



Module 3: Phosphorus Management

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Introduction

- Phosphorus (P) is essential for plant growth
 - required for many plant functions
 - energy transfer and protein synthesis
 - increases cell multiplication, stem and root growth, stem strength
 - increases biological nitrogen (N) fixation
- Symptoms of P deficiency:
 - stunting
 - dark green/purple coloration of leaves
- Phosphorus uptake and removal with harvest are highly dependent on yield
- Phosphorus removal can be used together with soil testing for P application recommendations
- Phosphorus loss from agricultural fields can significantly affect surface water quality



Phosphorus Amounts in Harvested Portions of Crops

Crop	Unit of Yield	Pounds P ₂ O ₅ per unit of yield
Corn	bu	0.37
Corn silage	bu grain equivalent	0.55
Soybean	bu	0.80
Oat and Straw	bu	0.40
Wheat	bu	0.60
Sunflower	100 lb	0.80
Alfalfa	ton	12.5
Tall fescue	ton	12.0

Source: Iowa State University Extension publication PM 1688.



Agronomic and Environmental Issues

- In most of the U.S., P availability in soils has increased due to long-term application of P in fertilizers and manure.
- Localized regions have seen increases in soil P availability due to long-term application of P nutrients in excess of crop needs.
- When soil P levels become excessive, the risk of P loss from fields and water quality impairment increases.
- The increased concentration and size of confined animal feeding operations have led to P transfer from grain to concentrated animal producing areas causing:
 - regional surpluses of P inputs as fertilizer and feed
 - increases of P application amounts and soil P buildup in excess of crop needs
 - increased risk of P loss from soil to underground and surface water resources



Agronomic and Environmental Issues

- Phosphorus management goal: consider P inputs, outputs, and appropriate soil and P application management practices to maintain or increase productivity while minimizing impacts on water quality.

- Strategies that increase nutrient use efficiency, productivity, and minimize P loss to surface water resources may involve:
 - using good soil sampling and testing and proper P application practices
 - implementing variable-rate P application with large within-field yield and soil-test P variation
 - transporting manure from areas with P surplus to areas with P deficit
 - implementing soil conservation practices to reduce soil erosion and surface runoff



Phosphorus Soil Testing

- Very useful tool to assess P requirements for crops and, together with other tools, estimate risk of P loss.
- Several soil test methods are used in different regions of the U.S:
 - Bray-1 (in many states)
 - Mehlich-3 (in many states)
 - Mehlich-1 (in the southeast)
 - Olsen (regions with calcareous soils)
 - Morgan (in the northeast)
- Soil samples are generally collected from the upper 6 to 8 inches of soil, since in many regions deeper or shallower sampling depths does not improve the prediction of crop response. However, in some states a shallower depth is recommended for pastures and no-till.
- Soil-test methods must be correlated and calibrated with crop yield response for soils with contrastingly different soil properties using the most appropriate sampling depth and sampling time.



Phosphorus Interpretation and Recommendation Concepts

- Researchers concepts and economic considerations further influence the recommended optimum soil-test levels for crops.
- The optimal soil-test P level from an economic perspective will depend on:
 - the grain and P fertilizer price ratio
 - producer management philosophy
 - other enterprise management decisions
- Due to variation in soils and both economic and philosophy considerations the interpretation of test results and the recommended P application rates vary greatly across regions.



