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Illinois Migrant Council

Preparing a New Generation of Illinois Fruit and Vegetable Farmers

a USDA NIFA Beginning Farmer and Rancher Development Program Project

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http://www.newillinoisfarmers.org

new ILLINOIS fruit & vegetable FARMERS

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GROWING A NEW GENERATION OF ILLINOIS FRUIT AND VEGETABLE FARMERS

CONVENTIONAL AND ORGANIC FERTILIZERS

Shelby Henning and Jeff Kindhart
March 2015

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What is fertilizer?

- "Any organic or inorganic material of natural or synthetic origin that is added to a soil to supply one or more plant nutrients essential to the growth of plants"

- Conventional/inorganic/synthetic: Manufactured
  - But what about organic synthetics such as urea $(NH_3)_2CO$?
- Organic: Naturally occurring mineral deposits or
- organic materials

Crop residue, animal waste, other organic waste products such as ash, biosolids, compost, seaweed, peat

Saltpeter = KNO_3= bat guano
Rock phosphate
Greensand
Limestone

Do I need fertilizer?

- Crop demands more than soil supply
- Can the plant tell where it comes from?
- Mechanisms of plant uptake
- Genotype vs phenotype
- Non-responsive soils?

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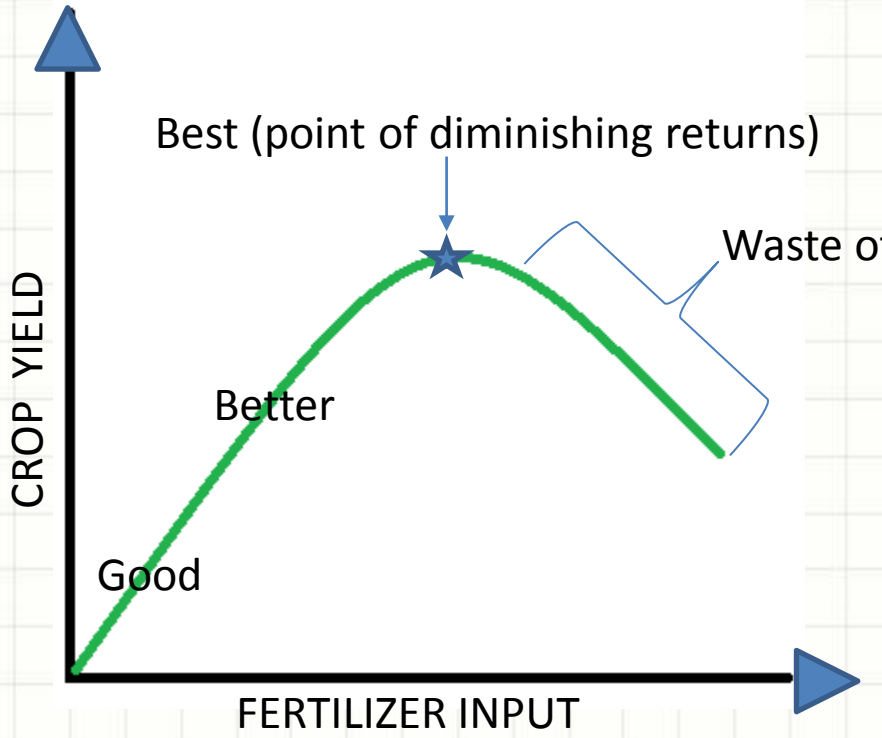
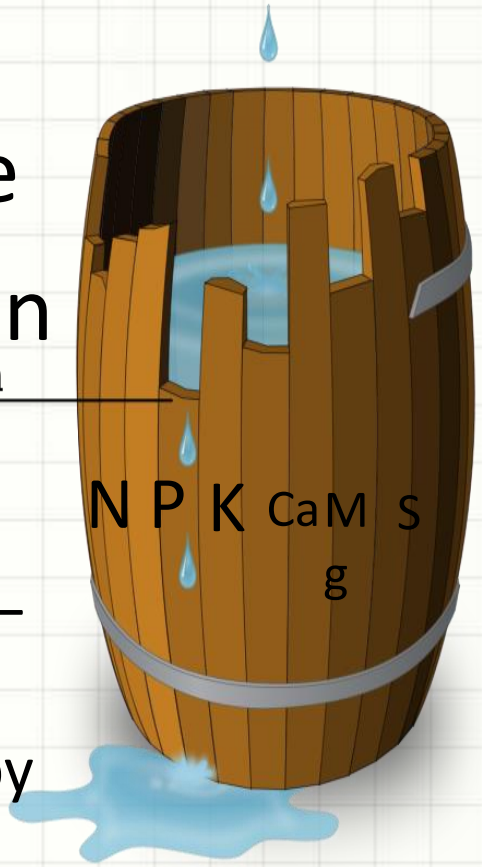
Optimizing returns on fertilizer inputs

