REDUCTION OF WATER SOLUBLE PHOSPHORUS IN POULTRY LITTER USING INDUSTRIAL CO-PRODUCTS

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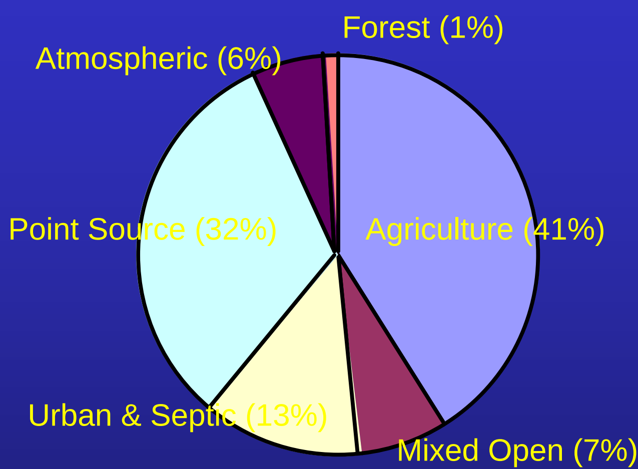
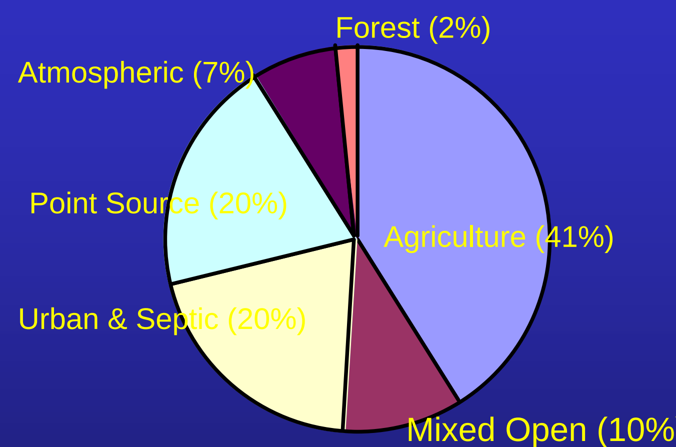
Sources of Nutrient Loads to the Bay

Phosphorus in 1985



28.6 Million Pounds

Phosphorus in 2000



21.9 Million Pounds

Bay-Wide Concern

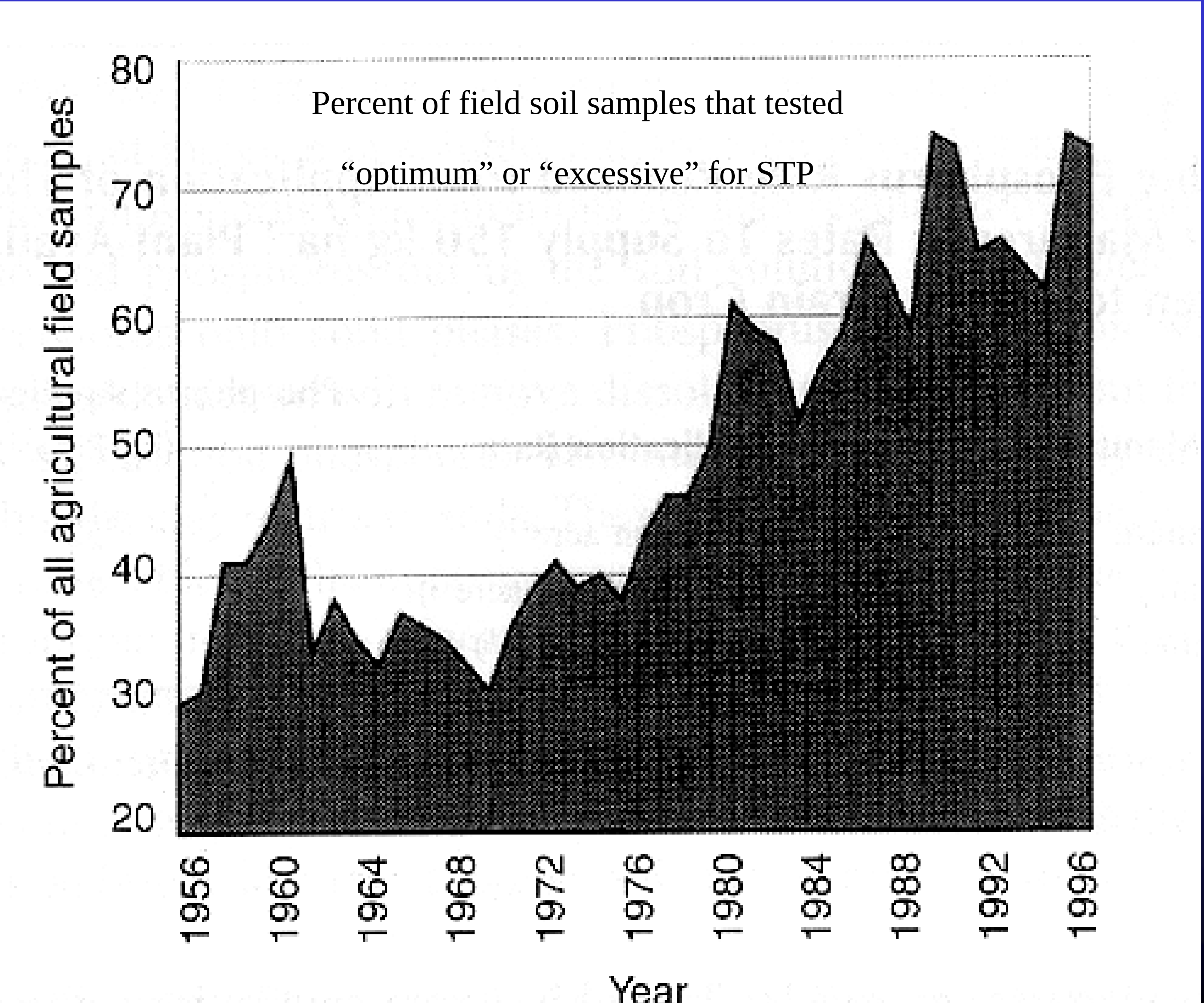
After 2000 it will be more of a problem to hold the line on phosphorus loadings than it will be for nitrogen. This is because we still have a number of nitrogen-reduction methods for use at treatment plants, but we have pretty well run out of ways to reduce the phosphorus. The phosphorus levels will begin to creep up unless we can find new ways to achieve reductions

