Fluids:

The Keystone Of All Fertility Programs

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Fluid Advantages

1. **Value**
   - Performance, Profitability & Stewardship
2. **Agronomics**
   - Uniquely Suited To 4R Stewardship
   - Nutrient Use Efficiency
   - Soil Chemistry
3. **Flexibility**
   - Adaptability
   - Versatility
4. **Precision - Right Rate**
   - Application Uniformity & Accuracy
   - Homogeneous, No Segregation, Continuous Bands
   - Calibration
   - Variable Prescription Applications
5. **Logistics**
   - Special equipment not required
   - Product transfer/storage logistics
   - Equipment complexity, versatility & cost

Fluid Fertilizer Foundation Mission Statement

The FFF funds research and education of fluid fertilizers as integral components of crop nutrition programs to achieve precision placement, environmental stewardship, nutrient use efficiency and yield improvement.

Fluid Fertilizer Foundation Mission Statement

- Integral component of crop nutrition programs
  - not simply 100% fluid programs
- Precision placement
  - time and method
- Environmental stewardship
  - 4R's (aka BMP's)
- Nutrient use efficiency
  - agronomics, flexibility and adaptability
- Yield improvement
  - emphasis on promoting high yields

SOME FACTORS TO BE CONSIDERED

- Recognize how fluids, dry's and anhydrous may fit together for a 'best' fertility program
- Idea is not to replace heavy rates of P and K but to look at how systems complement each other
- Recognize push toward reduced/no-tillage
- Importance of Starters, especially reduced tillage
- Emphasis on ever increasing yields
- 'Necessity' of split N applications – agronomic, financial and environmental

NITROGEN MANAGEMENT

- High N Starters
  - Especially with move to reduced/no-till
  - Cooler seedbeds, greater need for early N
- Dribble N Application
  - Manage N availability,
  - Reduce potential for N loss via volatilization
- Split N Applications
  - Well documented advantage for split N
    - Increased yield and/or reduced risk of loss
    - Environmental benefits
    - Genetic requirement for late season N

Starter Effects On No-Till Corn

NPK Starter	With Seed	2x2	Dribble Over Row	B'cast Over Row
	- - - - - - - *Bu/A* - - - - - - -			
5-15-5	164	190	185	171
15-5-5	172	191	194	177
30-15-5	166	213	209	181
45-15-5	166	211	209	186
60-15-5	159	211	209	194
Average	167	202	201	182

No Starter = 159 bu/A

B. Gordon, Scandia, KS - 2001

Agronomics: Dribble N Application

Drs. J. L. Havlin, A. J. Schlegel and G. M. Pierzynski — Fluid Journal 1993

Improved yields improve environment

Tests made on grain sorghum and winter wheat to determine optimum recovery and minimize N leaching.

Table 2. Fertilizer management effect on ANR and soil N content after harvest.

Rate (lbs/A) N	Rate (lbs/A) P_2O_5	Placement Method	Grain Sorgum ANR* %	Grain Sorgum Soil N* lbs/A	Winter Wheat ANR* %	Winter Wheat Soil N* lbs/A
0	0		-	41	-	25
40	0	Broadcast	22	70	31	44
40	20	"	36	59	44	40
40	40	"		52		36
80	0	"	**31.8%**	86	**36.7%**	57
80	20	"	30	66	32	50
80	40	"	34	64	33	48
40	0	Knife	37	61	46	41
40	20	"		50		39
40	40	"	**42.5%**	48	**54.0%**	33
80	0	"		76		49
80	20	"	36	58	50	43
80	40	"	38	57	49	40
40	0	Dribble	35	64	43	45
40	20	"		48		41
40	40	"	**41.2%**	50	**50.2%**	35
80	0	"	29	79	42	54
80	20	"	34	55	51	41
80	40	"	37	51	50	40

*ANR = apparent N recovery; Soil N = inorganic N content, 0 to 4-foot depth

Fluid Fertilizer Foundation

Nitrogen Effectiveness by Timing

1998 – 2007 TX & OK Hi-Plains

N Application Timing	75% + of Total N as Pre-Plant	75% + of Total N as In-Season Splits
Avg Yield	207.7	215.9
Avg #N Used/A	247	192
N Use/Bushel	1.19	0.86

In-Season N 28% more efficient than preplant

Source: Better Harvest Inc., Dumas, TX

Effect Of Late UAN Application On Corn Yield

Dupont/Pioneer, 2010

All N Applied Before Tassel *19 Plots*	Portion Of N Applied At Brown Silk *21 plots*
Avg Yield 217 bu/acre	**Avg Yield 248 bu/acre**
Low yield: 170 bu/acre **High yield: 269 bu/acre**	**Low yield: 183 bu/acre** **High yield: 302 bu/acre**
3 plots over 240+ bu/acre	**14 plots over 240+ bu/acre**

Russell French, CCA
Account Manager
Amarillo, TX
DuPont Pioneer

DUPONT PIONEER

Fluid Fertilizer Foundation

Photo by Alyssa Abbott, DuPont/Pioneer Account Manager; NE IL

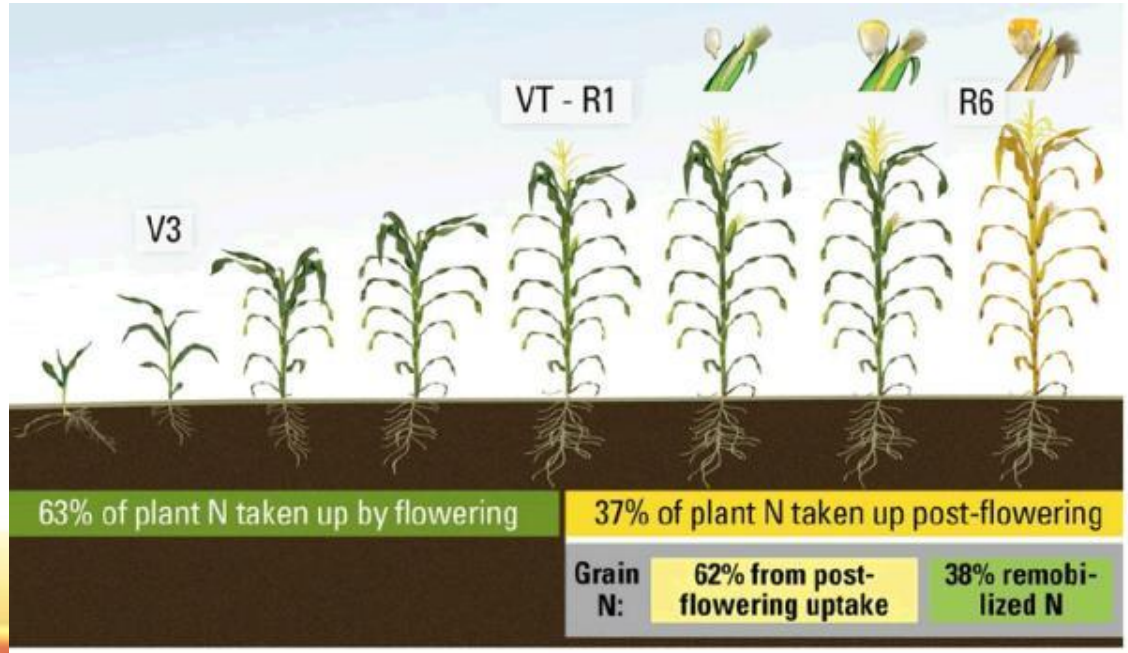
2013 Top 10 Highest Average Plots
Texas & Oklahoma Panhandles

Location	Avg Yield	Plant Date	GPM/acre	Tillage	Starter	Miticide Pre-Tassel	Post Tassel Nitrogen
Sherman Co	285.2	5-17-13	5.5	ST	Y	Y	Y
Hansford Co	284.5	5-4-13	6.0	ST	Y	Y	Y
Hansford Co	282.2	5-10-13	5.3	ST	Y	Y	Y
Moore Co	281.4	4-30-13	6.0	ST	Y	N	N
Texas Co	280.9	5-17-13	5.6	ST	Y	Y	Y
Ochiltree Co	275.0	5-17-13	6.0	ST	Y	Y	Y
Sherman Co	267.2	5-13-13	5.4	ST	N	Y	Y
Moore Co	265.4	4-29-13	5.0	ST	Y	Y	Y
Texas Co	263.4	5-13-13	6.0	NT	Y	Y	Y
Hansford Co	262.7	5-22-13	4.5	ST	Y	Y	Y

Table 1. Nitrogen uptake timing and quantities for old and new hybrids.

