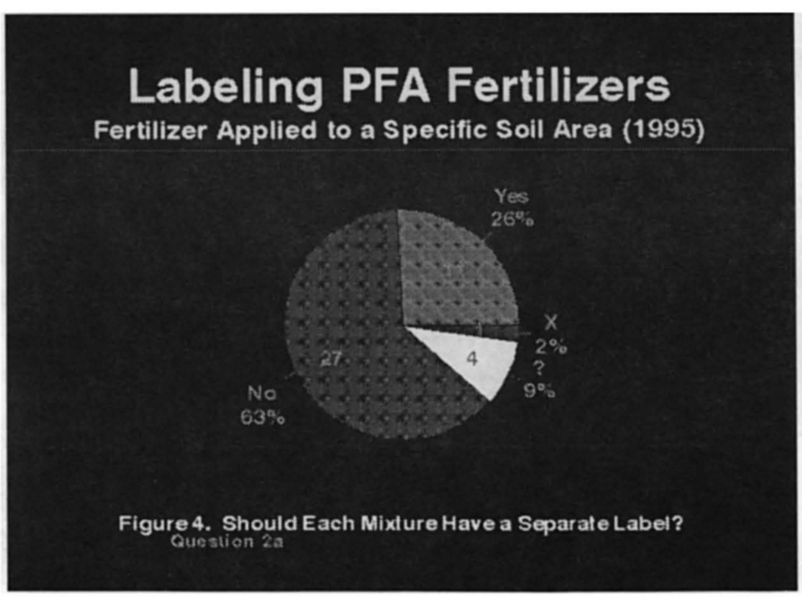


Figure 4. Should Each Mixture Have a Separate Label?
Question 2a

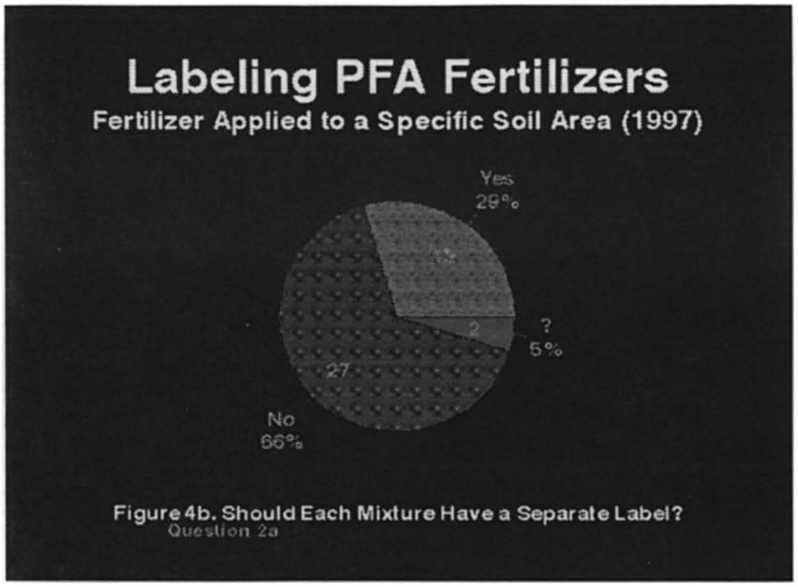


Figure 4b. Should Each Mixture Have a Separate Label?
Question 2a

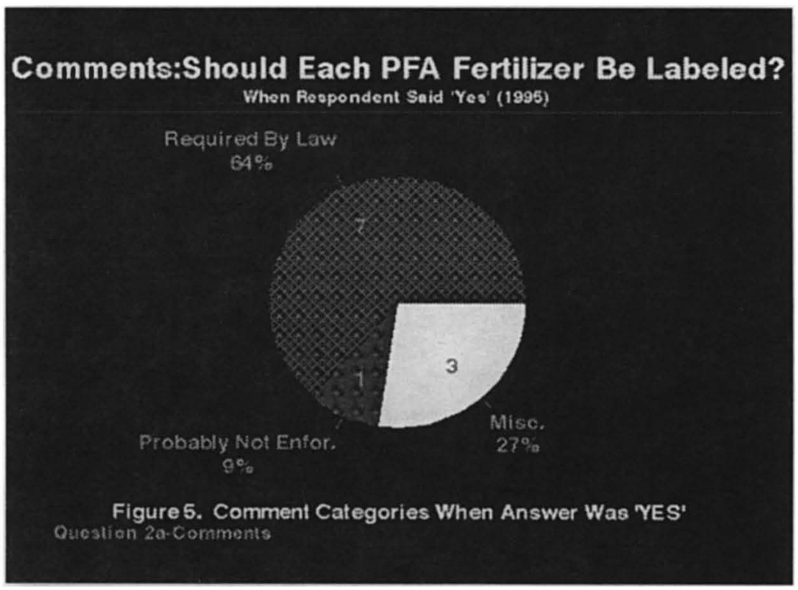


Figure 5. Comment Categories When Answer Was 'YES'
Question 2a-Comments