Agricultural Concern

- MD's livestock and poultry industries generate copious amounts of manure which farmers spread on their land.
- Until recently, nitrogen (N)-based nutrient management systems were used exclusively.
- MD farmers use no-till and it is likely that NT practices can contribute to phosphorus saturation in surface soil.

PROBLEM

- Long term application of manure to fields according to crop nitrogen requirements has resulted in excess soil phosphorus.
- Soluble phosphorus in surface runoff contributes to nutrient pollution.



Percent of field soil samples that tested
“optimum” or “excessive” for STP
Percent of all agricultural field samples
80
70
60
50
40
30
20
1956
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
Year

HYPOTHESIS

- Previous research indicates that both Red Gypsum and Iron Rich Residue have a high P sorption capacity. We hypothesize that these co-products can be used as a manure amendment for the purpose of reducing soluble phosphorus in field runoff.
- Efficiency will be reduced from laboratory to field.
- Crop production will not be effected.

OBJECTIVES

1) determine that the amendments will sorb P,
2) determine the reduction in WEP from a) individual amendments b) different litter:amendment ratios and c) compared to alum,
3) evaluate pH and EC of amendments as a function of initial P concentration,
4) evaluate trace metals in amendments to estimate any risk in using the products. Metal concentrations will be compared to any existing EPA limits for land application of biosolids.

OBJECTIVES

5) explore incubation time as a factor in amendment efficacy,

6) obtain desired litter:amendment ratio to reduce WEP by 90%,

7) develop predictor equations for RG and FC that will estimate the appropriate litter:amendment ratio to obtain a desired WEP reduction,

8) evaluate the loss in efficiency from using “wet” amendments (as received) rather than dried and ground amendments, and

9) evaluate the effect of amendments on soil test P.

Laboratory Methods

- Amendment Characterization
- Litter Characterization
- Treatments
- Water Extractable Phosphorus (WEP)
- Statistical Methods

Amendment and Litter Characterization

- ICPES, AAS, CVAAS - trace metals
- Total C, N, H, Ca, Fe, S, P, NH3-N

Laboratory Treatments

- Poultry Litter (PL) only
- PL + Secondary Gypsum (SG)
- PL + Filter Cake (FC)
- PL + 50-50 mix of SG and FC (MIX)
- 10 reps for some experiments, 6 for others

Water Extractable Phosphorus (WEP)

- Dried, sieved material
- Roll tube for one hour
- Centrifuged, filtered
- Analyzed for total P

Statistics

- 3X(4X3+1) experiment (not conventional factorial experiment)
- Contrast statements
- Variance varied with PL:amendment ratio, therefore, Proc MIXED w/heterogenous Var
- Inverse regression problem to find WEP reduction of 50% and 90%