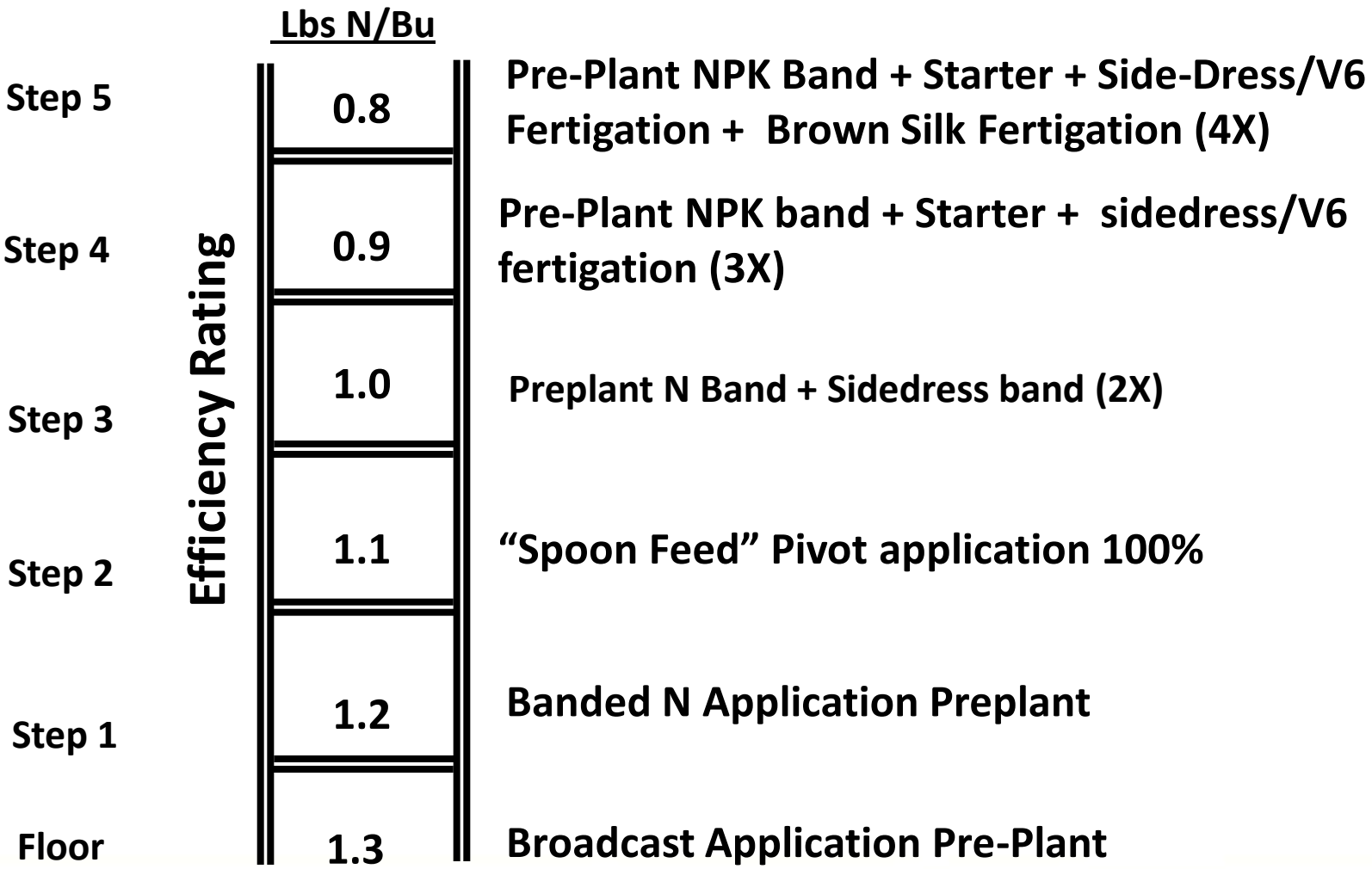
Era of hybrid release	N at R1	N at R6	Post-flowering N uptake	Increase in post-flowering N uptake
	- - - - lbs N / acre - - - -			%
Old (1940 to 1990)†	102	145	43 (30%)	28%
New (1991 - 2011)	97	152	55 (36%)	
Old (1970)‡	125	162	37 (23%)	40%
New (2000)	125	177	52 (30%)	

† Ciampitti and Vyn , 2012 ‡ Haegele et al., 2013



Jason BeBruin
Dupont Pioneer, 2011

Corn Nitrogen Management Ladder



Modern N Management ……

- **Regardless of location, crop or cropping system ….. Improved N Management a Must**
  - **For Corn – Fertility programs that includes multiple applications are necessary for more efficient N use no matter if talking about Ohio, Iowa, Nebraska or Texas.**
  - **For Wheat - Including split applications of N for is important for efficient production and N use no matter if we are talking about Ohio, Missouri, South Dakota or Kansas**
  - **Ditto for other crops !**

N Timing & Placement

- Residue break down, feed microbes, reduce immobilization
  - Broadcast nitrogen
    - Fall or early spring
    - AMS - (125-150 lb./acre, ~25-30 lb. N/acre)
  - Weed-n-Feed/Preplant broadcast
    - Just prior to planting or pre-emergence
    - 28% or urea/AMS
    - Stabilizers/inhibitors
- Starter Fertilizer Band or Strip-till Band
- Sidedress Band
- Later applications – Fertigation, Y Drop

B&M CROP Consulting

Nitrogen Timing & Placement

Missy Bauer

Summary

- Your nitrogen program should be designed to keep the crops needs met all the way to black layer

Fluid Fertilizer Foundation

P and K Management

- Necessity of fully adequate soil test levels
  - Eventually, nutrients removed must be replaced
  - Limitations of fluids vs. MAP/DAP/KCl
- Nutrient Availability vs. Nutrient Uptake
  - Soil test values vs. Nutrient uptake
  - Crop removal vs. Nutrient Demand per acre per day
- Banding
  - Importance of starter fertilizer
  - Limitations of broadcast, limitations of banding
    - Band vs. Broadcast ?

Are current fertilizer recommendations adequate for ever-increasing yields?

Dr. Gyles Randall
Univ. of Minnesota

Effect Of Bray P Soil Test Level On Corn Yield and Response To P Fertilization. (Gyles Randall, Univ. of Minnesota)

Application Method	P Rate [1]	Low P Soil
	Lbs P_2O_5/A	
None	0	148.0
Pop-Up	25/20	158.1
Deep Band	25/20	157.7
Broadcast	25/20	166.4
D. Band + Pop-Up	25/20 + 25/20	171.5
Pop-Up	50/40	165.7
Deep Band	50/40	166.0
Broadcast	50/40	167.0
	p > f	< 0.001
	LSD (0.05)	10.5
	Average	162.6
	Bray P1 Soil Test	6-9 ppm

[1] Rates are for Low Test Site/High Test Sites

Effect Of Bray P Soil Test Level On Corn Yield and Response To P Fertilization. (Gyles Randall, Univ. of Minnesota)

Application Method	P Rate [1]	High P Soil
	Lbs P_2O_5/A	
None	0	192.8
Pop-Up	25/20	191.6
Deep Band	25/20	196.4
Broadcast	25/20	196.2
D. Band + Pop-Up	25/20 + 25/20	189.0
Pop-Up	50/40	194.5
Deep Band	50/40	186.4
Broadcast	50/40	190.2
	p > f	0.84
	LSD (0.05)	NS
	Average	192.1
	Bray P1 Soil Test	20-27 ppm

[1] Rates are for Low Test Site/High Test Sites

Effect Of Bray P Soil Test Level On Corn Yield and Response To P Fertilization. (Gyles Randall, Univ. of Minnesota)