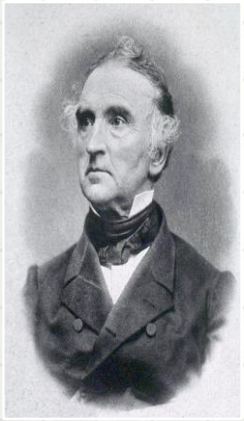
- The law of diminishing returns applies to fertilizer use
- Use just enough to provide for optimal crop response
- On-farm trials can help dial in specific needs



The essential nutrients

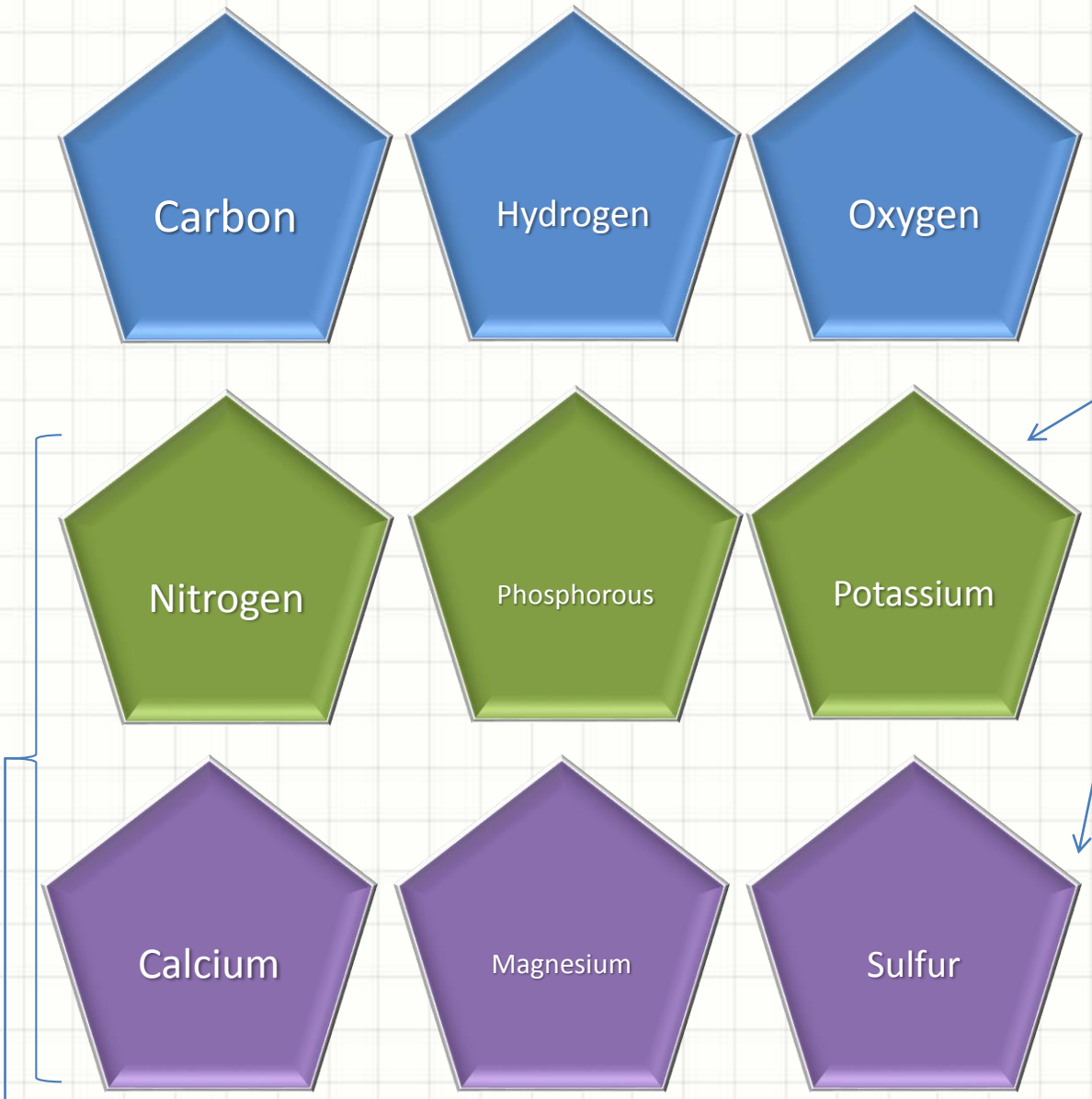
- The element must be required for the plant to complete its life cycle (AKA seed to seed)
- No other element may substitute
- The element is directly involved in the nutrition of the plant





Justus von Liebig's "law of the minimum"–
"Plant growth is controlled not by the total amount of resources available, but by the scarcest resource"

The essential nutrients



Not derived from soil or fertilizer
"Structural nutrients"

Macronutrients

~50 mg/kg in the plant

"Primary nutrients"

"Secondary nutrients"

Derived from soil or fertilizer

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The essential nutrients

- Micronutrients ← Derived from soil or fertilizer
  - < 50 mg/kg in the plant
  - Boron
  - Manganese
  - Copper
  - Molybdenum
  - Iron
  - Zinc

Definitely!

