Intensification and nutrient management in dryland cropping systems

Jay B. Norton
Farmers fret over fertilizer costs as natural gas prices soar

By EMILY FREDRICK
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OMAHA, Neb. -- Dave Nielsen just spent nearly $14,000 to fertilizer his crops, an amount he never could have imagined when he started farming 20 years ago.

But the $410 a ton Nielsen paid is symptomatic of the crunch farmers are feeling this year as the cost of fertilizer soars. While rising natural gas prices are causing lawmakers and homeowners to worry about heating costs this winter, farmers are wondering how they'll pay for fertilizer, which uses the energy source to produce its main ingredients, such as ammonia or nitroco.

The potential impact a fertilizer crisis may have on production numbers and food prices has been lost on many people outside the farming industry, said Rob Robertson, vice president of governmental relations at the Nebraska Farm Bureau.

"There's just a lot of uncertainty in agriculture right now because of the energy costs, and fertilizer is probably the best example of what the uncertainty means in their financial picture next year," Robertson said.

Although most farmers are still harvesting, they're thinking of next year, deciding how much to renew their operating loans for and how they'll rotate their crops. Farmers across Nebraska and beyond are weighing their options, which include using less fertilizer and planting more soybeans or wheat, which can thrive with less fertilizer than corn.

At his farm in northern Lancaster County, near Lincoln, Nielsen decided to plant 25 percent more wheat in the hope of curbing his consumption of anhydrous ammonia. He thought last year's prices for the fertilizer -- at about $335 a ton -- were high. In the early 1990s, prices hovered around $200 a ton for that type of fertilizer, according to the USDA.

Anticipating further price increases in the past two years, Nielsen said, he cut his fertilizer use on fall applications by 15 percent. Although the yields of corn, wheat and soybeans on his 1,750 acres have been fine, Nielsen said, he worries about the long-term quality of his soil without regular applications of fertilizer.

"If you go too much, then you start robbing your soil. Eventually, someday it's going to catch up with you," Nielsen said.

With farmers such as Nielsen choosing not to plant fertilizer-hungry corn, it's possible the country will see a drop in corn production next year, which would give way to higher prices at grocery stores months from now, said Rob Young, chief economist of the American Farm Bureau. The U.S. Department of Agriculture recently raised its estimates for this year's corn crop to more than 10.8 million bushels, up from 10.6 million bushels last month. But that
Optimizing yields

- Nutrient supply = yield potential $f(\text{available water})$.
- To increase yields must enhance:
  - Nutrient supply to the crop
  - Available water

- HOW?
Reduced till/reduced fallow

- Intensified cropping through reduced tillage and reduced fallow
  - increased available moisture
  - Improved soil nutrient supply potential
  - Crop diversification further increases yield potential
Overview

• Soil organic matter in Northern Plains croplands
• Nutrient cycling under crop-fallow
• Nutrient cycling under intensified cropping (reduced fallow, reduced till)
• Cropping system diversification
• Nutrient status assessment
• Discussion:
  – Conservation tillage in Wyoming
  – Nutrient management approaches and needs
Soil organic matter in Northern Plains croplands

- SOM increases soil porosity, which increases soil water holding capacity and water infiltration rates.
Soil organic matter in Northern Plains croplands

- SOM increases soil porosity, which increases soil water holding capacity and water infiltration rates.
- Also increases soil CEC, or ability to hold and release nutrients.
• Northern Plains croplands have lost 30 to 60 percent of original SOM since cropping began.

• Lost through erosion and because tillage and fertilization speed decomposition.
Nutrient cycling under crop-fallow

- Crop-fallow systems stabilize yields & create relatively predictable income:
  - Excess stored water and nutrients during fallow create buffer for crop years.
  - High available water at planting increases yield potential.
Nutrient cycling under crop-fallow

• A leaky system – very low water and nutrient use efficiency:
  – 75 percent of precip. is lost to evaporation, weeds, runoff, or movement below the root zone.
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Nutrient cycling under intensified cropping

• Reduced- or no-till systems conserve water to allow reduction or elimination of fallow:
  – Crop needs are more balanced with availability.
  – Higher average, but lower annual, yields.
  – A more synchronized system that requires more careful management.
Nutrient cycling under intensified cropping

Moisture and nutrient availability evens out: less at planting but more later when crops need it.
Resource availability

- Long-term monitoring studies show less water and nutrient availability following crops than fallow:
  - consistently lower soil nitrate (North Dakota).
  - lower available water, especially deeper in the profile (Kansas).

From Halvorson et al., 1999.

From Schlegel et al., 2002.
Grain yields

- But higher grain yields over the long term:
  - Yields increased with time.
  - Made better use of mid-range available water.

- No-till and minimum-till made much better use of moderate and high fertilizer N rates.