Application Method	P Rate [1]	3-year Average Corn Yield: Low P Soil	3-year Average Corn Yield: High P Soil	High P Advantage	
	Lbs P_2O_5/A	- - - - - *Bu/A* - - - - -		*Bu/A*	*%*
None	0	148.0	192.8	44.8	30.3
Pop-Up	25/20	158.1	191.6	33.5	21.2
Deep Band	25/20	157.7	196.4	38.7	24.5
Broadcast	25/20	166.4	196.2	29.8	17.9
D. Band + Pop-Up	25/20 + 25/20	171.5	189.0	17.5	10.2
Pop-Up	50/40	165.7	194.5	28.8	17.4
Deep Band	50/40	166.0	186.4	20.4	12.3
Broadcast	50/40	167.0	190.2	23.2	13.9
	p > f	< 0.001	0.84	- - -	- - -
	$LSD_{(0.05)}$	10.5	NS	- - -	- - -
	Average	162.6	192.1	29.6	18.2
	Bray P1 Soil Test	6-9 ppm	20-27 ppm		

[1] Rates are for Low Test Site/High Test Sites

Effect Of Bray P Soil Test Level On Soybean Yield and Response To Residual P Fertilization. (Gyles Randall, Univ. of Minnesota)

Application Method	Residual P Rate [1]	3-year Average Soybean Yield: Low P Soil	3-year Average Soybean Yield: High P Soil	High P Advantage	
		- - - - - Bu/A - - - - -		Bu/A	%
None	0	34.5	49.1	14.6	42.3
Pop-Up	25/20	36.4	49.1	12.7	34.9
Deep Band	25/20	34.7	48.8	14.1	40.6
Broadcast	25/20	36.7	50.3	13.6	37.1
D. Band + Pop-Up	25/20 + 25/20	40.8	49.3	8.5	20.8
Pop-Up	50/40	38.2	48.9	10.7	28.0
Deep Band	50/40	38.5	49.1	10.6	27.5
Broadcast	50/40	37.1	48.4	11.3	30.5
	p > f	0.39	0.01	- - -	- - -
	LSD (0.05)	NS	3.5	- - -	- - -
	Average	37.1	49.1	12.0	32.4
	Bray P1 Soil Test	6-9 ppm	20-27 ppm		

[1] Residual Rates are for Previous Corn Crop Low Test Site/High Test Sites

Fertilizer vs. Fertility

Does Fertilizer Substitute For Soil Fertility ?

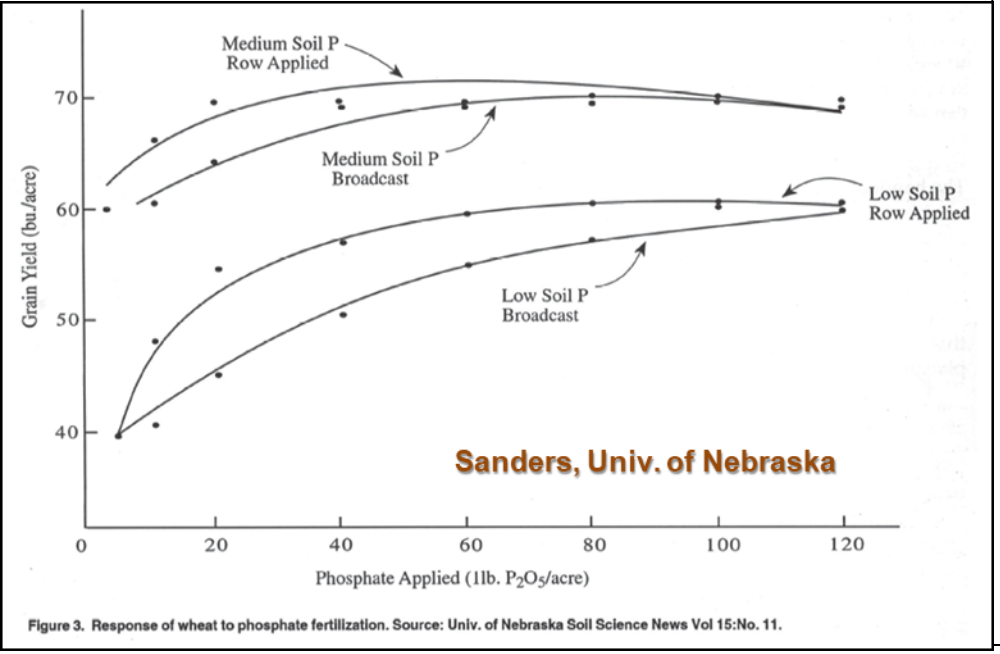


Figure 3. Response of wheat to phosphate fertilization. Source: Univ. of Nebraska Soil Science News Vol 15:No. 11.

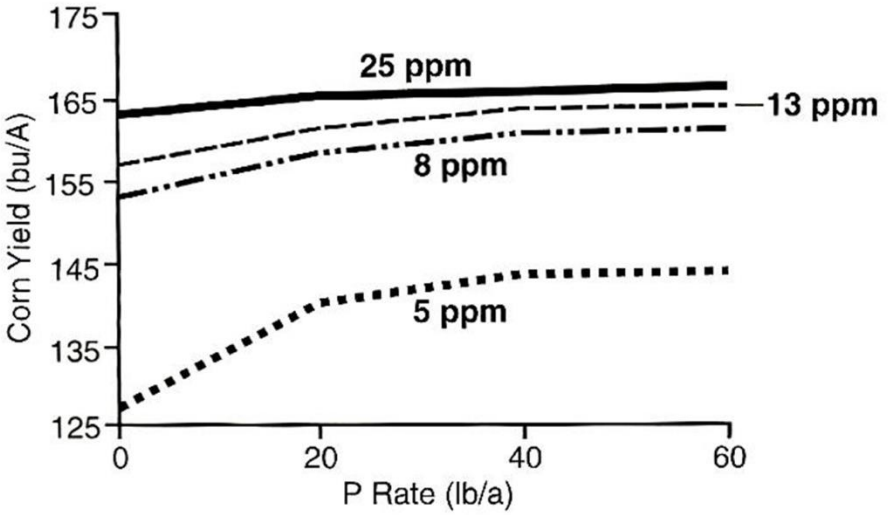
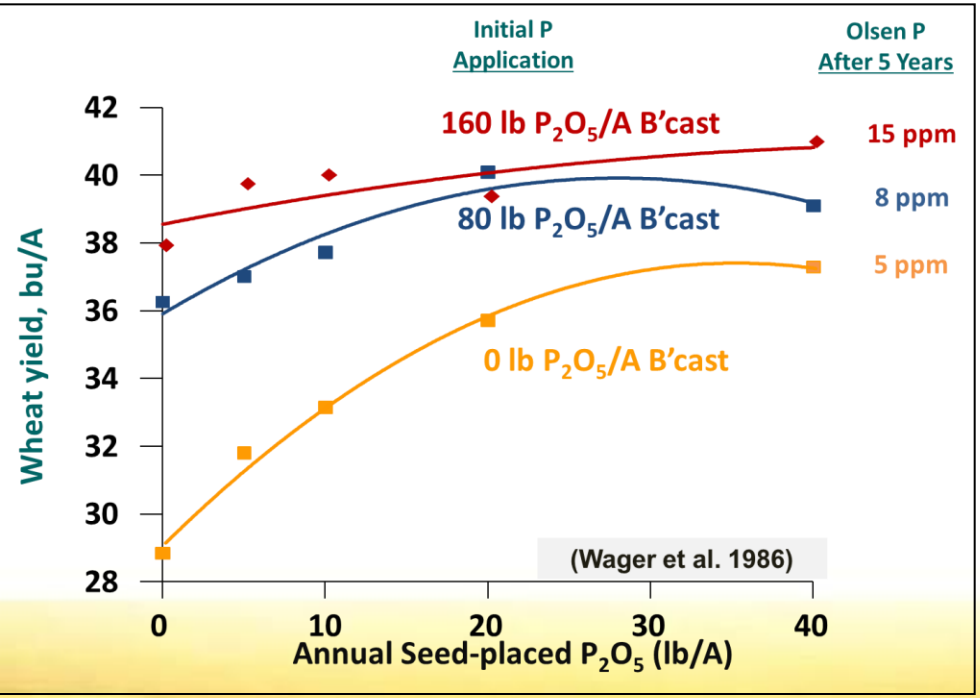
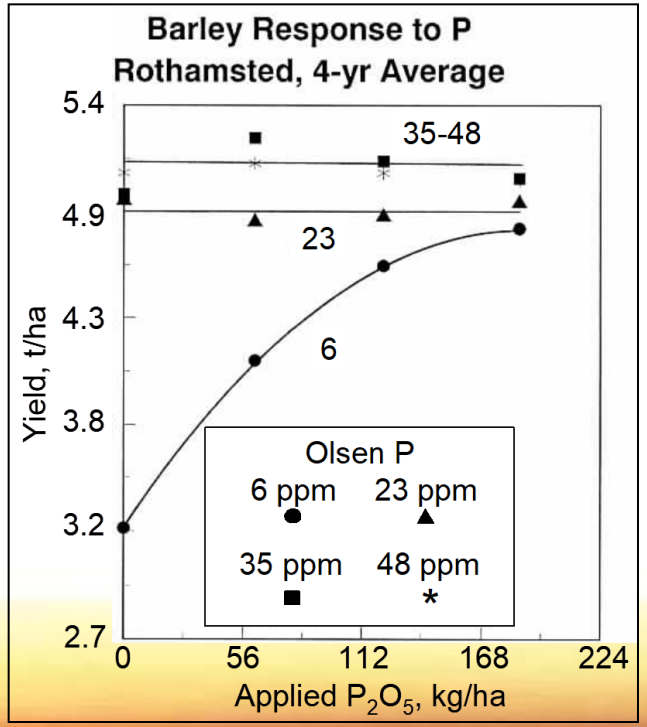