Purpose: Field Experiments

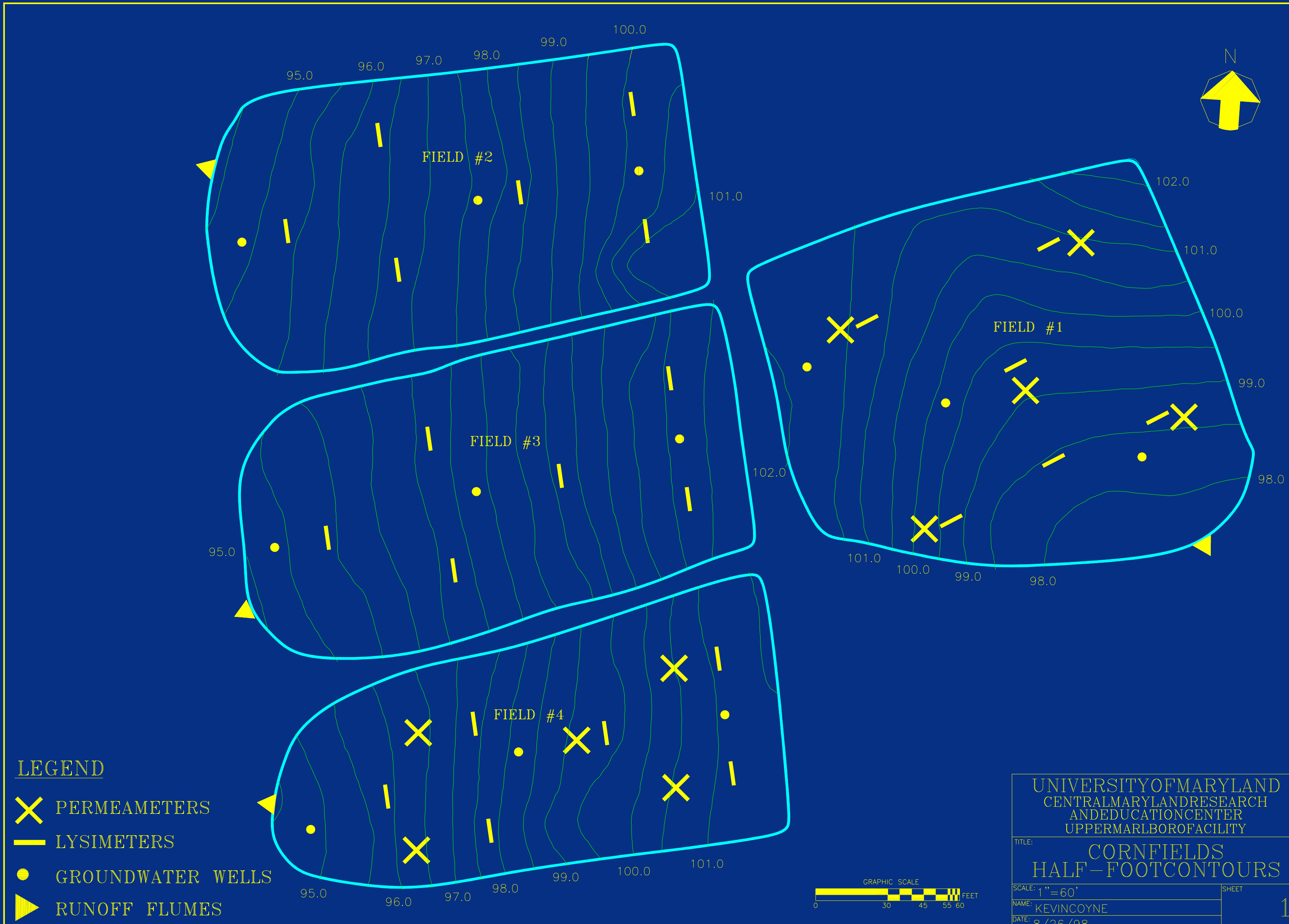
Field Experiments are being used to investigate and demonstrate the effect of co-product amended poultry litter on (a) crop production and yield under standard field conditions, and (b) soluble phosphorus in soil and surface runoff.

Field Methods

- Site Description
- Litter Nutrient Value
- Amendment Description - same as Lab work
- Mixing & Spreading
- Soil Sampling
- Runoff

Site Description

- Description
  - Four half-acre fields
  - Flumes with samplers and stage recorders
- Treatment
  - No-till, Conventional herbicide
  - Approximately 3 tons/ac MANURE
  - 2:1 manure:amendment



N
FIELD #1
FIELD #2
FIELD #3
FIELD #4
95.0
96.0
97.0
98.0
99.0
100.0
101.0
102.0
LEGEND
PERMEAMETERS
LYSIMETERS
GROUNDWATER WELLS
RUNOFF FLUMES
GRAPHIC SCALE
0 30 45 55 60 FEET
UNIVERSITY OF MARYLAND
CENTRAL MARYLAND RESEARCH AND EDUCATION CENTER
UPPER MARLBORO FACILITY
TITLE: CORNFIELDS HALF-FOOT CONTOURS
SCALE: 1"=60'
NAME: KEVIN COYNE
DATE: 8/26/98
SHEET 1

Methods

- Site Description
- Litter Nutrient Value
- Amendment Description
- Mixing & Spreading
- Soil Sampling
- Runoff

Nutrient content of litter and mixtures.

Amendment Mix	Year	Total Nitrogen (%)	Ammonia (% NH4-N)	Total Phosphorus (% P2O5)
Litter	2000	3.17	0.90	2.70
	2001	3.88	0.38	2.93
Secondary Gypsum	2000	1.98	0.52	1.52
	2001	2.88	0.46	2.30
Iron Rich Residue	2000	1.70	0.44	1.46
	2001	3.01	0.50	2.19
Gypsum & Residue	2000	1.76	0.51	1.23
	2001	2.63	0.38	2.00

Nutrient application rates for each field (2000).

Plot	Treatment	Application Rate (dry tons/acre)	N applied (lbs/ac)	Available N (lbs/ac)	P applied (lbs/ac)
1	Litter only	4.19	265.5	132.7	226.1
2	Red Gypsum	6.46	255.8	127.9	196.4
3	Red Gypsum-Iron Rich Residue	6.41	225.7	112.9	157.7
4	Iron Rich Residue	4.71	160.2	80.1	137.6

Methods

- Site Description
- Litter Nutrient Value
- Amendment Description
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Methods

- Site Description
- Litter Nutrient Value
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Soil Sampling

- Five random locations in each field
- Six soil samples (0-2 in.) randomly collected about each location and composited
- Samples split for a) conventional Soil Test Lab analysis and b) soluble phosphorus analysis.

Methods

- Site Description
- Litter Nutrient Value
- Amendment Description
- Mixing & Spreading
- Soil Sampling
- Runoff

Runoff

Original plan was to sample naturally occurring precipitation events over time for two years.