Phosphorus Interpretation and Recommendation Concepts

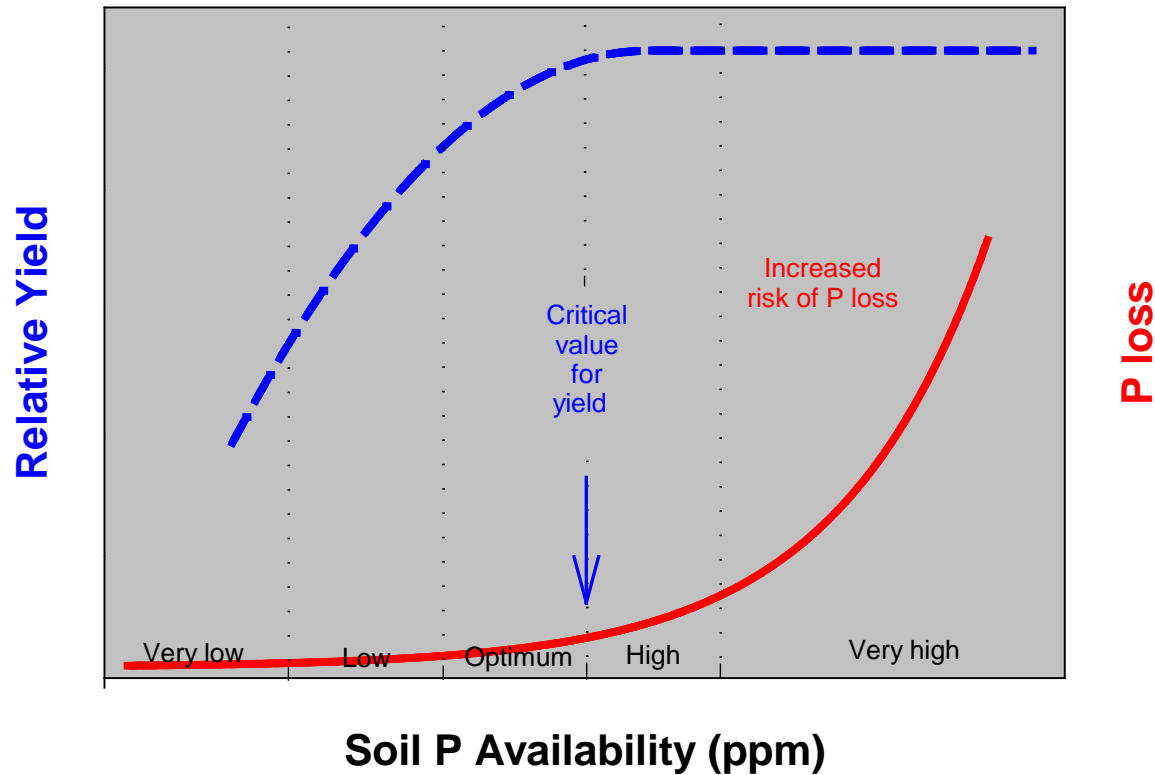
- Recommended approach in most states:
 - Response based application rates for low-testing soils to slowly increase soil-test P to the optimum level
 - Selected rates depend on soil test P value, rotation, economics
 - Time to reach optimum soil test level varies
 - Maintenance P rates based on crop removal with tests at or near the optimal range

- Avoid excessively high soil test levels to reduce risk of P loss to water resources