Figure 37. Influence of soil test and P fertilizer on corn yield, Beresford, SD, 1994. South Dakota State University

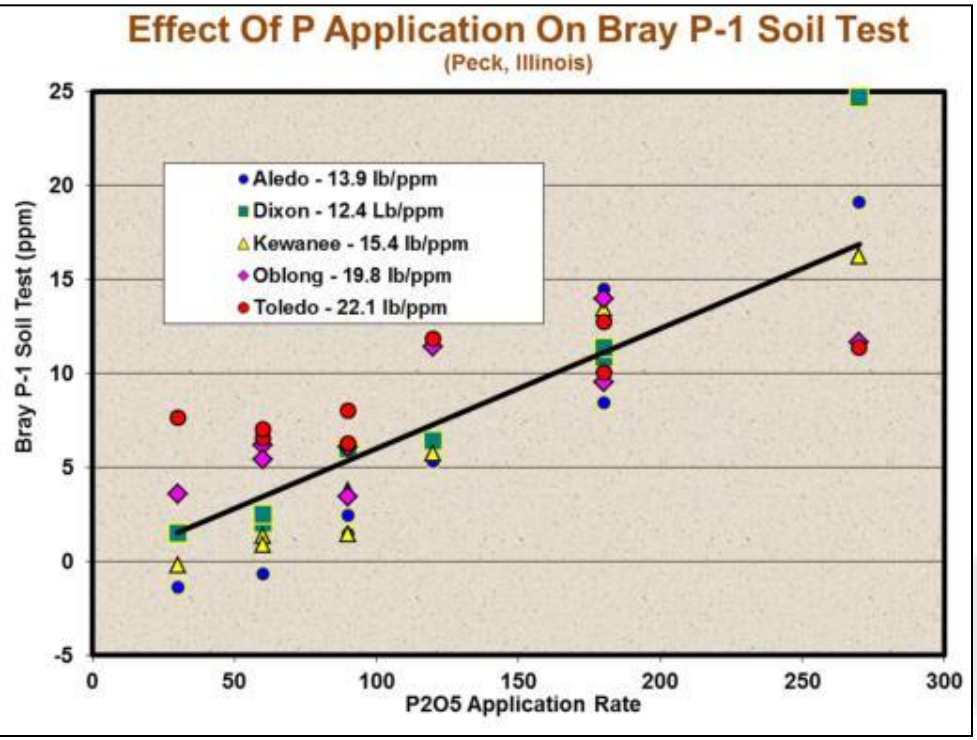




Fluid Fertilizer Foundation

Nutrient Application Rates

Eventually, for most nutrients, nutrients removed will need to be replaced and the soil replenished.

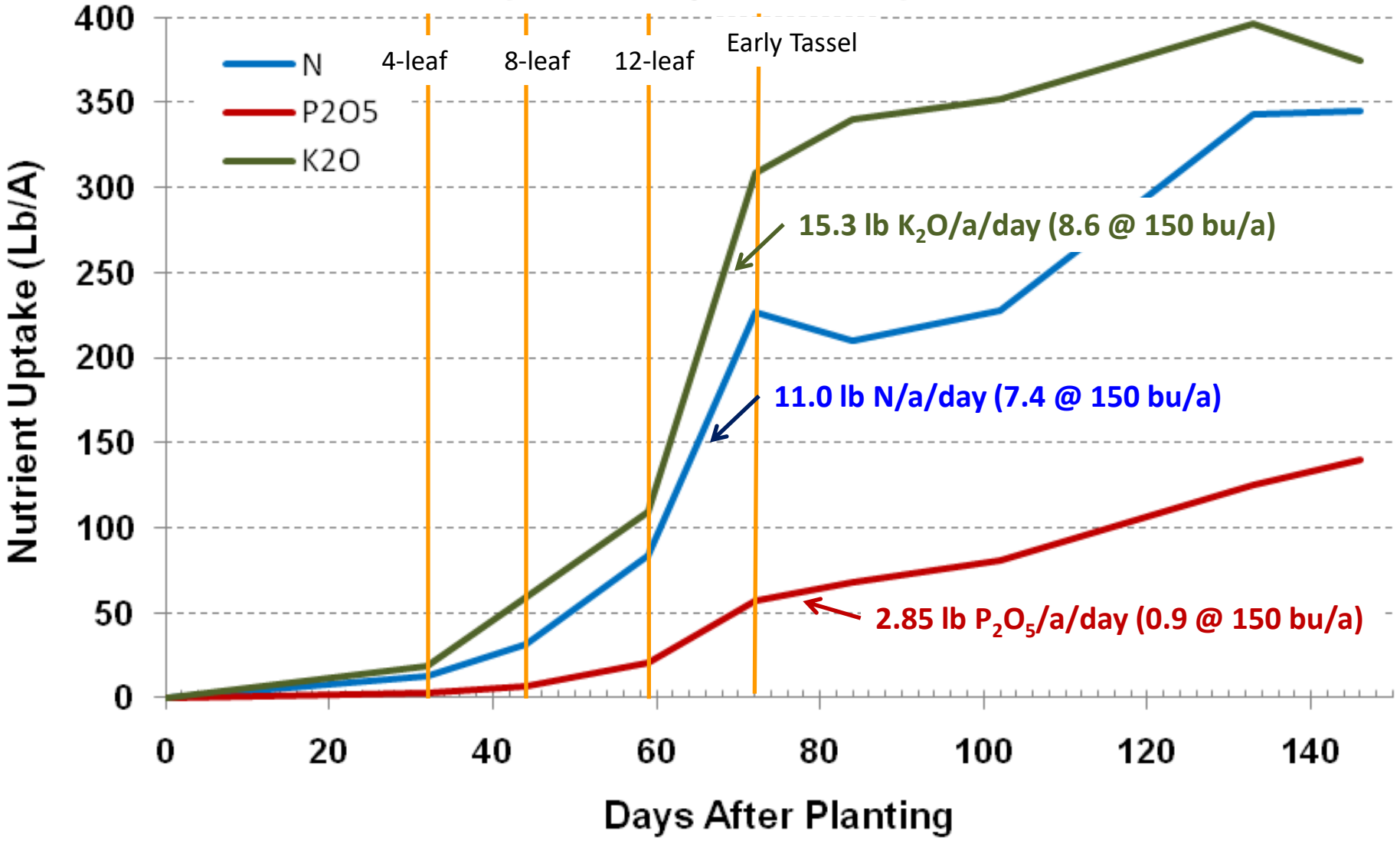


Typical Nutrient Uptake By Crops

Crop	N	P_2O_5	K_2O	S
	- - - - - - lbs/bu - - - - - -			
Corn Grain	1.00	0.35	0.25	0.08
Corn Stover	0.50	0.25	1.05	0.09
Corn Total	1.50	0.60	1.30	0.17
Wheat Grain	1.30	0.50	0.30	0.09
Wheat Straw	0.70	0.16	0.90	0.19
Wheat Total	2.00	0.66	1.20	0.28
Soybean Grain	4.20	0.90	1.50	0.20
Soybean Stover	1.30	0.30	0.90	0.22
Soybean Total	5.50	1.20	2.40	0.42

Nutrient Uptake For High Yield Corn

(R. Flannery - 308 Bu/A)



Corn Yield: Max K Uptake Rate

Yield [1] Environment	Population	Yield	Total K Uptake	Total K uptake per plant	Max K Uptake Rate
	plants/ac	bu/ac	lbs/ac	g/plant	lbs/ac/day
Low	27,100	204	216	3.6	**13.3**
High	36,000	225	245	3.1	**20.9**

[1] Results from 1980, Florence, SC, site had Mehlich 1 K of 47 mg/kg and received 150 lbs/ac K over multiple applications.
Source: Karlen, Sadler and Camp,. 1987. Agron J. 79:649-656.