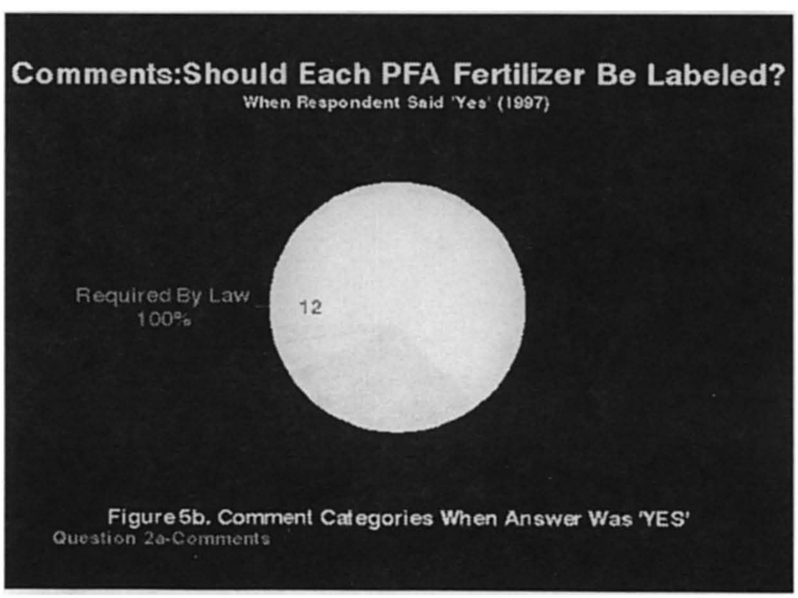


Figure 5b. Comment Categories When Answer Was 'YES'
Question 2a-Comments

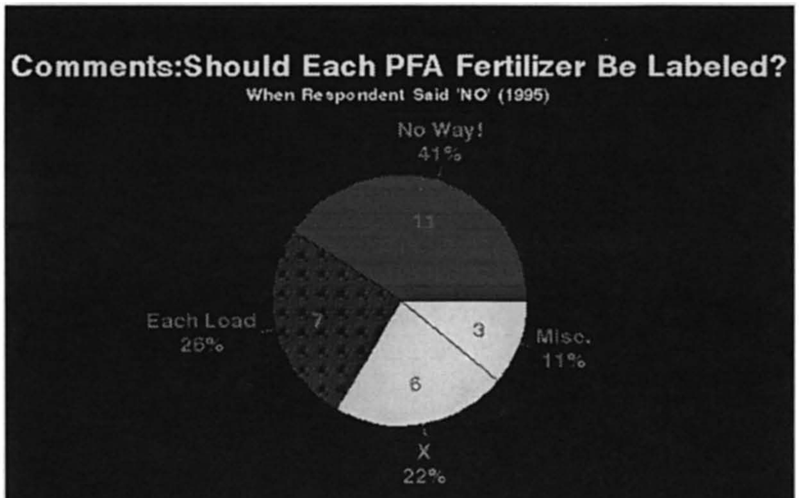


Figure 6. Comment Categories When the Answer Was 'NO'
Question 2a-Comments

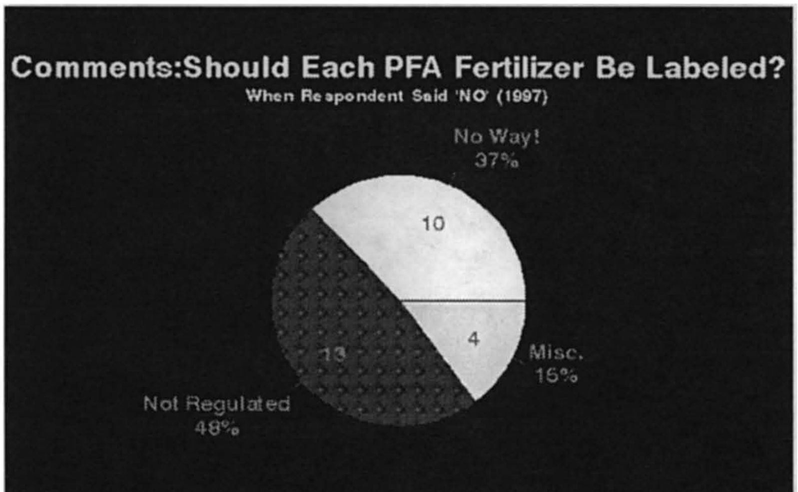


Figure 6b. Comment Categories When Answer Was 'NO'