- Soil-test P levels can be managed over time (buildup, drawdown) in most soils



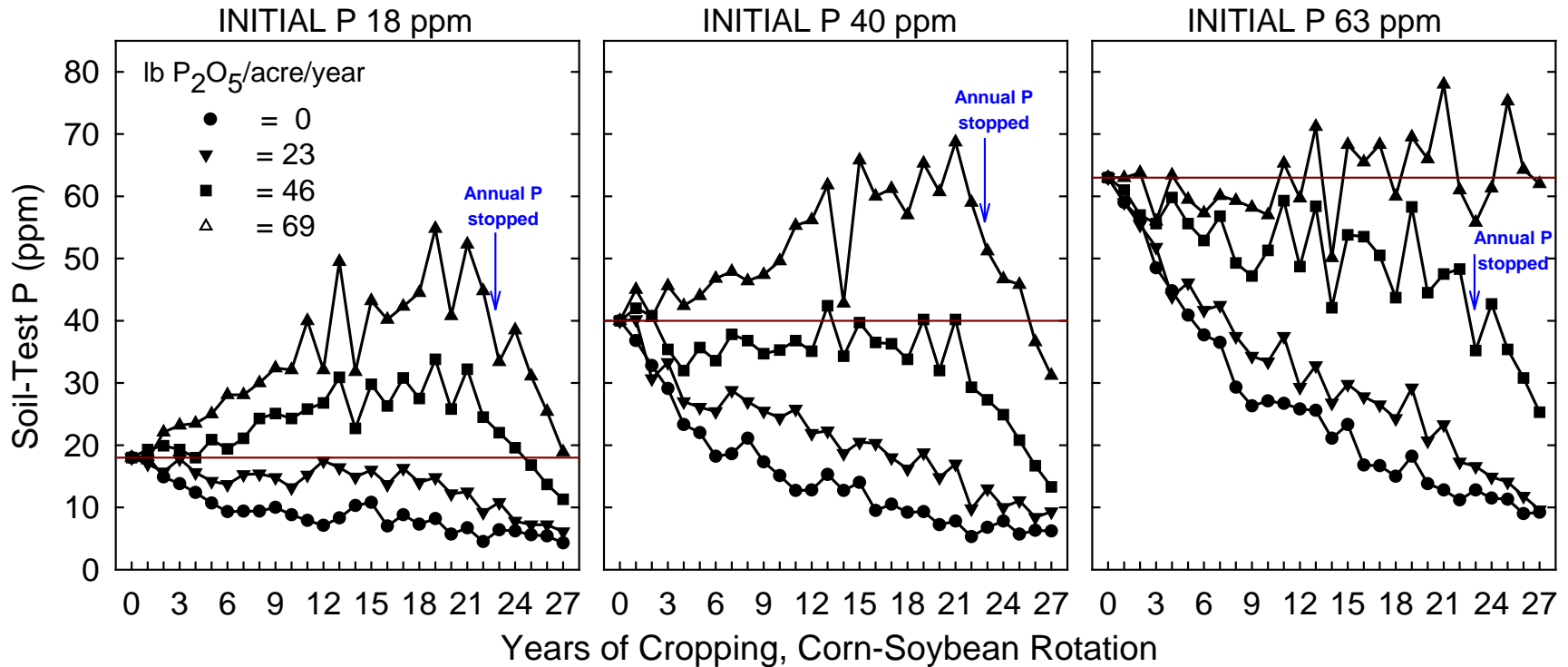
Phosphorus Soil Testing



Schematic representation of the relationship between relative crop yield and P loss.



Interpretation and Recommendations



Example of change in soil-test P (Bray-1) over time with different initial soil-test levels and annual P fertilizer rates in a corn-soybean rotation.



Phosphorus Sources

- Mostly water-soluble P or readily available shortly after application to soil
 - MAP (monoammonium phosphate) (11-52-0)
 - DAP (diammonium phosphate) (18-46-0)
 - Triple superphosphate (concentrated superphosphate) (0-46-0)
 - Ammonium polyphosphate (fluid) (10-34-0)
 - Polyphosphates (fluid) (10-34-0)

- Low or very variable water-soluble P
 - Rock phosphate (apatite and fluorapatite) (0-31-0)
 - Animal manures (variable concentration)
 - Other biosolids (variable concentration)



Application Rate and Soil-test P Level

- There is no crop production justification for increasing soil-test P levels higher than crop sufficiency levels.
- However, utilization of N in animal manures may justify further increases as long as a P risk assessment tool (such as the P Index) indicates that other conditions or management practices result in acceptable risk of P loss.
- Phosphorus losses to groundwater or to surface supplies with erosion, surface runoff , or or subsurface drainage can increase with too high P rates and soil-test P levels.



Application Rate and Soil-test P Level

- When soil-test P is above optimum, P application rates can be reduced to a starter level or eliminated until the soil-test values decrease to the optimum level.
- Subsurface banding often increases P use efficiency and crop yield compared with broadcast fertilization:
 - in soils that strongly retain or transform applied P into less available forms
 - when the soil surface is dry for long periods during the season
 - with thick residue cover in cold and wet soils.
- Subsurface banding also is recommended in soils where erosion and surface runoff is a major concern to reduce P loss impacts on water quality.