Max K uptake rate is proportional to higher populations (i.e. potential yields) have higher K requirements

Miller, 2016

Higher Yields & High Population: Impact on Root Mass & Nutrient Uptake?

High Plant Density = Smaller Roots

Normal Population
32,000 plants/acre

High Population
45,000 plants/acre

Important?

Decreasing Plant Root Volume

Population and K Removal

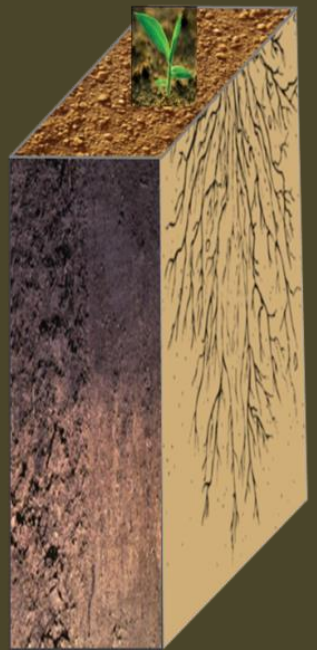
Increasing plant population has resulted in a 50% decrease in root volume per plant over 50 years in the Midwest.

Increase yields, have increased K removal in the grain.

The combined effect of population and grain K removal, has resulted in a 240% increase in soil K removal from the root zone of each plant.

Miller, 2013

1960 root soil volume per plant 16,000 plts/ac



2013 root soil volume per plant 32,000 plts/ac

Dr. Bob Miller
Colorado State Univ.

KR_X Corn Yield Response

Yield Results 2011, six IA and NE sites

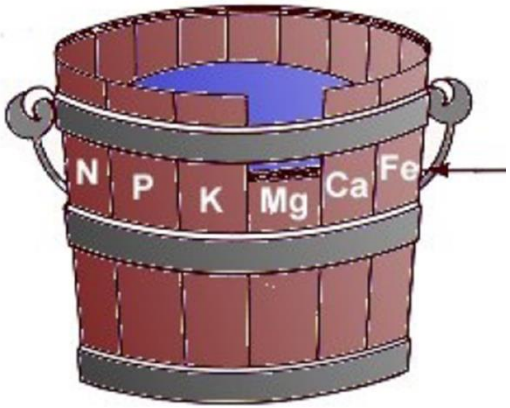
Site	STK	Check	+K	Increase
Cty / State	ppm	bu/ac		
Cherokee, IA	268	220	231	+11*
Calhoun, IA	296	194	207	+13*
Webster, IA	185	185	186	+1
Webster, IA	153	207	215	+8*
O'Brien, IA	238	212	208	-4
Hamilton, NE	423	231	232	+1

* Yield significant at the 0.10 level, corn 15.5% moisture.

K effect on ear size

K increased yield on soils STK > 250 ppm

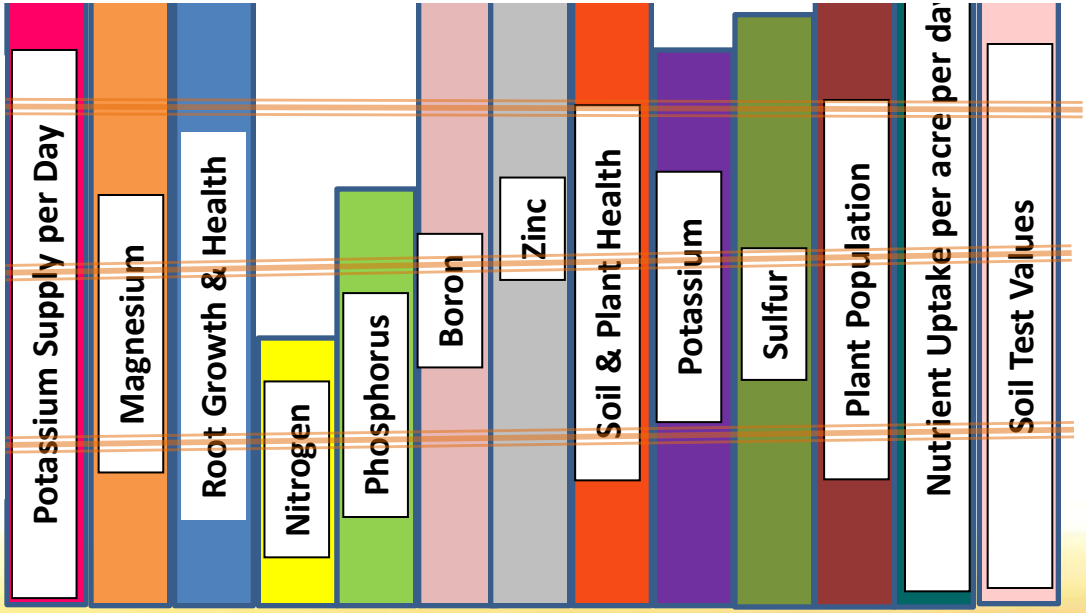
Miller, 2013



The wooden bucket represents the soil's nutrient supplying capacity

The Law of the Minimum

Law of The Minimum



Nutrient Availability vs. Uptake

Nutrient 'Availability'

vs.

Soil Test Values

Annual Crop Demand

vs.

Nutrient Demand per Acre per Day

Nutrient Availability and Nutrient Uptake Are Not The Same Thing!

DR. GYLES RANDALL AND JEFF VETSCH

NPKS Starters Improve Profitability On High-Testing Soils

Studies conducted at Southern Research and Outreach Center in Waseca, Minnesota.

Historically, starter fertilizers have not been commonly recommended for corn production on high or very high P-testing soils due to poor yield response even though early growth responses may be seen. However, we've seen renewed interest in starter (band-placed) fertilizers as 1) corn yields continue to increase, 2) tillage intensity tends to decrease, and 3) corn planting comes earlier. With this renewed interest, questions have been raised regarding the inclusion of K and S in the fluid starter, as well as about optimum placement (in-row with seed vs. bands 2 inches from the seed or bands dribbled on the soil surface). Objectives of the research in this report were:

- Determine the effect of various combinations and rates of N, P, K and S as starter fertilizers for improving corn production and profitability on high P- and K-testing soils
- Evaluate starter placement positions for NPKS fluid fertilizers for corn grown on high P- and K-testing soils
- Provide to corn producers, crop advisors, and the fertilizer industry management guidelines on fluid starter fertilizer rates and placements for corn grown on high P- and K-testing soils with reduced tillage.

Concentration

Concentrations of N, P, K, and S in the whole small plant at the V6 stage were inconsistently affected by NPKS treatments (Table 1). This was particularly true for N and P where statistically significant differences were found but there was no clear effect of rate or placement and no interaction between rate and placement. Whole-plant K concentrations were not affected by starter P and K treatments. Whole-plant S concentration was increased by the 2 x 2 and 2 x 0 treatments that received S. Concentrations of NPKS were similar between 2 x 0 and 2 x 2 placement.