Question 2a-Comments

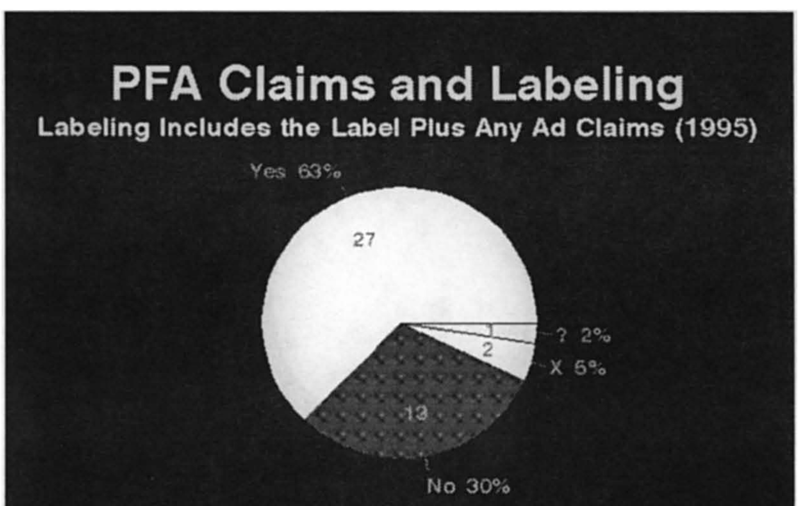


Figure 7. Are Claims for Benefits of PFA Regulated?
Question 2b

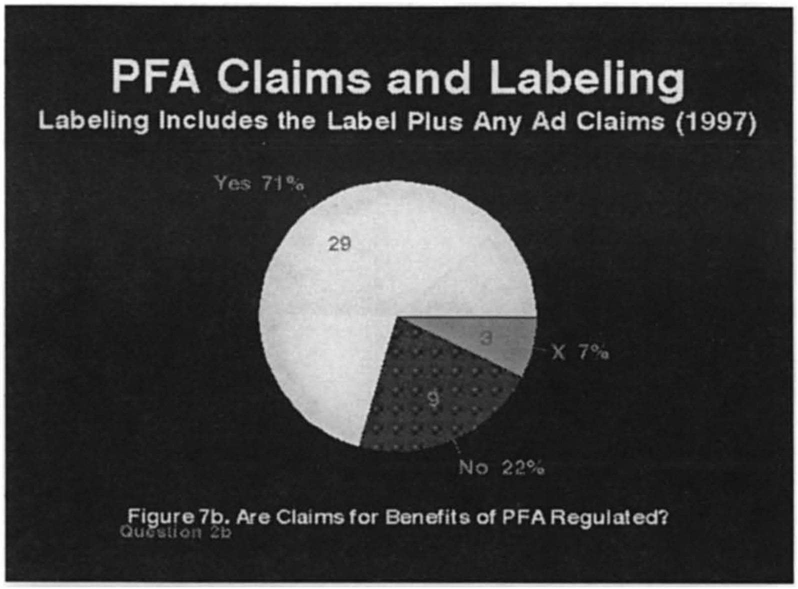


Figure 7b. Are Claims for Benefits of PFA Regulated?

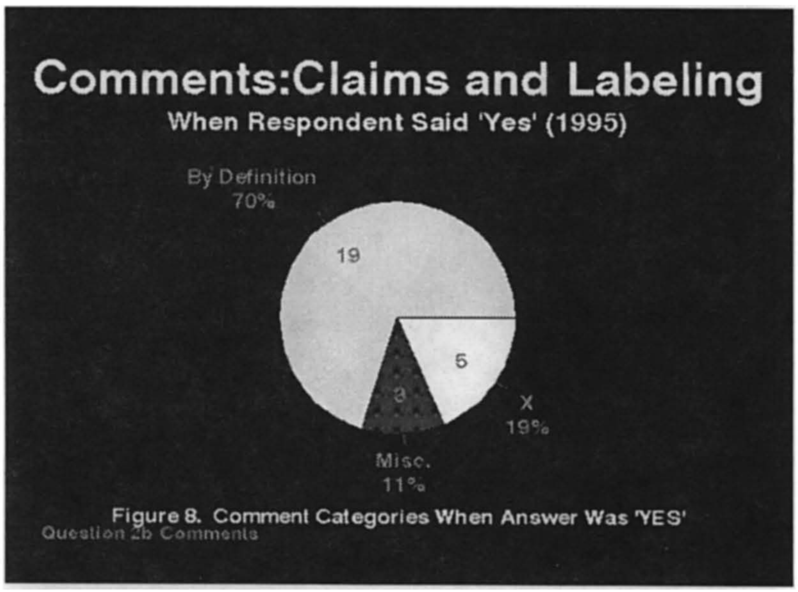


Figure 8. Comment Categories When Answer Was 'YES'