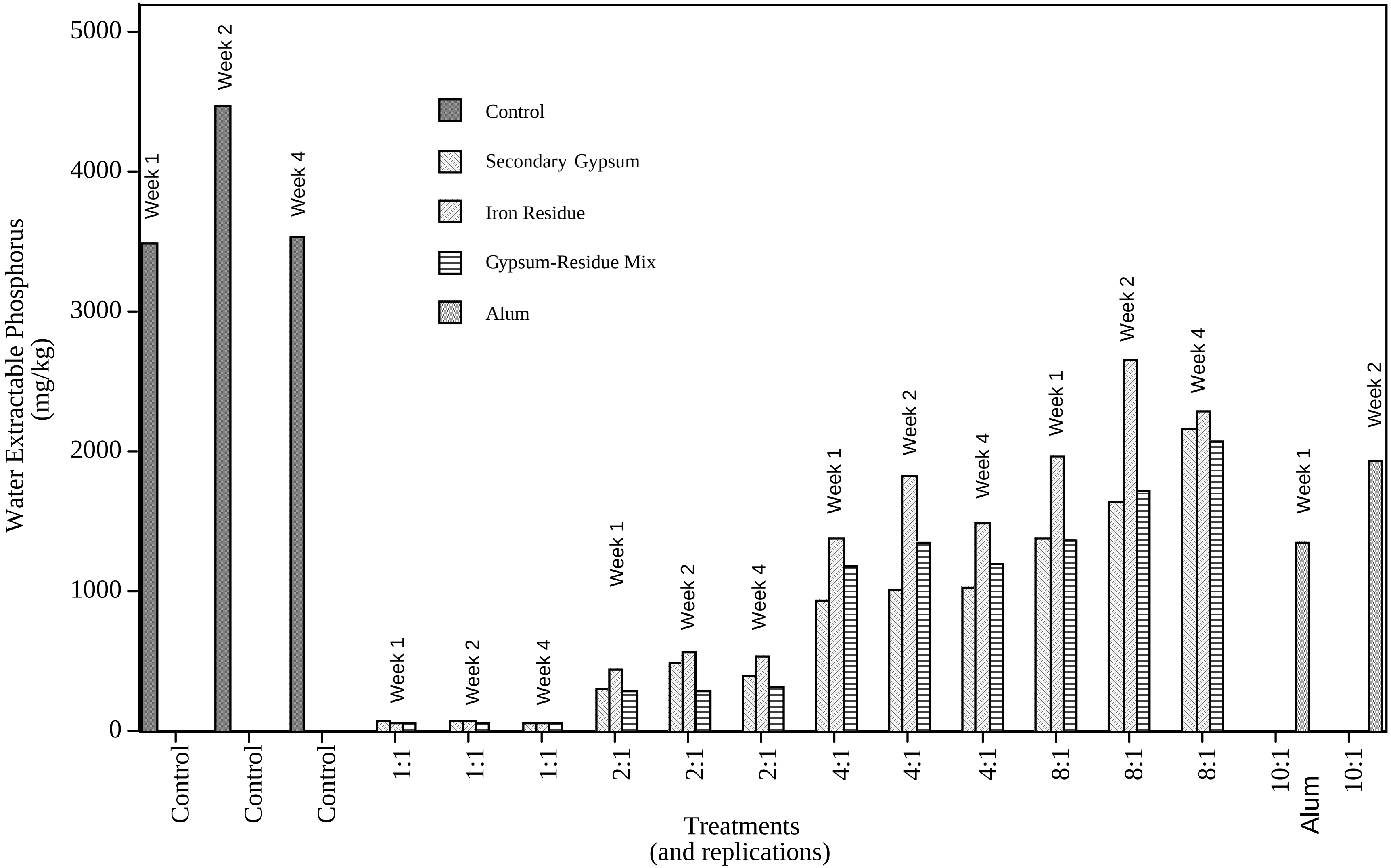
Each field was equipped with a 1-foot H-flume, flow meter, and ISCO sampler.

Laboratory Results

Element	Secondary Gypsum (mg/g)	Filter Cake (mg/g)	Poultry Litter (mg/g)
NH4-N	0	0	9
Total N	0	0	32
P2O5	0	0	27
Ca	231	48	13
Fe	111	189	19
S	126	2	7

Ratios of Litter to Amendment

- Control=100% litter
- PL:RG or PL:FC or PL:Mix
- 1:1, 2:1, 4:1, 8:1 on dry mass basis