Dry matter

Dry matter accumulation at V6 was affected by the starter P

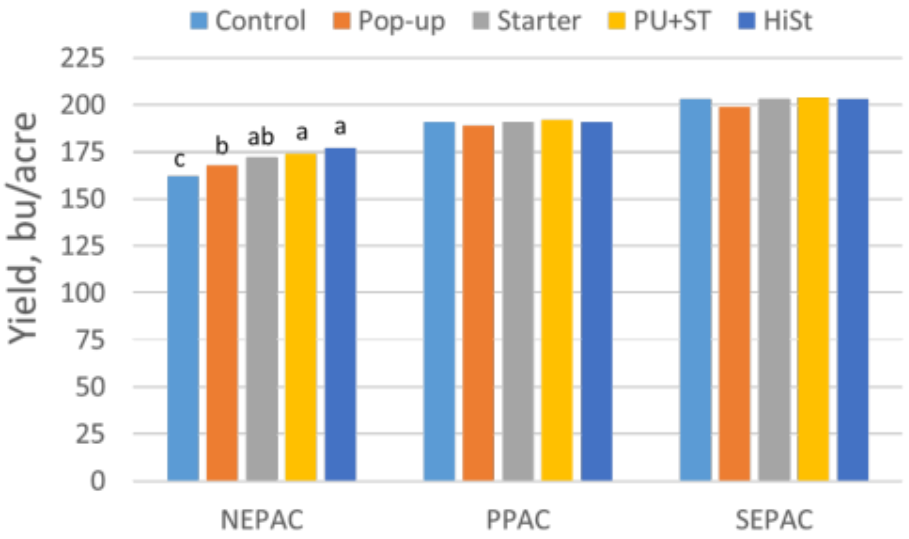
Conclusions

….. In a warm year with cool early May conditions, a significant plant growth response was found for all of the starter fertilizer treatments on this high P-testing soil .....

…….. Corn grain yields were increased over the no-starter control by half of the starter treatments. Greatest yields were produced by the NPKS treatments that contained 10 lbs/A of K_2O and S. Yields were increased an average of 18 bu/A when S was included in the starter ……

Fluid Fertilizer Foundation

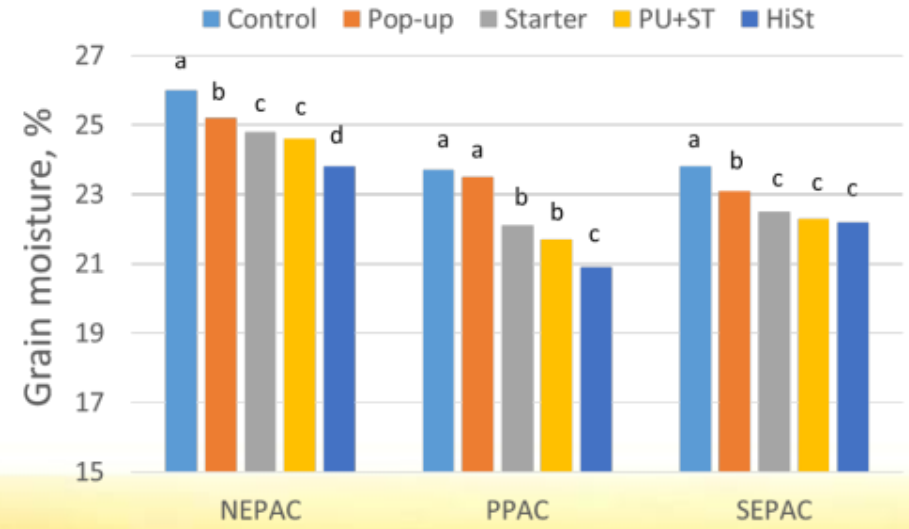
Corn Yield



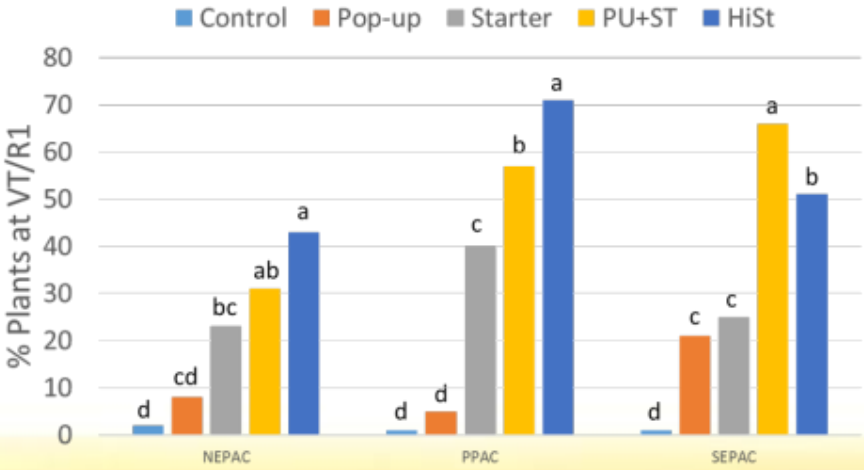
Jim Camberato, Bob Nielsen, Cody Hornaday
Purdue University

- No starter
- Pop-up (PU), 10-34-0 in-furrow at 3 gal/acre
- Starter (ST), APP-UAN 2x2 - 25 lb N/ac
- PU+ST
- High starter (HiST), APP-UAN 2x2 – 50 lb N/ac
- Sidedress N rate adjusted for N applied in starter (not P), applied at V7

Grain Moisture



Plant Maturity



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DR. GEORGE REHM, DR. JOHN LAMB, AND MARK BREDEHOEFT

A Look At Seed-safe Applications Of Fluids

Fluid Journal, Winter, 2007
Rehm, Lamb & Bredehoeft

Table 2. Corn yield as affected by fluid material, rate and placement in soils with two contrasting soil textures, 2005

	Texture, Placement, Rate											
	Silty clay loam						Loamy find sand					
	with seed		top of seed		below seed		with seed		top of seed		below seed	
Material	high	low	high	low	high	low	high	low	high	low	high	low
	Check 208.7 bu/a						Check 185.5 bu/a					
5 & 10 gpa 10-34-0	211.6	203.6	213.8	208.9	213.6	209.6	154.9	176.8	170.5	190.6	151.7	199.3
5 & 10 gpa 4-10-10	204.7	196.9	210.3	208.4	203.0	210.3	192.8	203.7	188.4	208.7	201.3	190.9
3.4 & 6.8 gpa 3-18-18	201.0	212.2	215.3	209.3	211.0	206.7	189.3	207.8	205.7	203.5	201.1	204.4

Control (no fluid fertilizer) = 208.7 and 185.5 bu/A for silty clay loam and loamy fine sand sites, respectively.

"Grower interest in use of banded fluid fertilizer at planting is increasing. This renewed interest is due, in part, to frequent observations that banded fertilizer increases crop growth and subsequent yield. ……. there are now several inexpensive attachments that can be added to planters to place fertilizer in a band near the seed at the time of planting."

Fluid Fertilizer Foundation

Band Uniformity

by Drs. B. Eghball and D.H. Sander

Does Variable Distribution Affect Liquid P-Use Efficiency?

Florida scientist offers tips on how to use starters, plus describes the many benefits that accrue from their use. He focuses on corn.

'Results of this study suggest that lower analysis P fertilizers could be more effective than widely used 10-34-0 for preplant banding and starter row applied fertilizers. Mixing of 10-34-0 with UAN may improve P-use efficiency both through improved P distribution and through ammonium-N effects on P uptake and P fixation.'

Fluid Journal
Winter 2001

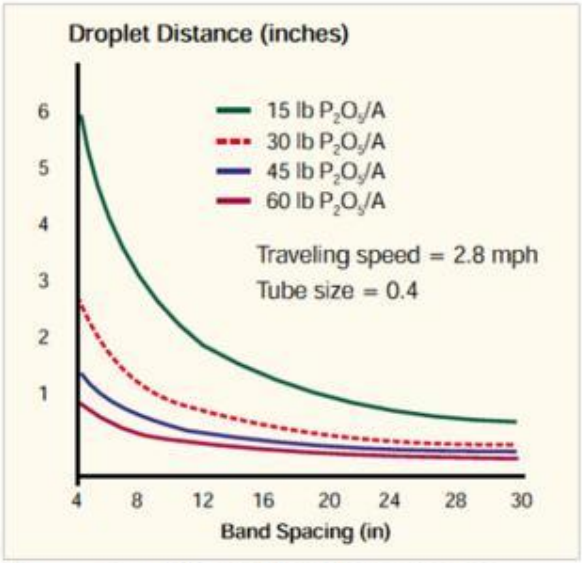

Figure 3. Effect of band spacing on distance between droplets at different rates of P application

***'Root contact*. The probability of root-P contact is known to be very important to P efficiency. The growth rate of roots is much greater in P-treated than untreated soil. It has been shown that very sizable quantities of P can be absorbed by only a portion of the root system. ..... It appears that when roots contact a P droplet, root proliferation can be expected, as well as an increase in root growth in that part of the soil. *However, exhaustion of P in that soil area affected by the P droplet or dry particle could be a limiting factor*.'**