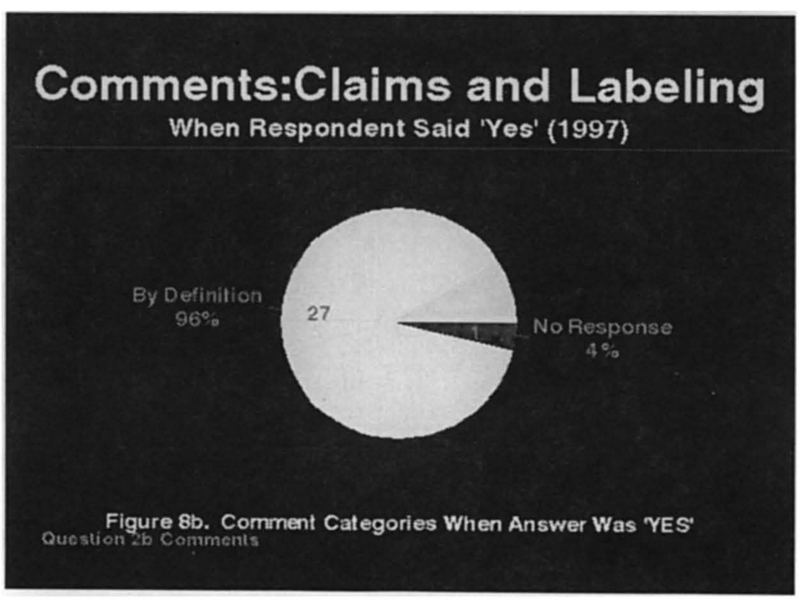


Figure 8b. Comment Categories When Answer Was 'YES'

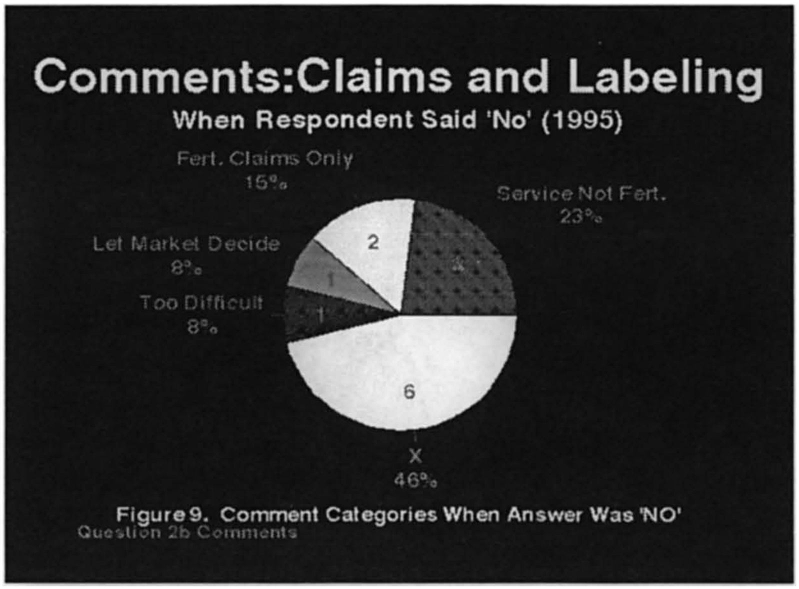


Figure 9. Comment Categories When Answer Was 'NO'