- You very rarely have to worry about micronutrient deficiencies.
- Micronutrients are required by plant in very, very low amounts.
- Fertilizing with micronutrients frequently causes more problems than the application was supposed to solve

Uncertain!

- Silicon
- Sodium
- Vanadium
- Chlorine
- Cobalt
- Nickel

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What's in the bag?

- For routine plant culture, macronutrients most important
- For instance a typical fertilizer bag will have a guaranteed analysis *aka* grade.
- What's on the bag varies from state to state but usually includes…
  - Name, brand, or trade-mark
  - Guaranteed chemical analysis
  - Potential acidity ($CaCO_3$ equivalent)
  - Manufacturers name and address
  - Net weight of the fertilizer in the container
- Complete vs. incomplete (usually, but not always 3 numbers)
  - 20 – 20 -20 vs. 46 – 0 – 0 vs. 15 – 0- 15

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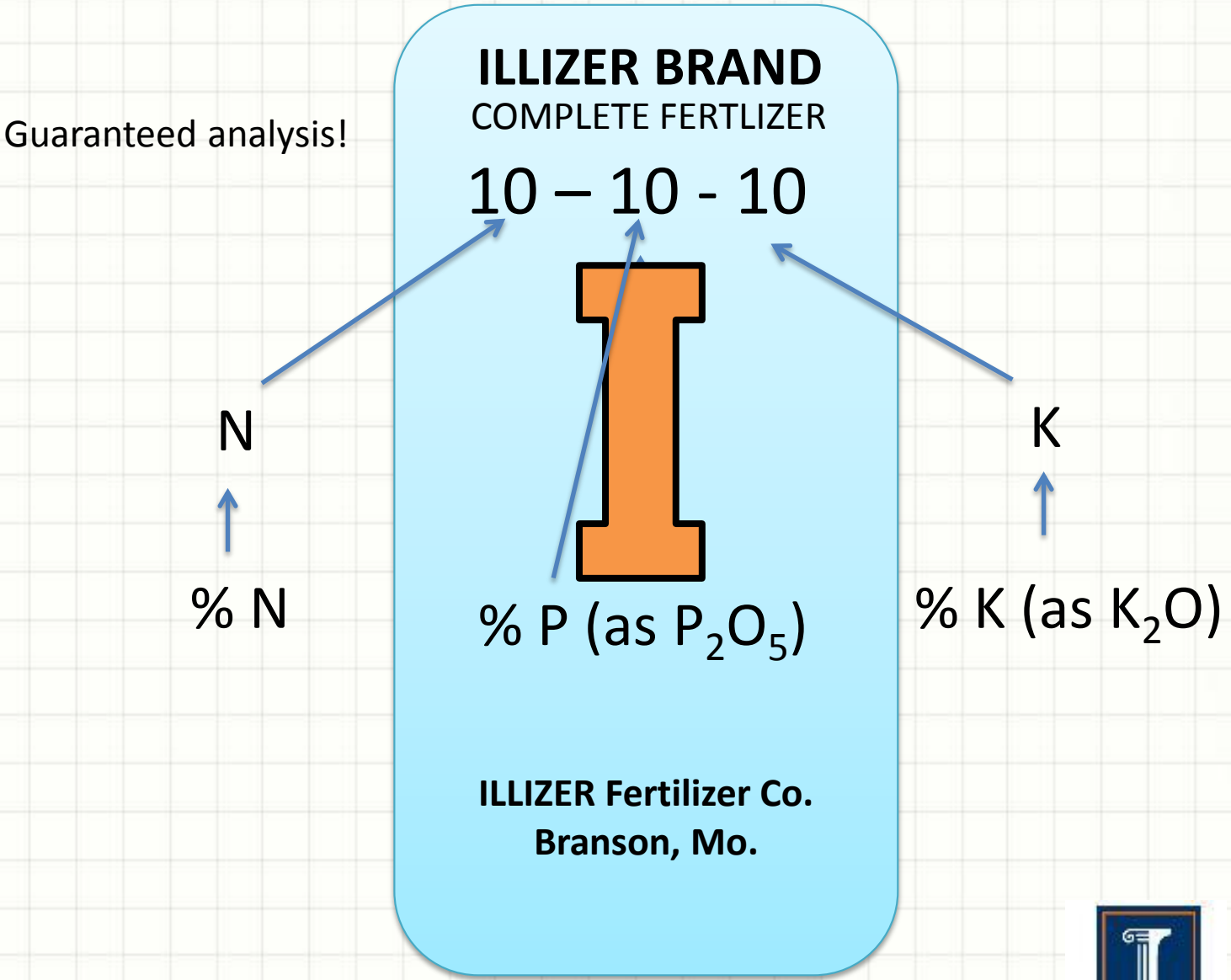
What's in a typical fertilizer?