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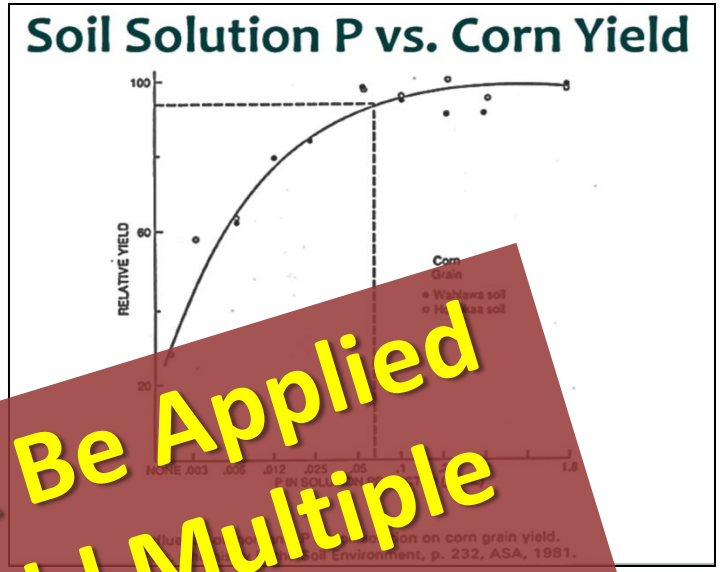
Are current fertilizer recommendations adequate for ing yields?

'Recommendation' Does Not Simply Mean Rate !!!

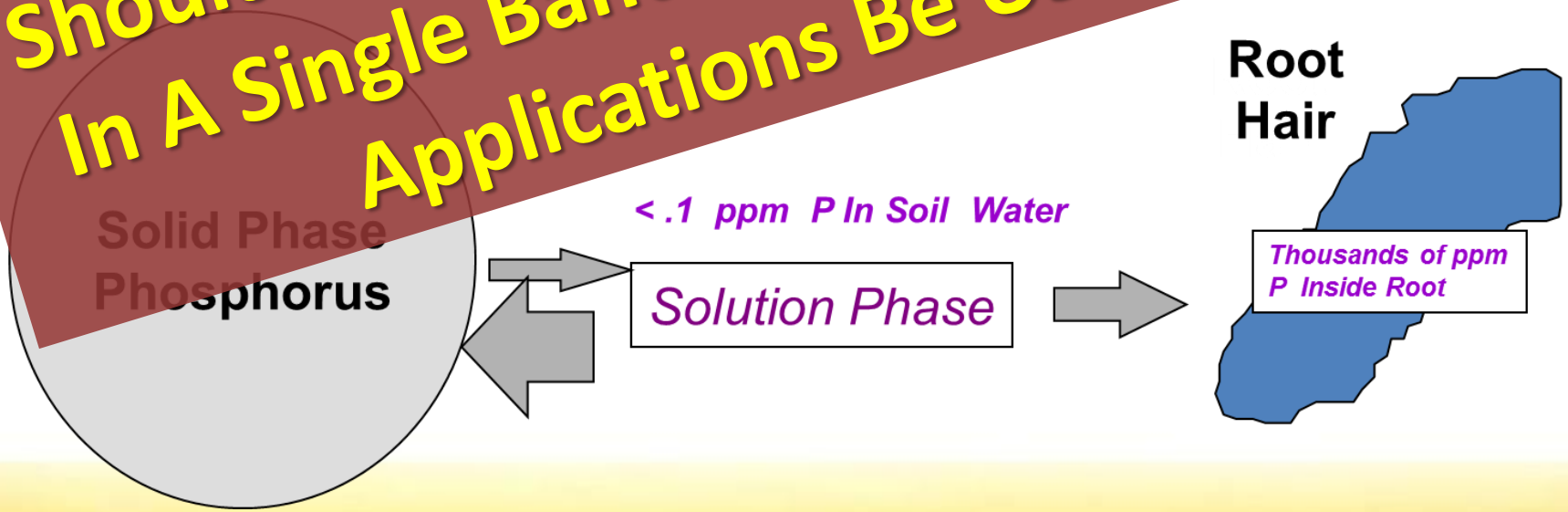
- **Status: Rece**
  - **- based on research from the**
  - **- average corn yields ranged from 80-12[illegible] u/A with 175 bu/A seldom exceeded in research studies**

Gyles Randall
Univ. of Minnesota

- Nutrients such as N, P, K, Zn require energy to be absorbed into the roots
- Higher solution nutrient concentrations reduces the energy requirement for nutrient uptake
- As the concentration in soil solution increases, nutrient uptake increases at a maximum rate.



Should All Of The P and K Be Applied In A Single Band Or Should Multiple Applications Be Used?



Potassium Application Effects On Corn Yield

K_2O Rate	Hybrid A		Hybrid B	
Lbs/A	*Yield*	*Test Weight*	*Yield*	*Test Weight*
0	125	56	199	61
40	170	59	208	61
80	189	58	204	61
120	179	59	203	62
Sig. Level	0.01	0.01	NS	0.25

Leikam, 2004

Average K Test = 153 ppm
Minimum K Test = 112 ppm
Maximum K Test = 229 ppm

No-Till
Surface Broadcast Application
No Incorporation

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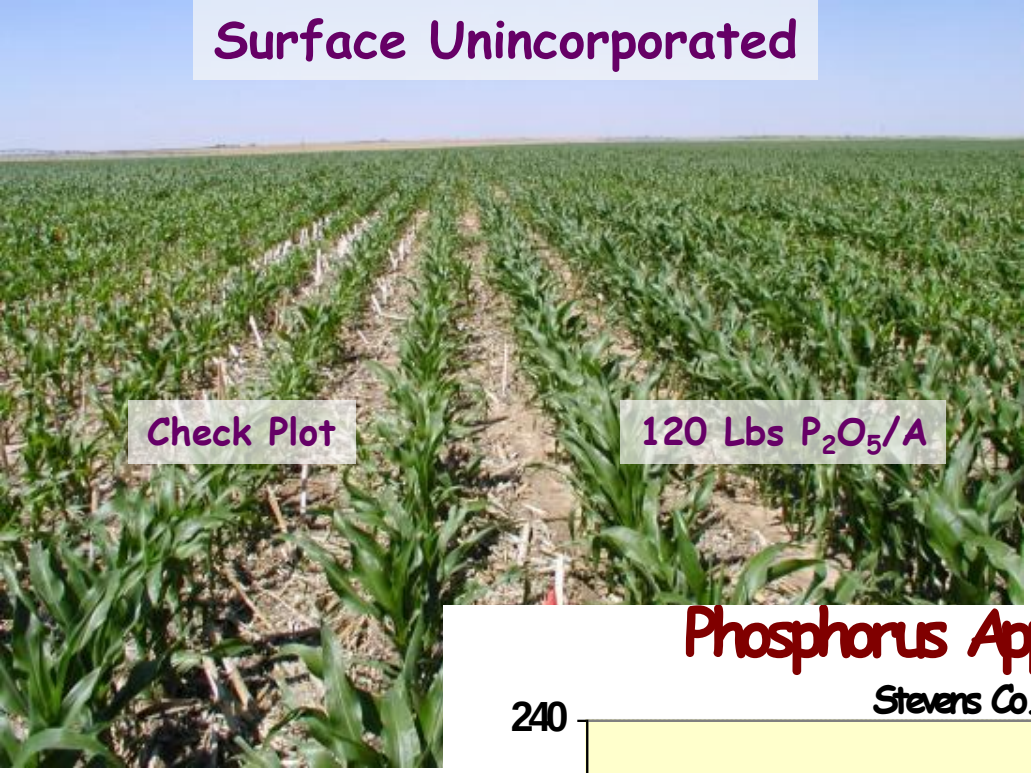
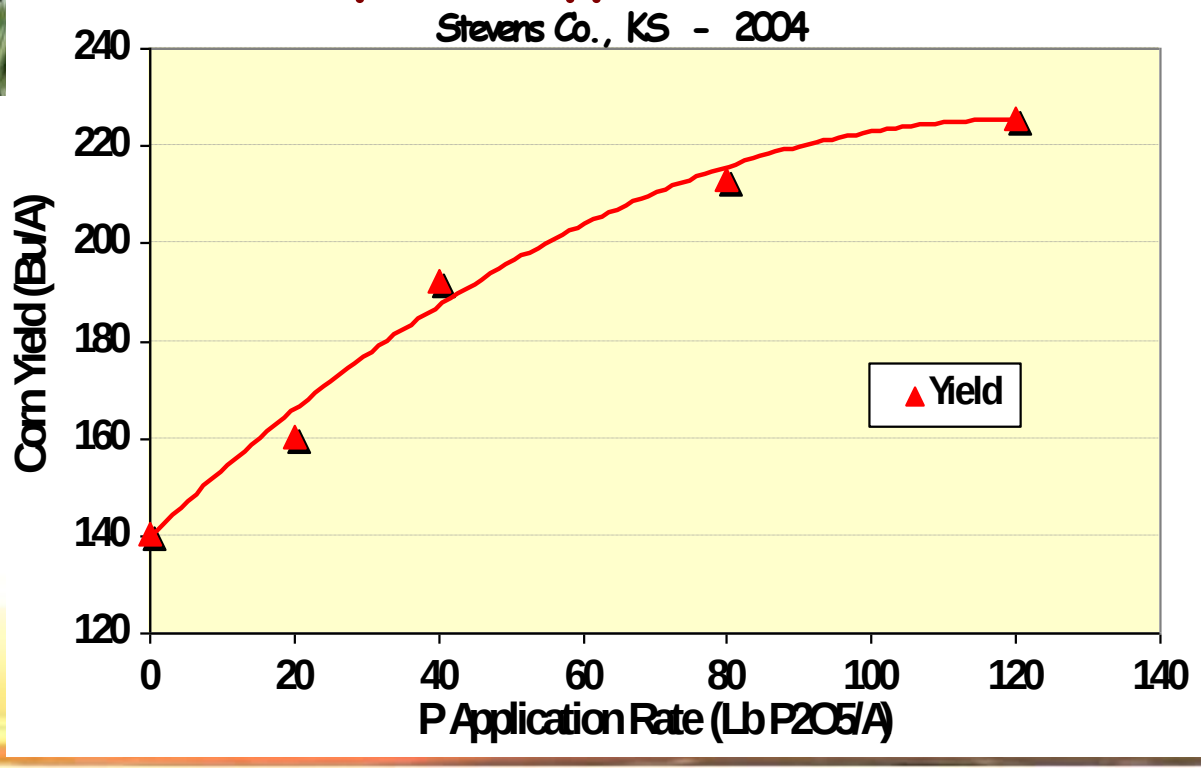
Surface Unincorporated