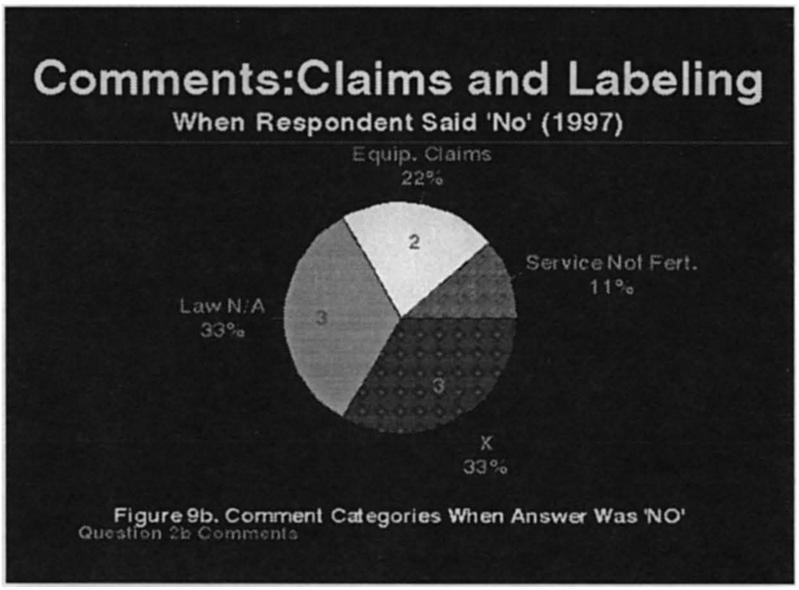


Figure 9b. Comment Categories When Answer Was 'NO'

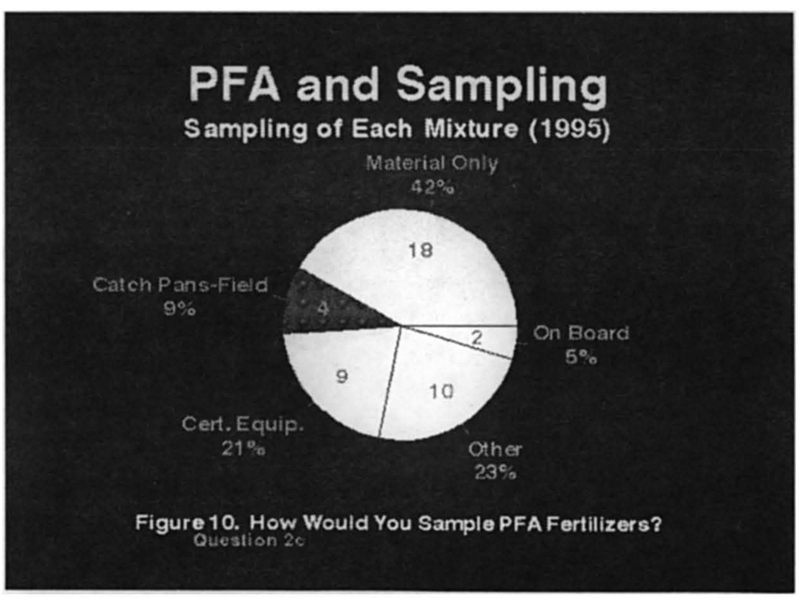
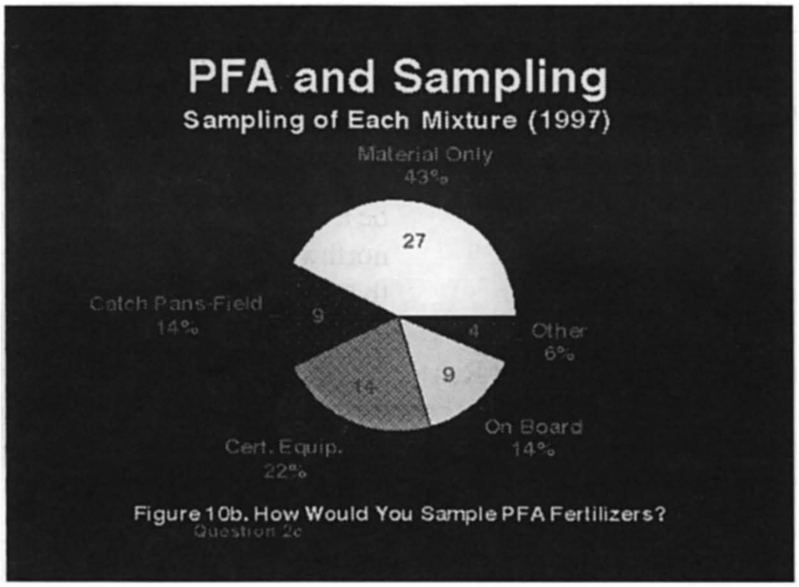
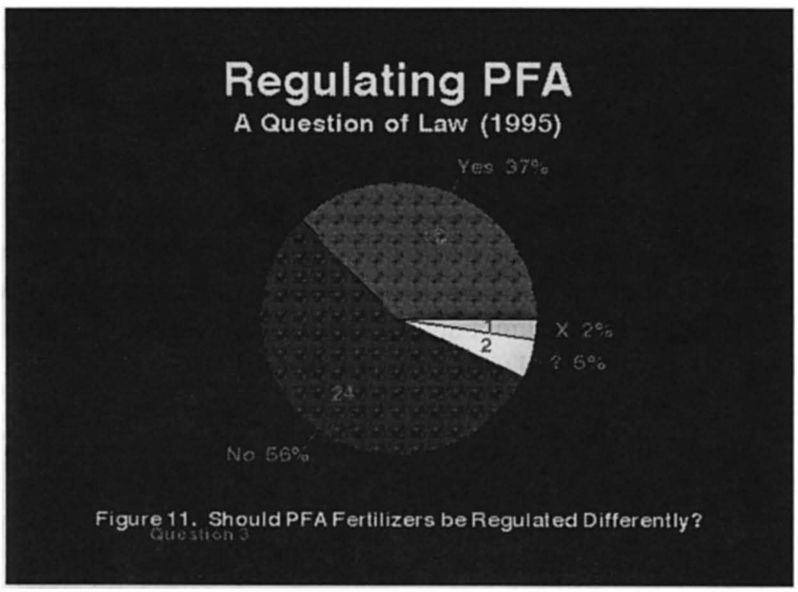
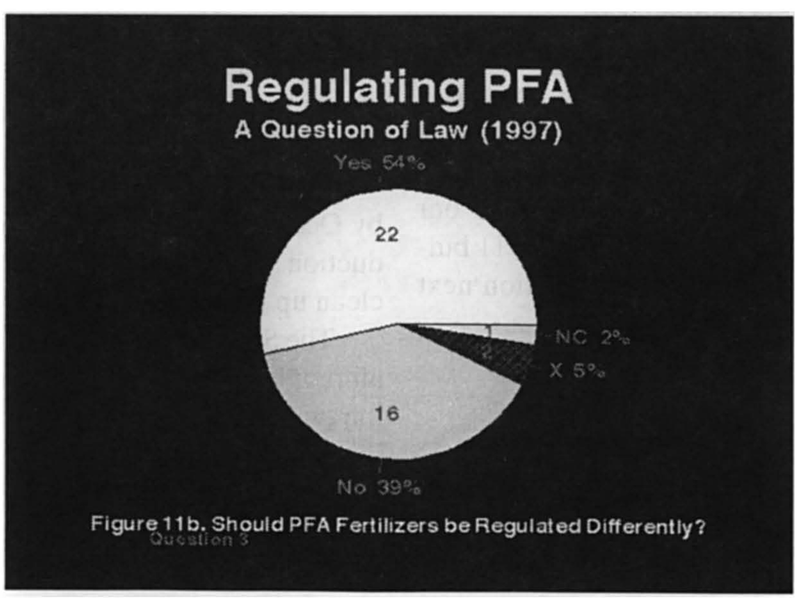