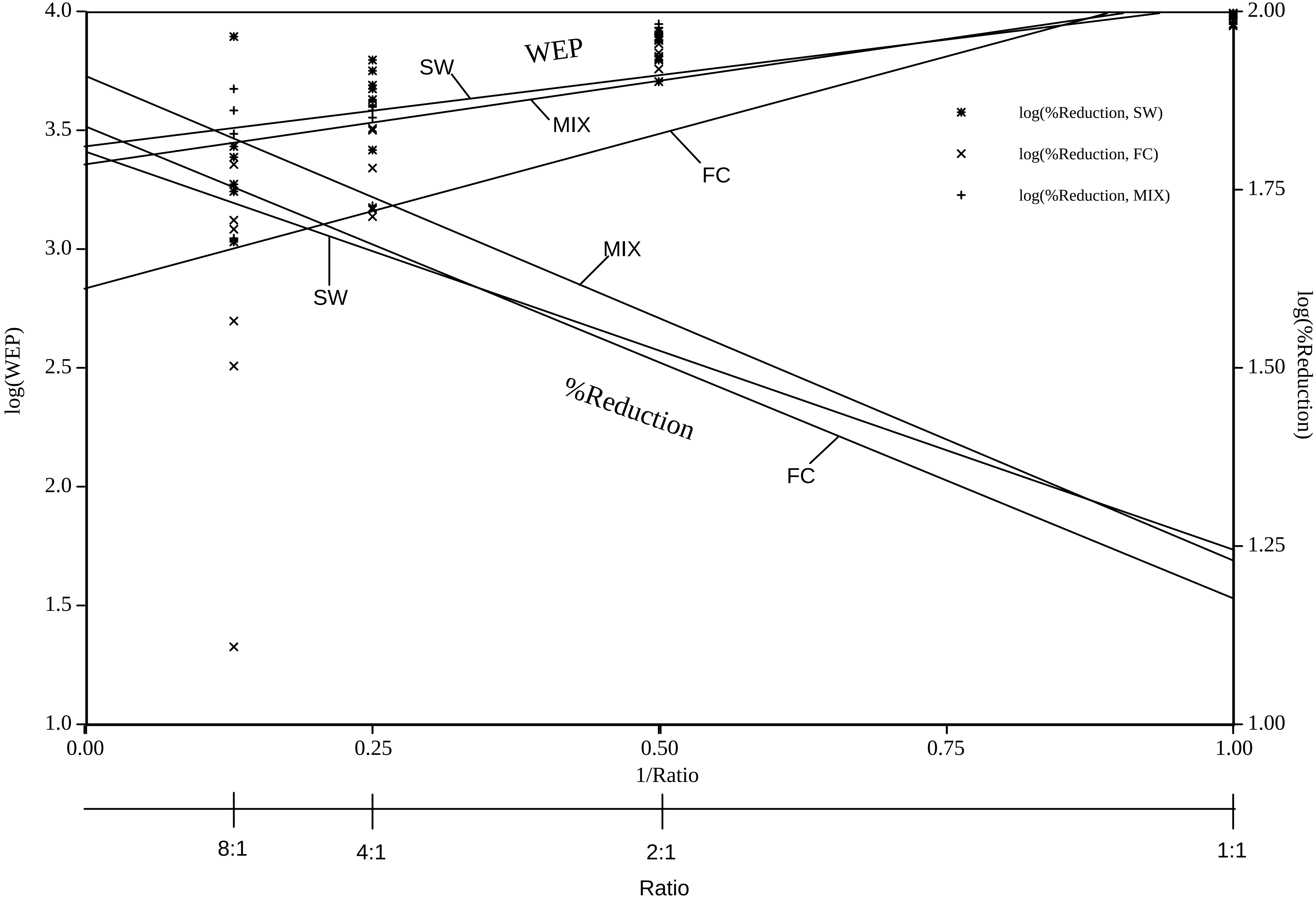
Water Extractable Phosphorus
(mg/kg)
5000
4000
3000
2000
1000
0
Control
Secondary Gypsum
Iron Residue
Gypsum-Residue Mix
Alum
Week 1
Week 2
Week 4
Control
Control
Control
1:1
1:1
1:1
2:1
2:1
2:1
4:1
4:1
4:1
8:1
8:1
8:1
10:1
Alum
10:1
Treatments
(and replications)

Linear Plots

- 1/ratio vs log(WEP)
  - Most linear
  - Variance not uniform

Percent Reduction

- Most calculations were done with WEP; the raw data
- %reduction is what we are interested in in practice
- % reduction =WEP(treatment)/WEP(control)



4.0
3.5
3.0
2.5
2.0
1.5
1.0
log(WEP)
2.00
1.75
1.50
1.25
1.00
log(%Reduction)
WEP
SW
MIX
FC
%Reduction
SW
MIX
FC
log(%Reduction, SW)
log(%Reduction, FC)
log(%Reduction, MIX)
0.00
0.25
0.50
0.75
1.00
1/Ratio
8:1
4:1
2:1
1:1
Ratio