Crop utilization of fertilizer N

Fertilizer N uptake efficiency varies (FNUE)

- Soil N-supplying capacity
- Weather conditions
  - Crop growth and N uptake
  - Soil N mineralization
  - N losses

- Typical uptake efficiency is 30-50% of N fertilizer applied
- Even with high N rates, the soil often supplies the majority of crop N
- Proportion of N uptake decreases during the growing season
  - Progressive depletion of fertilizer N
    - Plant and microbial uptake
    - N losses from the system
  - Ongoing soil N availability through
  - mineralization

Synthetic N fertilizer

- The percentage of N in the fertilizer
  - Weight * analysis = amount of N per unit amount (Lb./Lb., etc.)
- Additional information is usually supplied regarding the N present (generally for synthetic N)
  - Water insoluble nitrogen (WIN) – Slowly available
  - Water soluble nitrogen (WSN) – Quickly available
  - WSN - 4-6 week response
    - Over-application can cause injury, too much vertical growth
  - WIN – much less likely to injure, much slower response

Synthetic N fertilizer

- Why does fertilizer “burn” plants?
  - Over-application (please calibrate your equipment)
  - Improper post-application handling
- Some more prone than others
  - Corrosivity
  - Salt index (classifies fertilizer material relative to each other and shows which is most likely to cause injury)
  - http://www.soils.wisc.edu/extension/wcmc/2008/pap/Laboski1.pdf

Salt index continued

Relative sensitivity of common crops to fertilizer salts.†

Crop	Relative sensitivity
Wheat	Least sensitive ‡
Corn	
Forage legumes	
Soybean and edible bean (dry or snap)	
Vegetables including sweet corn	Most sensitive

† Reproduced from Reid (2006).

† Least sensitive does not mean that the crop is not sensitive to salt.

http://www.soils.wisc.edu/extension/wcmc/2008/pap/Laboski1.pdf

Reid, K. 2006. Soil fertility handbook. Ontario Ministry of Agric., Food and Rural Affairs. Publ. 611.

Synthetic N fertilizers – Anhydrous NH_3

- Advantages:
  - High N content (82-0-0)
    - Reduces transport, distribution, and storage cost
    - Lost cost of manufacture compared to other synthetic N fertilizers
    - Used to make other fertilizers
- Disadvantages
  - Must be stored and applied under pressure
  - Hazardous to health
    - High concentrations can be lethal
    - Highly corrosive
    - Safety equipment is critical (goggles, gloves, gas mask, bucket of water)
  - Has a drastic effect on soil
    - Partial sterilization
    - Solubilzation of organic matter
    - pH 9 or higher
  - Diversion for illicit drug synthesis
  - Normally used for cash-grain crops, specialty crops not so much

Synthetic N fertilizers – Aqua NH_3

- Low-pressure solution of NH_3 in water (ammonium hydroxide solution)
- Contains 20-25% N
- Not suitable for surface applications
- Not common in vegetable crop culture

Synthetic N Fertilizers – Urea Ammonium Nitrate (UAN)

- UAN is a nonpressure solution of ammonium nitrate, urea, and water.
  - Two grades are most common: 28-0-0 and 32-0-0
  - The lower analysis material contains more water and can be stored at lower temperatures.
  - Salt crystals will form at about 0°F for 28 percent solution and at about 32°F for the 32 percent solution.
- UAN solutions have an advantage in terms of handling
  - Can be pumped, mixed with chemicals and sprayed
  - They are corrosive and will quickly destroy brass, bronze and zinc, carbon steel and cast iron
  - UAN doesn't corrode aluminum alloys, stainless steel, rubber, neoprene, polyethylene, vinyl resins, and glass.