- Less resources but higher yields???

From Halvorson et al., 1999.
Nutrient cycling under intensified cropping

• No-till improves soil physical properties including macro and micro porosity.
  – Better use of in-season rainfall.
  – Leads to more in-season decomposition/availability.
  – Late-season N availability boosts protein.

From Shaver et al., 2005. Based on 12 years of data.
Effects on Soil Organic Matter

• Higher average yields mean more plant residue contributed:
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  – Soil organic matter increases over time.

*From Grant et al., 2002. Based on 34 years of data.*
Effects on Soil Organic Matter

- Higher average yields mean more plant residue contributed:
  - Soil organic matter increases over time.
  - Each fraction also increases.
  - More SOM means more decomposition and more nutrient availability, BUT:

From Sherrod et al., 2005. Based on 12 years of data.
Effects on Soil Organic Matter

- Higher average yields mean more plant residue contributed:
  - Soil organic matter increases over time.
  - Each fraction also increases.
  - System more closely resembles perennial grass:
    - tight nutrient cycle: diverse microbial community rapidly takes up and turns over available nutrients.
Effects on Soil Organic Matter

Grass or Reduced Till/Reduced Fallow

- Active SOM
- Slow SOM
- Passive SOM

Conventional Crop-Fallow

- Active SOM
- Slow SOM
- Passive SOM
At first recovering SOM system ties up nutrients, increasing fertilizer requirements.
• At first recovering SOM system ties up nutrients, increasing fertilizer requirements.
  - As the slowly decomposing pools build the nutrient-supplying potential of the soil increases and fertilizer requirements decrease.
  - Excess nutrients are held in SOM, not lost.

From Grant et al., 2002. Based on 34 years of data.
A new paradigm

• Average yields increase but annual yields drop significantly:
  
  – lower fertilizer requirements to match annual yield.

  – High C/N residue: incorporate fertilizer below to avoid immobilization.

  – Becomes easy to over fertilize relative to available water, which can decrease yields, pollute water resources, and waste money (need approaches to determining soil nutrient supply).

  – Crop diversification possibilities increase and contribute to yet higher yield potentials.
Cropping system diversification

- Using multiple crops in rotation increases yield potential by influencing:
  - Disease cycles.
  - Weeds.
  - Root distribution.
  - Moisture utilization.
  - Nutrient availability: both N and non-N effects.
Deep-rooted crops

• **Improve Nutrient use efficiency:**
  – Capture deeply infiltrated moisture and nutrients.
  – Slow in cold climates.

• **Alfalfa + smooth brome for two years removed nitrate from greater than 10 feet.**
  – Chance of nitrate loss if alfalfa is followed by fallow.
Annual legumes

- Fix N from atmosphere: positive effects even if harvested.
  - Lentil in rotation increased nitrate in root zone and decreased it below root zone compared to continuous wheat.

From Grant et al., 2002.
Annual legumes

- Low C/N ratio residue means more rapid decomposition during growing season: Higher grain protein
- Legumes in rotation may affect grain protein more than yield.

From Grant et al., 2002.
New approaches for assessing nutrient status
New approaches for assessing nutrient status

- False color imagery for remote sensing nitrogen response in wheat:
    - N response on footslope but not summit/backslope.
  - 2002: drought conditions.
    - No N response.
  - Can determine N needs under adequate moisture.

From Upper Midwest Aerospace Consortium (www.umac.org)
New approaches for assessing nutrient status

- NDVI Zoning for variable rate application in sugarbeets:
  - Normalized Difference Vegetation Index: greener means more residue N credits.
  - Zoned for variable N application on next year’s wheat crop.
  - Saved $99 per acre.
  - 35% less N applied.
  - Used with differential GPS.

[Color codes: Red: 190 pounds
Yellow: 160 pounds
Green: 130 pounds]
New approaches for assessing nutrient status

- High resolution false color for precision agriculture:
  - Aircraft mounted sensors.
  - Shows areas of vigor and areas of stress.
Rangeland applications

- Landsat imagery for predicting forage production and anticipating shortages.
- Weed mapping.
Conclusions

• Optimal yields: nutrient supply = yield potential supported by available moisture.
• Reduced- and no-till systems increase both available moisture and soil nutrient supplying potential.
• Makes annual cropping possible.
• Restores soil organic matter:
  – Better use of in-season water and nutrient availability.
  – Stores excess nutrients in “slow-release” forms.
• Per crop yields reduced but overall yields increased.
• Uptake synchronized with availability: reduces pollution.
• Requires more careful management.
• Diversification, including deep-rooted and annual legume crops, increases yield potential and grain protein.
• New remote sensing techniques enable precise management.
Discussion

• Needs for soil fertility and nutrient management research in Wyoming