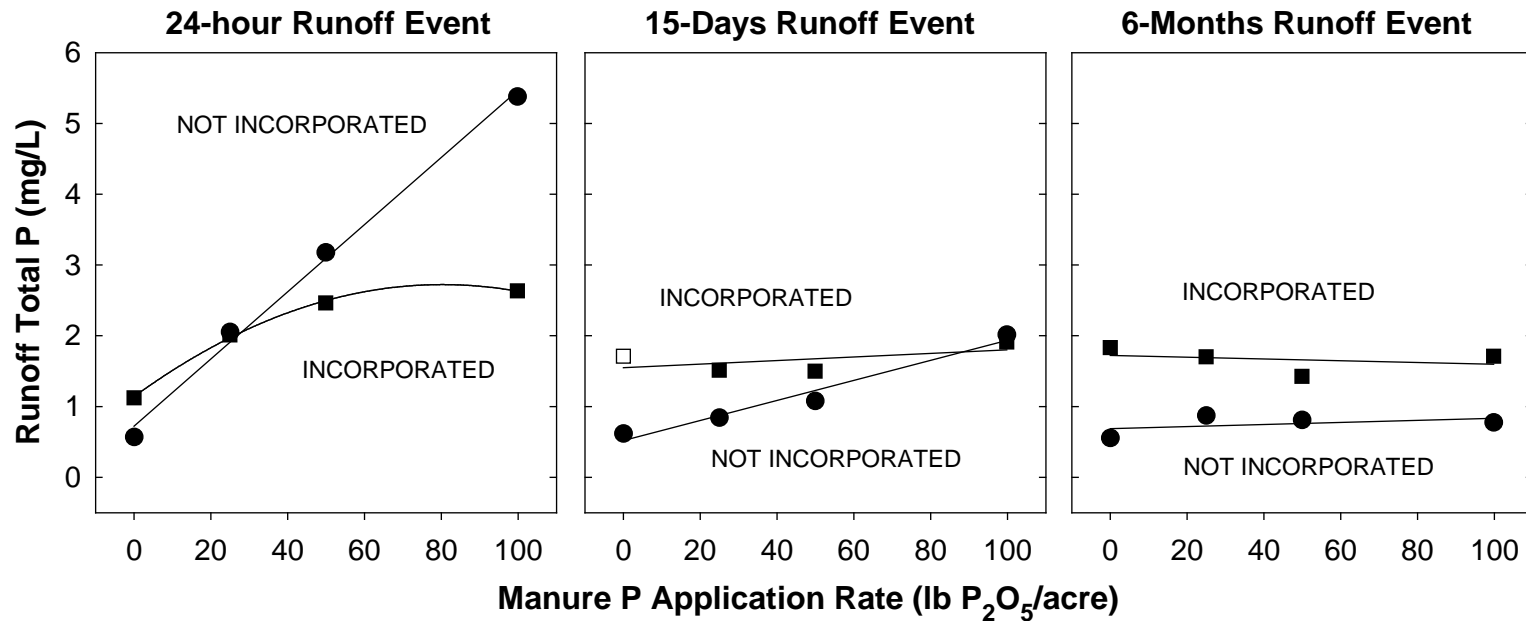
Placement Method

- Phosphorus is less mobile than N and other nutrients in soil, so surface application of P increases soil-test P at the soil surface in reduced tillage systems.

- Total runoff P loss may or may not be reduced with incorporation or subsurface application of manure or fertilizer P because loss also depends on factors affecting soil erosion and surface runoff:
 - Slope
 - soil hydrology
 - soil disturbance and residue cover with incorporation or injection



Application Rate and Placement



Effect of liquid swine manure P application rate, incorporation, and time (days after P application) of simulated rainfall on runoff P.



Application Timing

- The timing of P application before planting typically has little or no impact on crop P use efficiency, except in soils with very high P retention capacity managed with tillage.
- In high P-fixing soils with P well mixed with the soil, application well in advance of crop growth may reduce P use efficiency.
- Fall P application for summer crops and application every other year are common in the northern regions.
- Phosphorus is very important for early crop growth and development. In-season P application is not recommended, except for forages crops and pastures.
- The timing of P application to the soil surface and of tillage to incorporate broadcast P may have a significant impact on runoff P loss for events shortly after application.