Synthetic N Fertilizers - Urea

- Fertilizer grade 46-0-0
- Undergoes enzymatic hydrolysis and subsequent nitrification
  - $H_2NCONH_2 + H_2O \leftrightarrow 2NH_3 + CO_2 \rightarrow 2\ NO_3^-$
- Advantages
  - High N content
  - Water soluble
  - No health hazard
  - No danger of fire or explosion
- Disadvantages
  - Subject to losses if not properly managed
  - NH_3 toxicity (avoid placement with seed)
  - Rapid nitrification

Synthetic N fertilizers – Ammonium Nitrate

- Fertilizer grade 31-0-0
- More popular in Europe than the U.S.
- Cakes during storage
- Half the N is NO_3^- (leaching issues)
- Fire and explosion hazard
- Can be difficult to obtain

Synthetic N Fertilizers – Ammonium Sulfate

- Fertilizer grade 21-0-0-24
- Advantages
  - Acidic
    - No need to incorporate
    - Slows nitrification
  - Also supplies S
  - Good physical properties
- Disadvantages
  - Can easily cause injury to above ground plant parts
  - Low N content

Synthetic N Fertilizers – Potassium Nitrate

- KNO_3 is especially useful where a highly soluble, chloride-free nutrient source is needed.
  - All of the N is immediately available for plant uptake as nitrate
  - Vegetable and orchard crops sometimes are fertilized with a nitrate-based source of nutrition in an effort to boost yield and quality
  - Contains a relatively high proportion of K, with a N to K ratio of approximately 1:3.
  - Many crops have high K demands and can remove as much or more K than N at harvest.
  - Applications of KNO_3 to the soil can be made before the growing season or as a supplement during the growing season
  - A diluted solution is sometimes sprayed on plant foliage to stimulate physiological processes or to overcome nutrient deficiencies.
  - Foliar application of K during fruit development can be advantageous for some crops, since this growth stage often coincides with high K demands during the time of declining root activity and nutrient uptake.
  - Commonly used for greenhouse plant production, fertigation, and hydroponic culture.

Synthetic N fertilizers – Calcium Nitrate

- 15.5-0-0
- Also supplies calcium (19% Ca)
- Water soluble
- Suitable for preplant fertility, sidedressing, fertigation, foliar applications
- No volatile N losses
- Popular for correcting blossom end rot in tomato, pepper and eggplant as well as correct cork spot and bitter pit in apple and pear.

Synthetic N Fertilizers – Ammonium Phosphates

- Monoammonium phosphate (MAP) 11-52-0
- Diammonium phosphate (DAP) 18-46-0
- Ammonium polyphosphate (APP) 10-34-0

- Advantages
  - Provide P as well as N
- Disadvantages
  - Can overapply P if using as sole source of N

Slow/controlled release synthetic N fertilizer

- Controlled-release nitrogen – designer N release: 70-270 d
- Slow-release i.e. urea form, sulfur-coated urea, PCSCU, IBDU, WIN
- Advantages
  - More uniform growth
  - Not likely to cause damage
  - Losses through soil or air less likely
- Disadvantages
  - May not work on cold soil
  - Most are expensive
  - May not see quick plant response