Figure 10. How Would You Sample PFA Fertilizers?


PFA and Sampling
Sampling of Each Mixture (1997)
Material Only
43%
27
Catch Pans-Field
14%
9
4
Other
6%
9
14
On Board
14%
Cert. Equip.
22%
Figure 10b. How Would You Sample PFA Fertilizers?
Question 2c


Regulating PFA
A Question of Law (1995)
Yes 37%
X 2%
2
? 5%
24
No 56%
Figure 11. Should PFA Fertilizers be Regulated Differently?
Question 3


Regulating PFA
A Question of Law (1997)
Yes 54%
22
NC 2%
2
X 5%
16
No 39%
Figure 11b. Should PFA Fertilizers be Regulated Differently?
Question 3

The Fertilizer Business in Russia Today — Pitfalls for Americans

John Myrick

Myrick International, Ltd.

Paul Tatum in "The Ugly American"

I would like to dedicate this speech about Russia to Paul Tatum.

Paul Tatum was the first American who was killed in Russia doing business with the Russians. He died on November 3, 1996 - *Newsweek*, the November 25, 1996 issue, covered his story.

He and his investors owned 50% of the Radisson Hotel and Business Center. The Radisson was where President Clinton and Vice President Gore stayed during their visits to Russia. The City of Moscow owned the other 50%, after the breakup of the Soviet Union.

Paul was helpless against the Russian Government during the take-over of government by the now President Boris Yeltson.

He had previously slipped into the Duma and provided a cellular telephone that was used to communicate with the army to stop the attack on the Duma Building now the Hotel and Business Center built by Armand Hammer.

All my meetings with Paul were in his Hotel Suite on the eighth floor overlooking the Moscow River. We always traveled in separate cars because Paul normally had three bodyguards.

He had met with one of my associates in the metro delivering information from me about one of our future business projects. It was to be a large Casino in the building next to the Radisson.

He was on his way to see another one of our business associates when he was killed by 11 bullets as he was going into the subway station next to the Radisson Hotel.