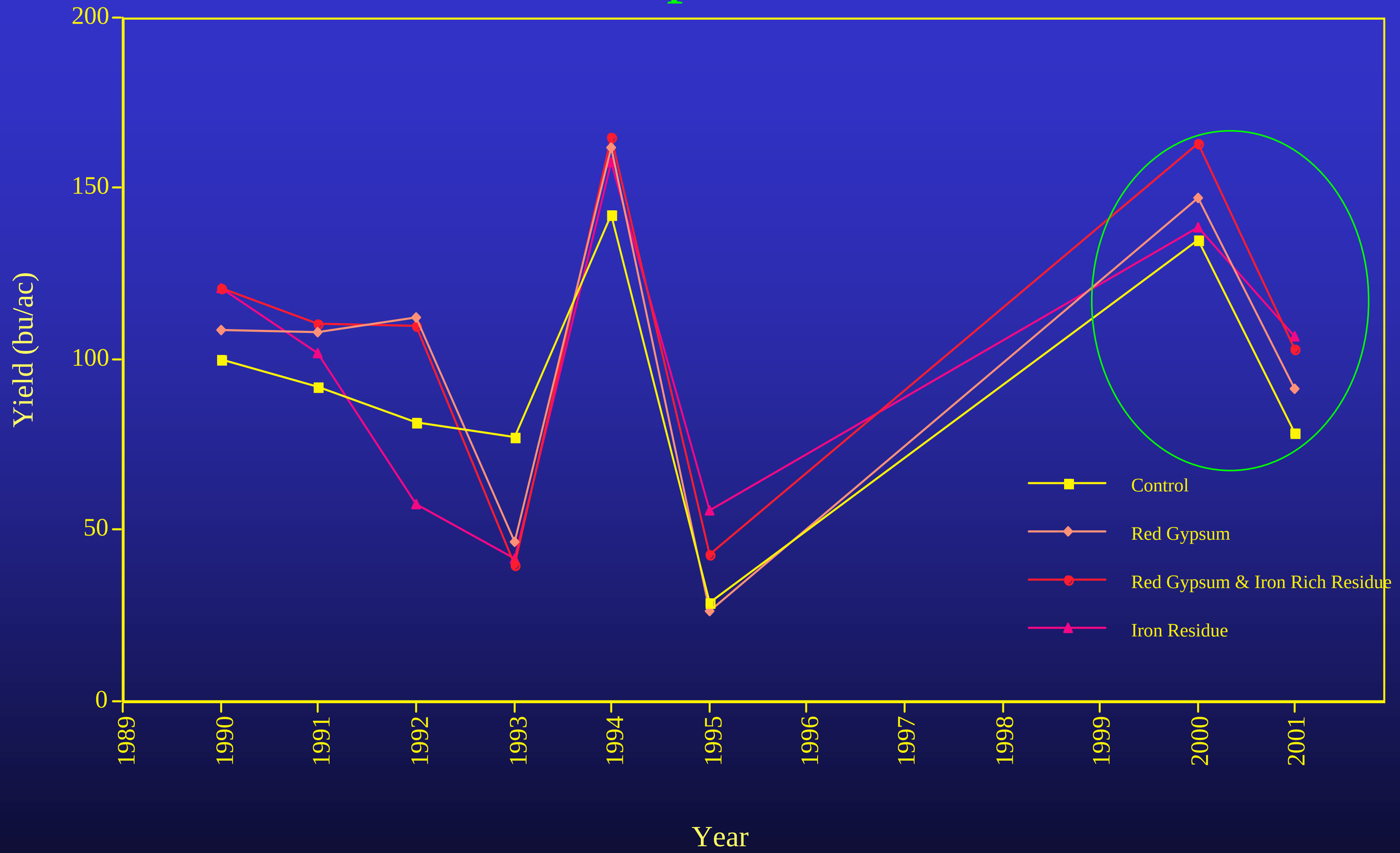
Field Results

- Six water samples collected over two years

Field Results

- Crop Yield
- Soils
  - Soil Test P
  - Soluble P
- Runoff
  - Design modification
  - Simulation results

Crop Yield



200
150
100
50
0
Yield (bu/ac)
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year
Control
Red Gypsum
Red Gypsum & Iron Rich Residue
Iron Residue

Hypothesis: Yield in 2000 (2001) was equal to the average yield from 1990-1995

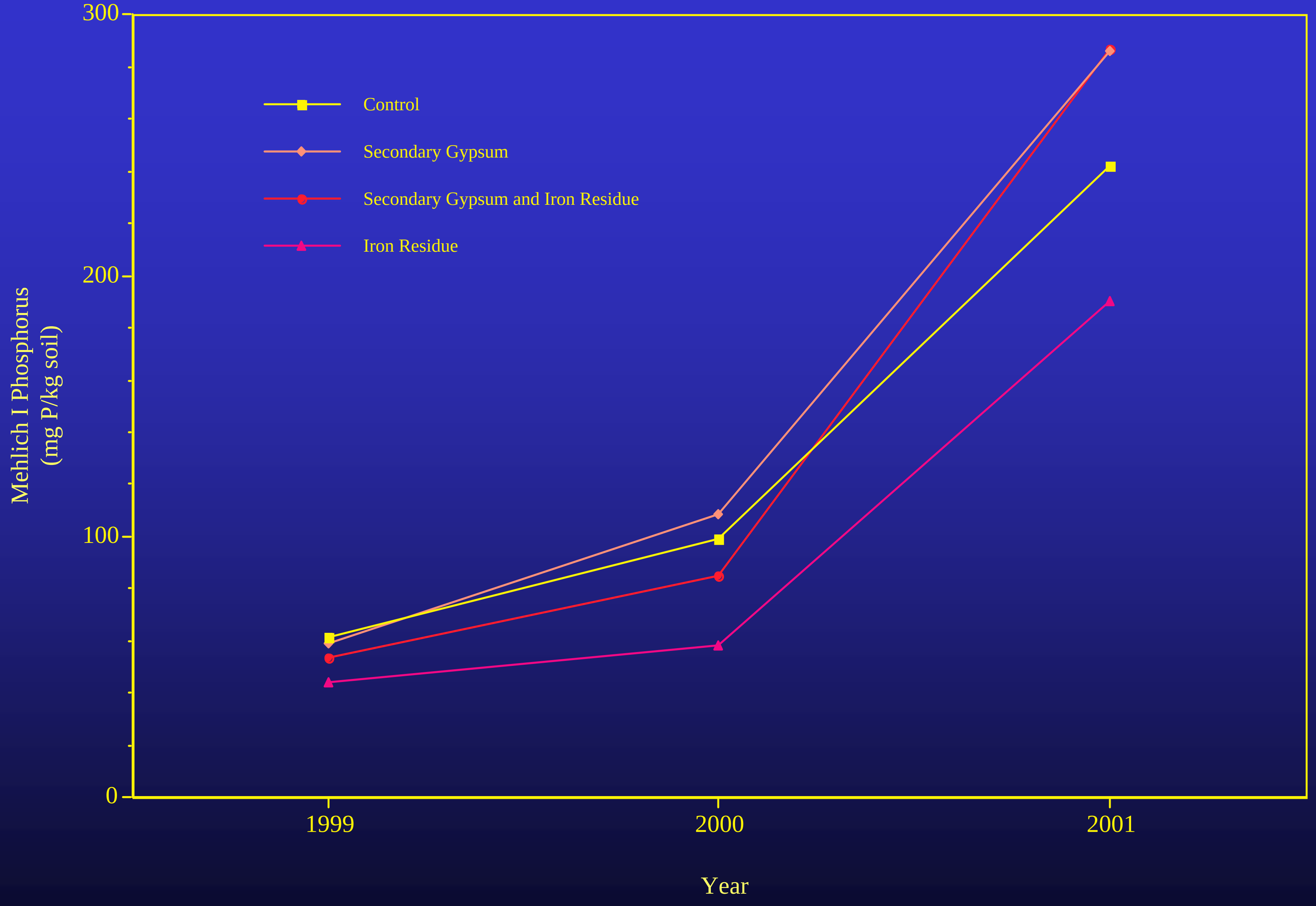
$$t = \frac{\bar{X} - \mu}{s/\sqrt{n}}$$

In all cases, null hypothesis was accepted.