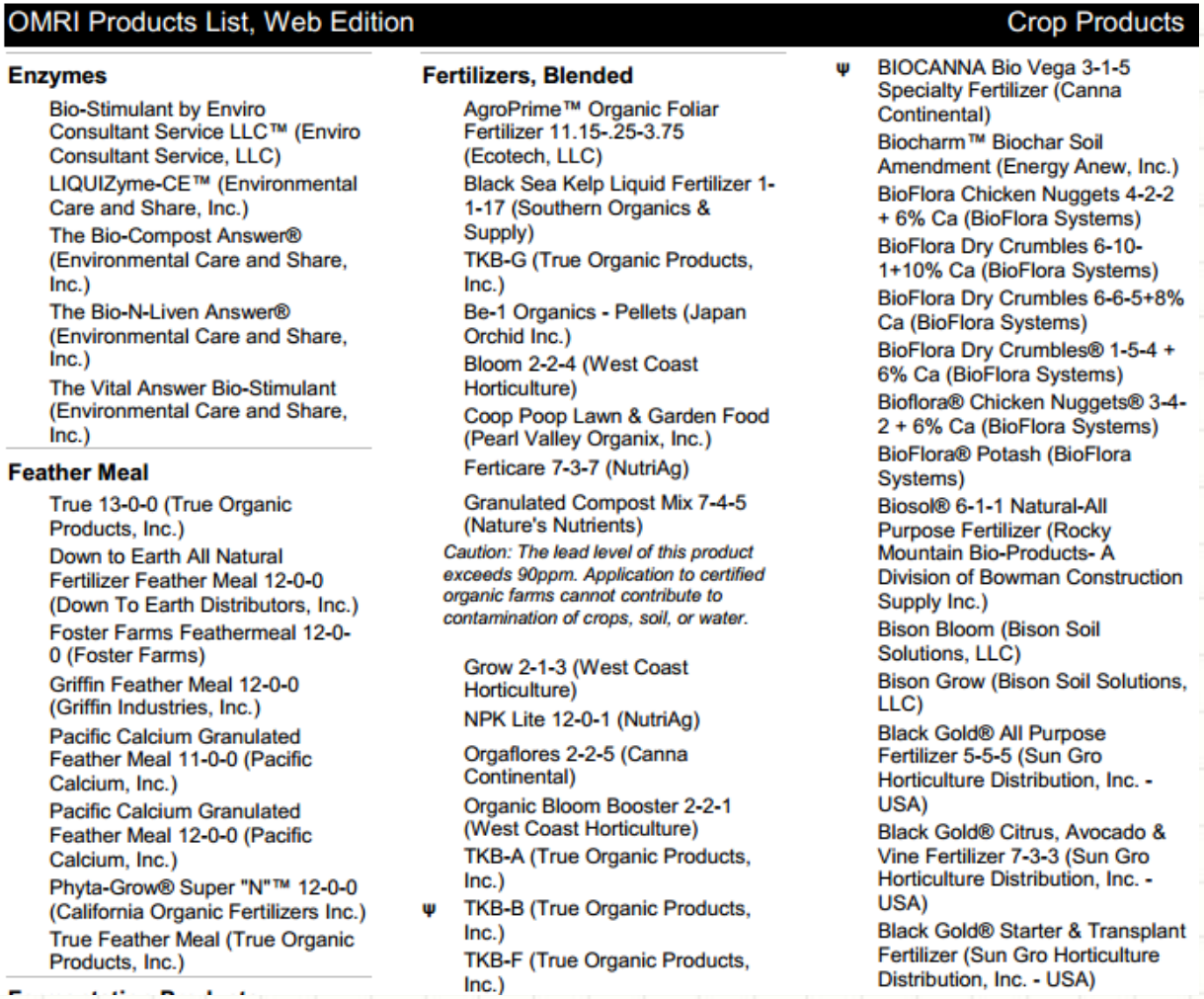
Stabilized synthetic N fertilizers

- N fertilizer formulated to include compounds intended to decrease N losses and increase fertilizer N use efficiency
- Generally urea or ammonium-based
- Examples:
  - N-n-butyl-thiophosphoric-triamide (NBPT)
  - DCD (dicyandiamide)
- Stabilized ≠ slow or controlled release
- May or may not work, sometimes decrease yield
- Cost can be a concern

Organic N fertilizers

- The major agricultural source of fixed N prior to 1920
- Wide variety of materials
- Low N content
- No negative consequences?/Can't over-apply?

Organic N Fertilizers



OMRI Products List, Web Edition — Crop Products

Enzymes

- Bio-Stimulant by Enviro Consultant Service LLC™ (Enviro Consultant Service, LLC)
- LIQUIZyme-CE™ (Environmental Care and Share, Inc.)
- The Bio-Compost Answer® (Environmental Care and Share, Inc.)
- The Bio-N-Liven Answer® (Environmental Care and Share, Inc.)
- The Vital Answer Bio-Stimulant (Environmental Care and Share, Inc.)

Feather Meal

- True 13-0-0 (True Organic Products, Inc.)
- Down to Earth All Natural Fertilizer Feather Meal 12-0-0 (Down To Earth Distributors, Inc.)
- Foster Farms Feathermeal 12-0-0 (Foster Farms)
- Griffin Feather Meal 12-0-0 (Griffin Industries, Inc.)
- Pacific Calcium Granulated Feather Meal 11-0-0 (Pacific Calcium, Inc.)
- Pacific Calcium Granulated Feather Meal 12-0-0 (Pacific Calcium, Inc.)
- Phyta-Grow® Super "N"™ 12-0-0 (California Organic Fertilizers Inc.)
- True Feather Meal (True Organic Products, Inc.)

Fertilizers, Blended

- AgroPrime™ Organic Foliar Fertilizer 11.15-.25-3.75 (Ecotech, LLC)
- Black Sea Kelp Liquid Fertilizer 1-1-17 (Southern Organics & Supply)
- TKB-G (True Organic Products, Inc.)
- Be-1 Organics - Pellets (Japan Orchid Inc.)
- Bloom 2-2-4 (West Coast Horticulture)
- Coop Poop Lawn & Garden Food (Pearl Valley Organix, Inc.)
- Ferticare 7-3-7 (NutriAg)
- Granulated Compost Mix 7-4-5 (Nature's Nutrients)

Caution: The lead level of this product exceeds 90ppm. Application to certified organic farms cannot contribute to contamination of crops, soil, or water.

- Grow 2-1-3 (West Coast Horticulture)
- NPK Lite 12-0-1 (NutriAg)
- Orgaflores 2-2-5 (Canna Continental)
- Organic Bloom Booster 2-2-1 (West Coast Horticulture)
- TKB-A (True Organic Products, Inc.)
- Ψ TKB-B (True Organic Products, Inc.)
- TKB-F (True Organic Products, Inc.)