Irrigated
Surface Broadcast Application
No Incorporation

Phosphorus Application To Corn



Leikam, 2004

Fluid Fertilizer Foundation

Fluid JOURNAL
Official Journal of the Fluid Fertilizer Foundation
Early Spring 2009
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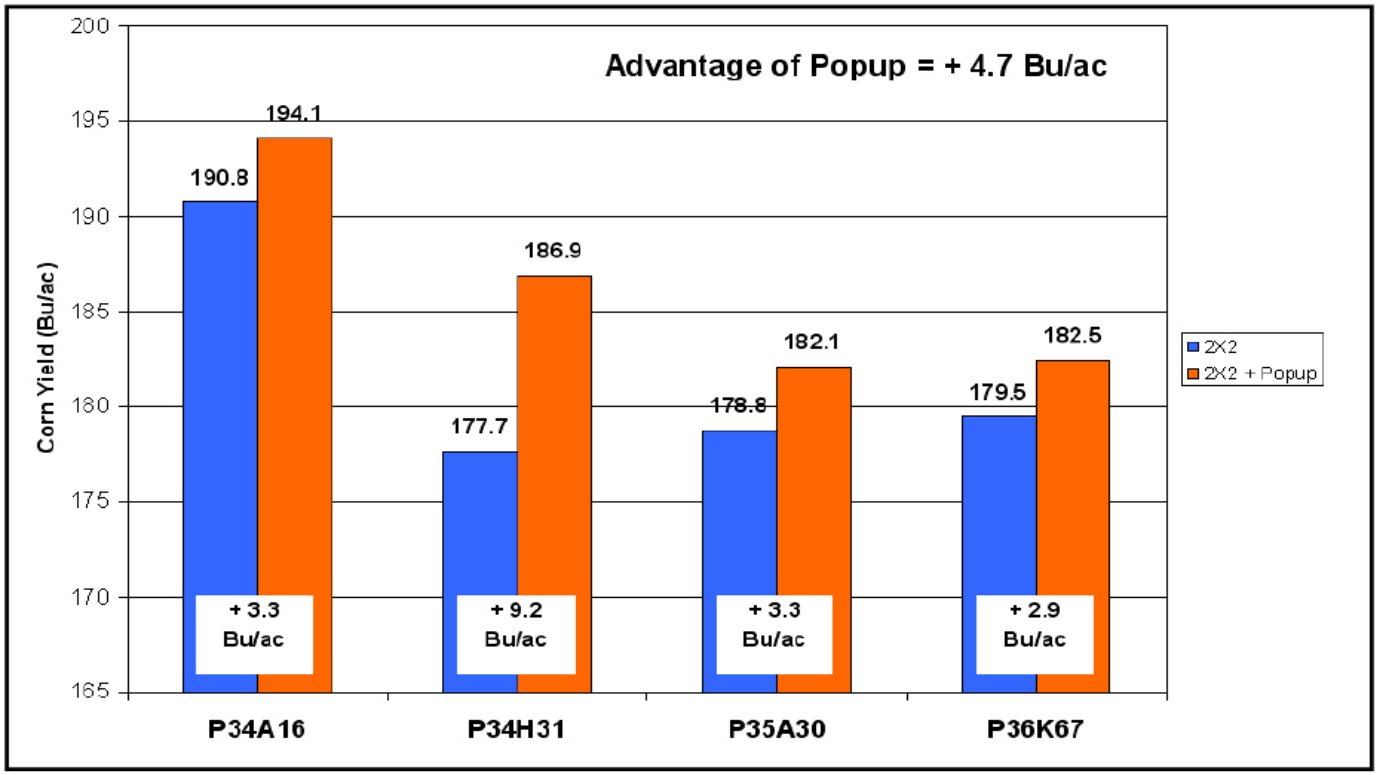


Figure 2.Starter fertilizer 2x2 (19-17-0 Zn 15gal/ac) band placement + popup (6-24-6 3gal/ac) in-furrow in comparison to 2x2 only across four different Pioneer hybrids near Butler, IN. 2005, M. Bauer.

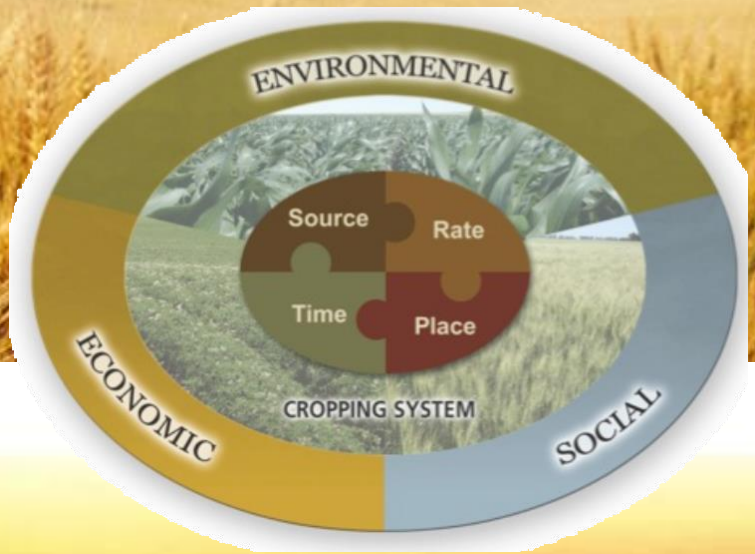
Figure 1. Starter fertilizer 2x2 band placement + popup in-furrow in comparison to 2x2 only. 2007, M. Bauer.

Fluid Fertilizer Foundation Mission Statement

The FFF funds research and education of fluid fertilizers as integral components of crop nutrition programs to achieve precision placement, environmental stewardship, nutrient use efficiency and yield improvement.

Fluids: The Keystone Of All Fertility Programs

"Right source at the right rate, right time, and right place"



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