The Fertilizer Business in Russia

Russia and the former Soviet Union all have fertilizer plants - Latvia, Estonia, Lithuania, Ukraine, and in many other parts of Russia.

Murmask is the home of a large phosphate deposit. It has one of the largest mines and a plant that ships phosphate rock all over Russia by rail cars. Murmask is the Port that America used to deliver arms during World War II. It continues to be a major port for both imports and exports to the northwest part of Russia. Ships are used to export the rock to the world year round.

There are phosphate rock deposits in southern Russia that have yet to be mined. The rock from this area has been tested in Bartow, Florida. Russian phosphate rock is 82 BPL. Ammonia is produced near all the fertilizer plants and in eastern Russia near the natural gas deposits. Ammonia is shipped by pipeline to Odessa on the Black Sea in the south, and Ventspile on the Baltic Sea in the west. Russia has a waterway system from the Baltic Sea at St. Petersburg to the Black Sea. This island waterway system also goes to the Casbian Sea near Iran. They have MAP plants near the Volga River entrance. They also produce MAP at a plant close to Finland.

The Voga River travels through Russia, north, south and west. This river way is used for commercial and passenger transportation.

Armand Hammer Project

Armand Hammer through Occidental designed a $20,000,000 project to ship phosphate to Russia from Florida and then ship ammonia from Russia to America, via New Orleans and Savannah.

The phosphate was shipped in the form of superphosphoric acid in three ships, one named for him, one his wife and another after a friend. The World Bank guaranteed by the U.S. Government provided the money for the project.

Superphosphoric acid was produced in Florida by Occidental at two plants, where I was the Production Manager and it holds the U.S. Patent to clean up the SPA by removing the magnesium.

The SPA was shipped to Russia and mixed with ammonia in six liquid fertilizer plants, similar to the two plants I sold in Russia and commissioned in 1990. Four large ammonia plants were built in Eastern Russia as part of the project.

The project to swap SPA from Florida for ammonia from Russia was a good deal for America because if you will remember oil and gas were in short supply and ammonia was needed at that time, 1976.

The project was underway but was stopped by President Jimmy Carter as an embargo on Russia. It was restarted in 1980 when the embargo was lifted. This was when I made by first trip to the port in Odessa in the Ukraine to deliver pump parts to restart the system.

The project continued to operate from 1980 until 1992 when the Soviet Union ended. The Russians continued to ship ammonia, however, they kept the money and stopped paying for the SPA. This stopped the supply of SPA to the Ukraine because they no longer had money from the sale of ammonia because all the ammonia plants were in Russia.

This is why the farms no longer have fertilizer, the fertilizer is sold overseas and not used for the farmers to grow their own crops. The money from the fertilizer being sold is kept in Switzerland.

Russian Economy

Russia is one of the richest countries in the world. They have:

- Oil & Gas Russia has more oil reserves than Saudi Arabia
- More timber than Canada
- More diamonds than South Africa
- More reserves
- Phosphate mines and reserves
- Technology in all areas, the first in space

There are only two forms of wealth, mineral (oil) and agriculture (timber) farming. Russia has them both; however, the Director of Russian economy has allowed the manager of the factories to sell the products overseas and take the profits without paying taxes and in return giving part to the Government.

Myrick – Fertilizer Plant

"Ammyinter" was a joint venture between "Ammophos" and "Myrick International". Two MAP plants were converted to DAP plants and DAP was shipped overseas to foreign markets. The Plant capacity was expanded by 40% for overseas sales and the original production was shipped to the farmers inside of Russia.

In 1993, 100% of the DAP was sold via the new way government. All of the profit was kept in Switzerland and only the cost of production was returned to Russia and to "Ammyinter". This was why Myrick had trouble with Bobkin, the manager of Ammophos. But that's another story. My experience in Russia was more than the fertilizer business.

Business with Russia

The U.S. Department of Commerce has a monthly publication that outlines Russia and former Soviet Countries business opportunities. They have twelve offices east to west. They are helping Americans join with Russians looking for money and technology and partners.

My advice to anyone doing business in Russia is easy:

- Show me the money

- Obtain world bank financing with American Government Guarantees

- Ask the question How do I get my money out?

- Realize this is not America, Laws do not apply and contracts are not binding.

Saga of a Successful Development Project

Lester Teichner

GOCA Industries

COGA Industries, L.L.C., Chicago, has announced plans to use natural gas rather than coal as the primary feedstock for its central Illinois nitrogen fertilizer plant. The announcement was made in a speech presented by Lester Teichner, the managing partner for the project, at the 47th annual meeting of The Fertilizer Industry Round Table in St. Petersburg.