Ψ BIOCANNA Bio Vega 3-1-5 Specialty Fertilizer (Canna Continental)

- Biocharm™ Biochar Soil Amendment (Energy Anew, Inc.)
- BioFlora Chicken Nuggets 4-2-2 + 6% Ca (BioFlora Systems)
- BioFlora Dry Crumbles 6-10-1+10% Ca (BioFlora Systems)
- BioFlora Dry Crumbles 6-6-5+8% Ca (BioFlora Systems)
- BioFlora Dry Crumbles® 1-5-4 + 6% Ca (BioFlora Systems)
- Bioflora® Chicken Nuggets® 3-4-2 + 6% Ca (BioFlora Systems)
- BioFlora® Potash (BioFlora Systems)
- Biosol® 6-1-1 Natural-All Purpose Fertilizer (Rocky Mountain Bio-Products- A Division of Bowman Construction Supply Inc.)
- Bison Bloom (Bison Soil Solutions, LLC)
- Bison Grow (Bison Soil Solutions, LLC)
- Black Gold® All Purpose Fertilizer 5-5-5 (Sun Gro Horticulture Distribution, Inc. - USA)
- Black Gold® Citrus, Avocado & Vine Fertilizer 7-3-3 (Sun Gro Horticulture Distribution, Inc. - USA)
- Black Gold® Starter & Transplant Fertilizer (Sun Gro Horticulture Distribution, Inc. - USA)

http://www.omri.org/sites/default/files/opl_pdf/crops_category.pdf

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Organic N Fertilizers – Animal Manure

- Of local importance
- Disposal a problem for confinement operations
- N content depends on
  - Kind of animal
  - Feed and bedding material
  - Method of:
    - Handling
    - Storage
    - Application
- Average N content: 10 lb N/ton (0.5%)
- 50% of the N is available in the first year after

Organic N fertilizer – sewage sludge

- Treated to reduce pathogens, odor, and heavy metal concentrations
  - By adding lime to precipitate heavy metals
  - Aerobic or anaerobic digestion
  - By dewatering
- Extent of treatment varies:
  - Class A: no restrictions, better grade
  - Class B: restricted use
    - Both classes may contain radioactive or pharmaceutical wastes
- Contains organic (complex N compounds) and inorganic N (as NH_4^+)
- Contains most other macro and micronutrients

Organic N fertilizer – sewage sludge

- N content of sewage sludge is variable
- Application rates determined by:
  - Crop N requirement
  - Content of plant-available N, including:
    - NO_3^--N
    - NH_4^+-N, with adjustment for volatilization losses
    - Mineralizeable organic N as estimated by incubation
    - assays
  - P content
    - Sludge applied at agronomic N rates supplies excessive P
  - Heavy metal content
    - Often determines annual and cumulative soil loading
    - limits

Organic N fertilizer – green manure/cover crops

- For summer cash crop, use as winter cover
  - Plant in fall
  - Kill or harvest in spring
    - By plowing under (green manure) or herbicide
- Source of N
  - Not all N is plant available
  - Supplemental N may be needed
  - Non-leguminous crops do not supply much N
- Reduced NO_3^- leaching from soil from assimilation
- Increase in soil organic matter
- Reduced erosion
- There are many options: http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/landuse/crops/?cid=stelprdb1077238

Organic N fertilizer – animal by-products

- Products of the slaughterhouse industry
- Blood meal (highest N of all the natural organics) (12-1.5-0.5)
- Bone meal
- Feather meal
- Fish meal/emulsion
- Tend to have offensive odor
- Generally expensive
- Slow-release of nutrients

Organic N fertilizer – mineral forms

- N does not normally occur in mineral forms
  - Except as fixed NH_4^+ in rocks and clay minerals
    - Fixed = not available
  - Or, as nitrate salts in arid regions
- Chilean nitrate = nitratine = $NaNO_3$
  - Acatama desert, Chile; Death Valley, CA
- Bat guano = KNO_3

P fertilizers

- Back to the bag: what does the number mean?
  - Actual % of P?
  - No (P_2O_5), to get the actual % P x by 0.44
  - Why?

Seasonal uptake of P by plants

- Unlike N
- Taken up throughout the life of the plant
- Early growing season most critical
  - A paradox: P required for root growth, root growth limits P uptake
- Root system not well developed in seedlings
- Cool weather slows plant growth – purple corn?