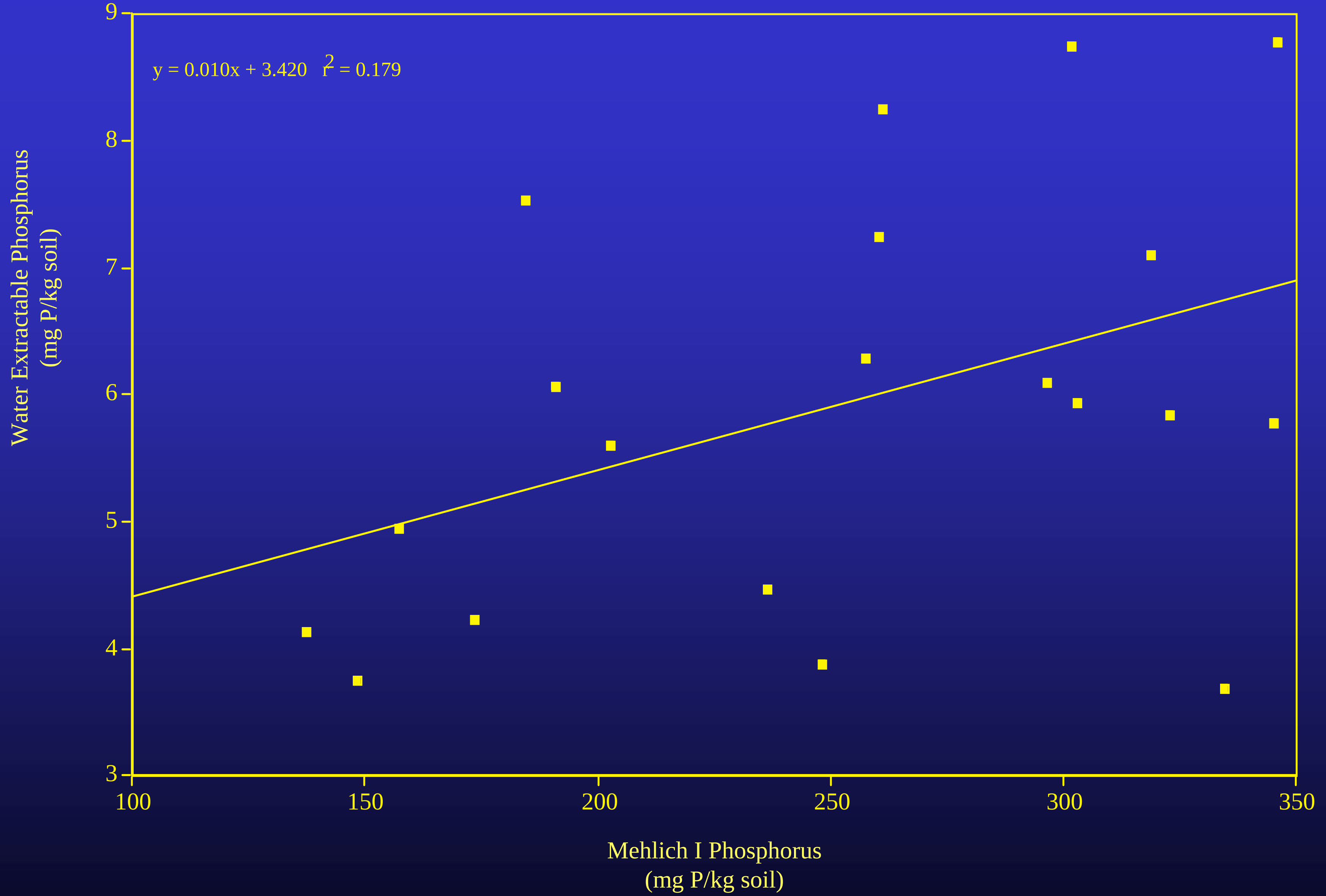
There was no adverse effects from treatments

Results

- Crop Yield
- Soils
  - Soil Test P
  - Soluble P
- Runoff
  - Design modification
  - Simulation results


Control
Secondary Gypsum
Secondary Gypsum and Iron Residue
Iron Residue
Mehlich I Phosphorus
(mg P/kg soil)
300
200
100
0
1999
2000
2001
Year