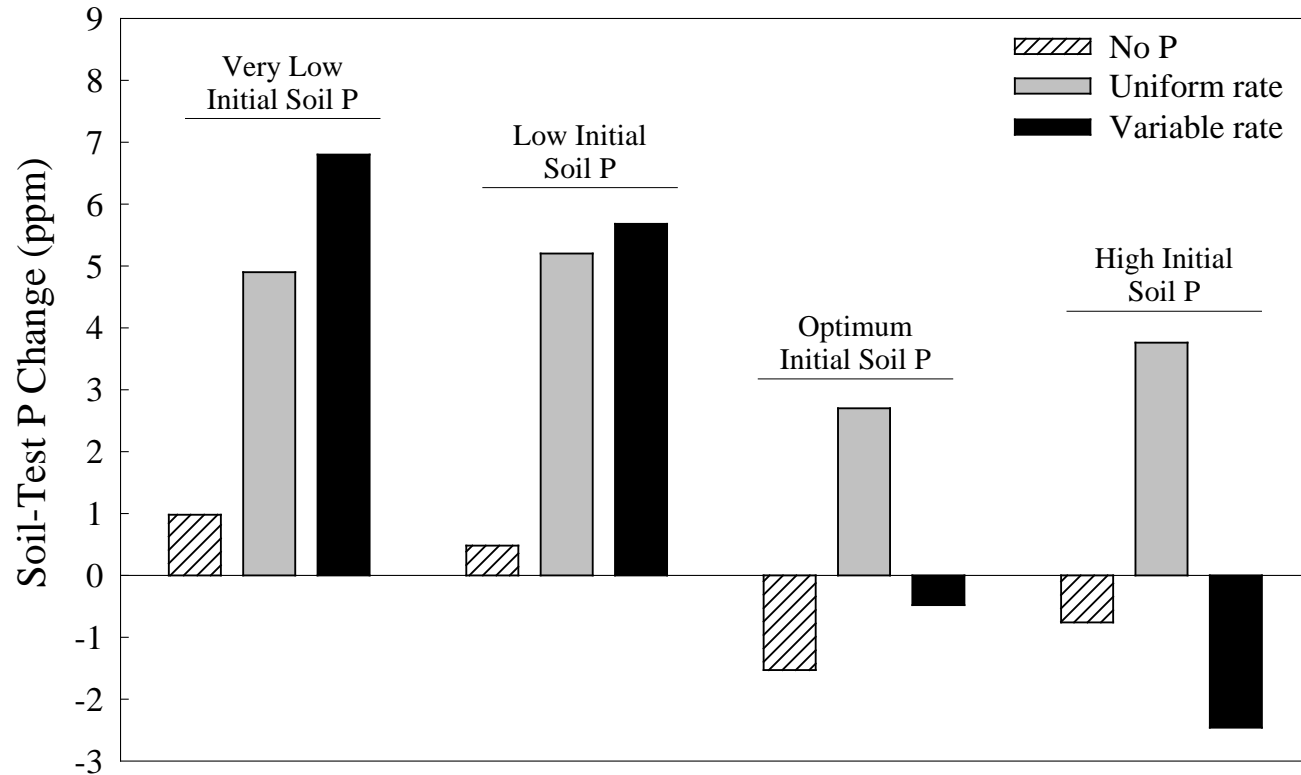


Variable-Rate Phosphorus Application

- Dense soil sampling from many fields has shown very large within-field spatial variability of soil-test P and crop yield.
- Precision agriculture technologies facilitate recording of where composite soil samples are collected and application of fertilizer or manure P at rates adequate for different parts of a field.
- Variable-rate P application:
 - may not always increase crop yield or increase profits
 - benefits depend on soil-test levels and variation
 - minimizes/avoids P application to high-testing field areas
 - reduces soil-test P variability within fields
 - improves P use efficiency
 - reduces risk of P loss



Variable-Rate Phosphorus Application



Effect of uniform application and soil-test P based variable-rate application of liquid swine manure on soil-test P change within a field for various initial soil-test P interpretation classes.



Management Practices for Phosphorus Fertilization

- Rate
 - Sample soil as frequently and as densely as economically possible and use appropriately calibrated soil-test methods.
 - Consider crop P removal, which depend mainly on yield levels, across and within fields to help maintain optimum soil-test P levels and avoid excess or too low application.
 - Fertilize P deficient soils or maintain optimum soil-test values using environmentally and economically sound agronomic practices.
 - Divide large, non-uniform fields into smaller fertility management units based upon yield potential, soil tests, and relevant soil properties.



Management Practices for Phosphorus Fertilization

- Source
 - Consider all available P from manures and other organic sources.
 - Use manure nutrient analysis and a P risk assessment tool in order to utilize as much manure nutrients as much as possible without increasing the risk of P loss and water quality impairment.
- Placement
 - Refer to local research and guidelines concerning P placement methods adequate to the region.
 - Incorporate, band, or inject high rates of inorganic or organic P sources into the soil where the risk of surface runoff or soil erosion is high.
- Timing
 - The timing of P application is less critical than for other nutrients in most soils.



Summary

- Proper P management is essential for many reasons:
 - to maximize profitability
 - maximize efficiency of a non-renewable resource
 - reduce impacts of P on surface water quality
 - avoid further federal or state regulation.

- Phosphorus management goal:
 - keep the soil-test P level at optimal ranges for crops
 - utilize application methods and timing that optimize P use efficiency and profitability
 - minimize water quality impairment.

- Substantial within-field variability of soil-test P levels and P removal justifies the use precision agriculture technologies for P management in many fields.