Synthetic P fertilizers – phosphoric acid

- Fertilizer grade 0-50-0
- Made from rock phosphate
- Some use in fertigation
- Main use is manufacture of other P fertilizers

Synthetic P fertilizers – calcium orthophosphates

- Single superphosphate
  - AKA ordinary superphosphate (OSP); normal superphosphate (NSP)
  - Fertilizer grade: 0-20-0-12 (8.6%P; 12% S)
  - Leading P fertilizer until 1950's
  - Main limitation is low P analysis
  - No longer available in the U.S., still used in other parts of the world
- Triple superphosphate (TSP)
  - AKA concentrated superphosphate
  - Fertilizer grade 0-46-0
  - Contains very little S
  - High analysis reduces costs
  - Leading P fertilizer in the U.S. in the 1950's and 1960's
  - Still widely available

Synthetic P fertilizers – ammonium phosphates

- Monoammonium phosphate "MAP"
  - Fertilizer grade 11-52-0
- Diammonium phosphate "DAP"
  - Fertilizer grade 18-46-0
  - Most common P fertilizer in the U.S.
- Ammonium polyphosphate "APP"
  - Fertilizer grade 10-34-0
  - Used in fluid fertilizers

Synthetic P fertilizers – ammonium phosphates

- Advantages
  - Completely water soluble
  - Supply P as well as N
  - High P content
    - Minimizes shipping, handling, and storage costs
  - Application flexibility
    - Liquid or solid
  - Increased P uptake in the presence of NH_4^+

Synthetic P fertilizers – ammonium phosphates

- Special advantages of MAP
  - Increased N efficiency
    - No NH_3 volatilization
    - No NH_3 toxicity
  - Easier to manufacture
    - Requires a lower grade of phosphate rock than DAP
- Advantages of PAP
  - High P content
  - High P solubility
  - Good agronomic effectiveness except in cool soils

Synthetic P fertilizers – nitric & potassium phosphates

- Nitric phosphate
  - Fertilizer grade 20-20-0
  - Only 50% of the P is water soluble
  - Best suited for acid soils
  - Mainly used in Europe
- Potassium phosphate
  - Two types:
    - KH_2PO_4 (0-52-35)
    - K_2HPO_4 (0-41-54)
    - Main use is for small areas/extremely valuable crops
  - Advantages
    - High content of P and K
    - P is 100% soluble
    - Supply K without Cl^-
  - Disadvantage
    - Cost can be prohibitive

Organic P fertilizers - animal manure

- Accounts for most organic P applied to cropland
  - Also contains inorganic P
- P form and content depend on:
  - Type of animal
    - High content of total and organic P in poultry manure
    - Feed
  - Storage
    - Decreases of organic P
    - Increases inorganic P
- General composition: 0.5-0.25-0.5 by weight
- Available P: <2 lb per ton
- High levels of available P in heavily manured soils

Organic P fertilizers – sewage sludge

- Contains 2-4% P (dry weight basis)
- Most of the P is inorganic
- Typical applications supply excessive P for crop production
- Can have problems with heavy metal accumulation

Organic P fertilizers – rock phosphate

- An important P fertilizer in the U.S. until the 1950's
- Still used in the tropics
- Mined from phosphate rock reserves in the U.S.
  - Florida
  - N. Carolina
  - Utah
  - Idaho
  - Tennessee
- Obtained by:
  - Strip mining (surface) in the East
  - Shaft mining (below ground) in the West
- Very limited fertilizer value unless the soil pH is <6
- Release depends on granule size

Synthetic K fertilizers

- These are all mined from mineral deposits

- KCl AKA muriate of potash
  - Fertilizer grade 0-0-60 (“red”) or 0-0-62 (“white”)
  - Most common K fertilizer
  - Mined from natural deposits of sylvite
  - Largest deposits are in Saskatchewan
  - Less expensive than N or P fertilizer

Processed mineral forms of K

- K_2SO_4 AKA sulfate of potash
  - Fertilizer grade 0-0-50-17 (S)
  - Used on Cl^- sensitive crops (potatoes, tobacco)
- KNO_3
  - Fertilizer grade 13-0-44
  - Main use for:
    - Fruit trees
    - Cotton
    - Vegetable crops

Processed mineral forms of K

- Alkaline K fertilizers
  - K carbonate
  - K bicarbonate
  - K hydroxide
  - Good for use on acid soils
    - Increase the efficacy of P fertilizers
    - Cost is the main limitation
- K fertilizers containing S
  - K thiosulfate
  - K polysulfide
  - Suitable for foliar applications and fertigation
  - Expensive

Organic K fertilizers

- Animal manure
  - K content less variable than for N or P
  - Lower for liquid than dry manure
  - Average composition: 0.5-0.25-0.5
  - Available K: <4 lb/ton
- Kelp & seaweed
  - Contain inorganic K salts
    - KCl, K_2CO_3, etc.
    - These water soluble salts will leach into the soil

Final thoughts to consider

- Is there a difference?
- There are ways to offset possible negative effects
- There is still a lot to learn, the fertilizer industry is massive, this presentation is not the whole story on fertilizer materials
- For maximum efficacy conduct on-farm trials
- What works for you, works for you. That's the bottom line

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If you have questions …

- University of Illinois Extension Local Food Systems and Small Farms team
  - http://web.extension.illinois.edu/smallfarm/
- USDA's Start2Farm site
  - http://www.start2farm.gov/

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