In his speech, Teichner also announced that Monsanto Enviro-Chem (MEC), St. Louis, has won the exclusive contract for the engineering, procurement and construction of the entire facility. MEC has previously been responsible for only the nitrogen fertilizer plant portion.

Finally, Teichner reconfirmed the COGA partnership's longstanding commitment to build the plant on an 1,100-acre site near Girard, Illinois, 30 miles southwest of Springfield.

When fully operational, COGA is expected to use 20.6 million MMBTU of natural gas annually to produce the equivalent of 1,600,000 tons of high-quality fertilizer. "We are currently reviewing formal proposals from major providers of natural gas and prospective constructors of the power facility," Teichner said. "We expect them to be concluded in a relatively short time."

"The decision to use natural gas as our primary feedstock instead of coal was a difficult one, particularly in view of the excellent working relationship we have developed with Freeman Energy Corp. of Springfield. Their assistance and willingness to meet us half way is a large part of why we want to remain in the Girard area. We owe them and the community in general a debt of gratitude for their efforts on behalf of the project."

He continued, "Ultimately, it came down to a question of using natural gas or losing the project altogether. We anticipate that the direct construction costs for a nitrogen plant using natural gas as the feedstock will be under $600 million, as compared to bids in excess of $850 million for the coal gasification alternative.

The lower construction cost, coupled with state-of-the-art technology, would enable COGA to operate profitably even at current urea price levels, compared with the present breakeven or loss experience of most existing plants."

"We have spent 15 years and many millions of dollars attempting to bring a coal gasification facility to Illinois," he added. "The gap in construction cost was only made up by the more attractive long-term price and supply outlook for coal. With the availability of abundant natural gas via pipelines to the region from the Gulf and from Canada, the price and supply differential that previously favored the use of local coal has disappeared."

"We are pleased that the plant will remain in Girard and provide much-needed jobs for the area," said Walter A. Gregory, president, Freeman Energy, "although it is unfortunate that we have lost the opportunity to provide coal for the project."

"We have taken the coal gasification portion of the plant off the table," Teichner noted. "That enables us to expand the role MEC will play in building the facility. Their experience and familiarity with the project make them an ideal partner with whom to move it forward. The company is heavily experienced in engineering and construction for facilities involving urea, nitric acid and co-generation of electric power. They have been associated with the development of the COGA project for more than 10 years, and provided significant developmental support in earlier phases."

"The financial engineering done on this project has been superb," he added. "Merrill Ring, one of the co-developers of the COGA project, was formerly a senior vice president of Bank of America worldwide. His expertise has been invaluable in enabling COGA to overcome the challenge of financing the project on a non-recourse, off-balance-sheet basis. By incorporating a blend of financial and commercial hedges, the price risk to the lenders has been sufficiently mitigated to enable the use of a project finance structure without requiring a floor price commitment from the fertilizer off taker. That will make it far easier to complete the financing."

Major institutional parties in COGA, in addition to project developer COGA Industries, L.L.C., include Unicom Resources, Inc. (URI), Chicago, a subsidiary of Unicom Corporation; Norsk Hydro a.s., Oslo, Norway, one of the world's leading fertilizer companies; and The Chase Manhattan Bank, the leading bank in arranging financing for the project. Both URI and Norsk Hydro have options for equity in the project.

"URI's financial support and technical expertise continue to be critical assets for the project," Teichner observed. "They remain committed to this project as a vehicle for promoting growth and economic development in the region."

FINANCIAL STATEMENT

OCTOBER 28, 1996 TO OCTOBER 27, 1997

Cash Balance October 28, 1996		$ 47,208.58
Income October 28, 1996 to October 27, 1997		
Registration Fees - 1996 Meeting & Cocktail Party & Coffee Break Receipts	$ 13,970.25	
Sale of Proceedings	1,118.73	
Registration Fees - 1997 Meeting & Cocktail Party & Coffee Break Receipts	24,400.00	
Total Receipts October 28, 1996 to October 27, 1997		39,488.98
Total Funds Available October 28, 1996 to October 27, 1997		$ 86,697.56
Disbursements October 28, 1996 to October 27, 1997		
1996 Meeting Expenses (Incl. Cocktail Party)	$ 19,135.05	
Misc. Expenses Incl. Postage, Stationery, etc.	692.27	
1996 Proceedings	7,000.00	
1997 Meeting Preliminary Expense	1,364.39	
Directors' Meetings	1,068.33	
Total Disbursements October 28, 1996 to October 27, 1997		29,260.04
Cash Balance October 27, 1997		$ 57,437.52

Respectfully submitted,

Paul J. Prosser, Jr.
Secretary\Treasurer

Meeting Attendance 158