Soluble P vs. Soil Test P

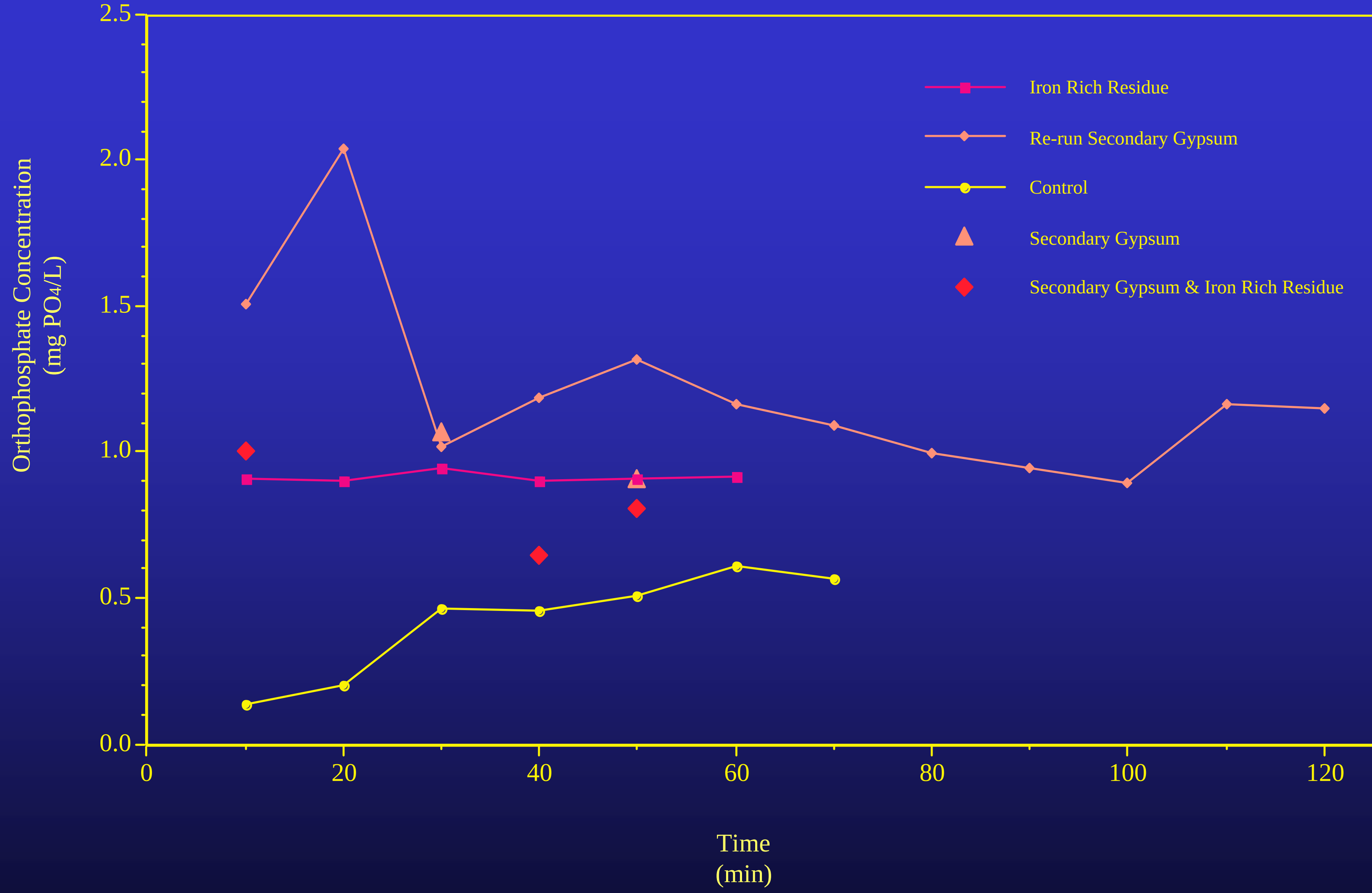


Soil test phosphorus and water extractable phosphorus after two cropping seasons.

Treatment	Mehlich I Soil Test Phosphorus (mg/kg)	Water Extractable Phosphorus (mg/kg)
Red Gypsum and Litter	285.8	5.2
Iron Rich Residue, Red Gypsum, and Litter	286.7	5.8
Iron Rich Residue and Litter	190.4	5.2
Litter	241.9	7.5

Results

- Crop Yield
- Soils
  - Soil Test P
  - Soluble P
- Runoff
  - Design modification
  - Simulation results



Orthophosphate Concentration
(mg PO4/L)
2.5
2.0
1.5
1.0
0.5
0.0
0
20
40
60
80
100
120
Time
(min)
Iron Rich Residue
Re-run Secondary Gypsum
Control
Secondary Gypsum
Secondary Gypsum & Iron Rich Residue

Findings

- Secondary Gypsum and Iron Rich Residue treatment means were equal ∴ treatments have similar effects on P concentration in surface runoff.
- Repeated run mean was not equal to mean of other treatments ∴ runs at a different time of year do not respond equally (i.e. there is a seasonal effect.)
- Control concentration was statistically less than treatments. This was not expected, to say the least.

Further Examination

- Moore et al. (1999) found P in the range 1.90 to 6.77 mg P/L. We found P in the range 0.137 to 0.393 mg P/L. We had lower slopes and sandy soils. Does this change the predominant factor that controls P in runoff?

Conclusions

Amendments do not adversely effect yields of corn.

Both the Red Gypsum and the Iron Rich Residue amendments reduced soluble phosphorus in field soils by approximately 30%. These amendments show promise for continuing the use of animal waste in agriculture.

The standard Mehlich extraction did not reflect the depression in soluble phosphorus.

Conclusions

All treatments had similar effects on the orthophosphate content of runoff water from intense precipitation events

There is a time of year effect in soluble phosphorus runoff.

Acknowledgements

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Central Maryland Research and Education Center Upper Marlboro Farm Crew.

Questions?

Power Point and Journal Article available at:

http://agnr.umd.edu/departments/ENST/People/Felton