Organic Soil Fertility: General Principles and New Research

Richard Smith
Vegetable Crop and Weed Science Farm Advisor
University of California Cooperative Extension
Monterey County

Organic Soil Fertility

- We will focus on organic fertility of vegetable crops
- We will mostly discuss nitrogen
- Obviously other nutrients are important, especially phosphorus and potassium
- Before we spend the time in this discussion on nitrogen we will briefly discuss phosphorus and potassium

Soil Phosphorus Levels bicarbonate-extractable (ppm)

Crop	Response likely	Response possible*	Response unlikely
Lettuce and Celery	< 40	40 – 60	> 60
Other cool-season vegetables	< 25	25 – 35	> 35
Warm-season vegetables	< 15	15 - 25	> 25

* especially in cold soils

Soil Potassium Levels ammonium acetate-extractable (ppm)

Crop	Response likely	Response possible	Response unlikely
Celery	< 150	150 – 200	> 200
Other cool-season vegetables	< 100	100 – 150	> 150
Potato, tomato, pepper	< 150	150 – 200	> 200
Cucurbits	< 80	80 – 120	> 120

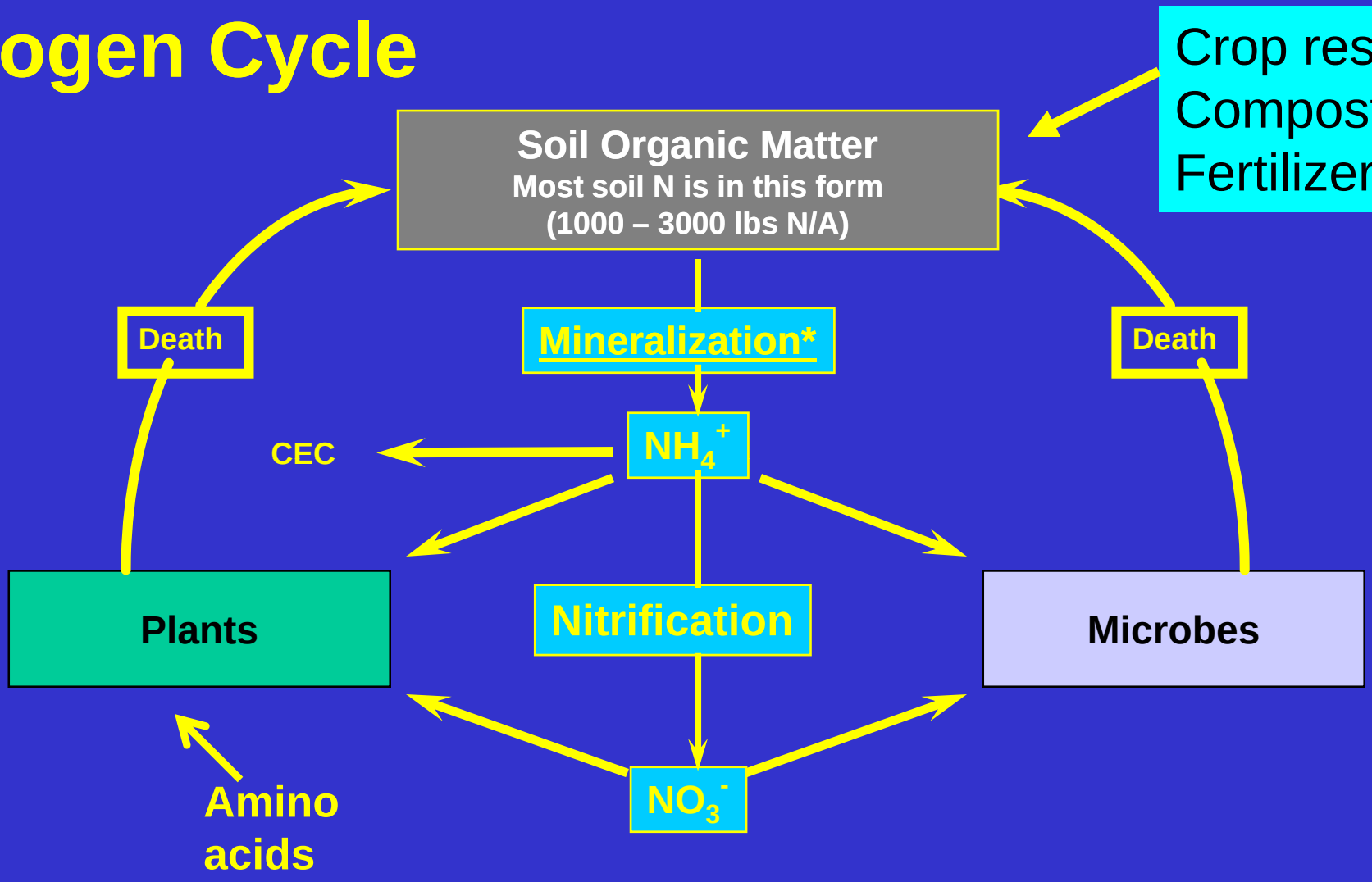
Phosphorus and Potassium

- Both of these nutrients can be monitored and managed with the use of soil tests
- There are several organic sources of these nutrients
- High soil pH reduces the availability of bone and rock sources of phosphorus
- Vegetable production systems can over time build up high levels of soil phosphorus

Organic Soil Fertility

- Nitrogen is particularly problematic because of various forms it occurs in and transformations it goes through
- Mineral nitrogen (nitrate and ammonium) is the plant available form of N in the soil
- Large quantities of N also exists in complex forms in soil organic matter which are not available for plant growth
- The challenge in organic agriculture is to get sufficient mineral N from non-mineral N sources

Nitrogen Cycle



*** Mineralization is a key step in making N available for plant growth**
It is dependent upon adequate soil temperatures (i.e. > 50 F)

Sources of Nitrogen for Organic Ag

- Storage
  - Organic Matter
- Legumes (N from air)
  - Green Manures
    - Vetches, clovers, peas
  - Alfalfa Meal
- Mined
  - Sodium nitrate
- Seaweed
- Recycling/Scavenging
  - Prior crops, cereal cover crops
  - Meat, Fish, Blood, Feather, Bone
  - Seed Meals (cotton, soybean, etc)
  - Manure, Guano
  - Green Waste Compost

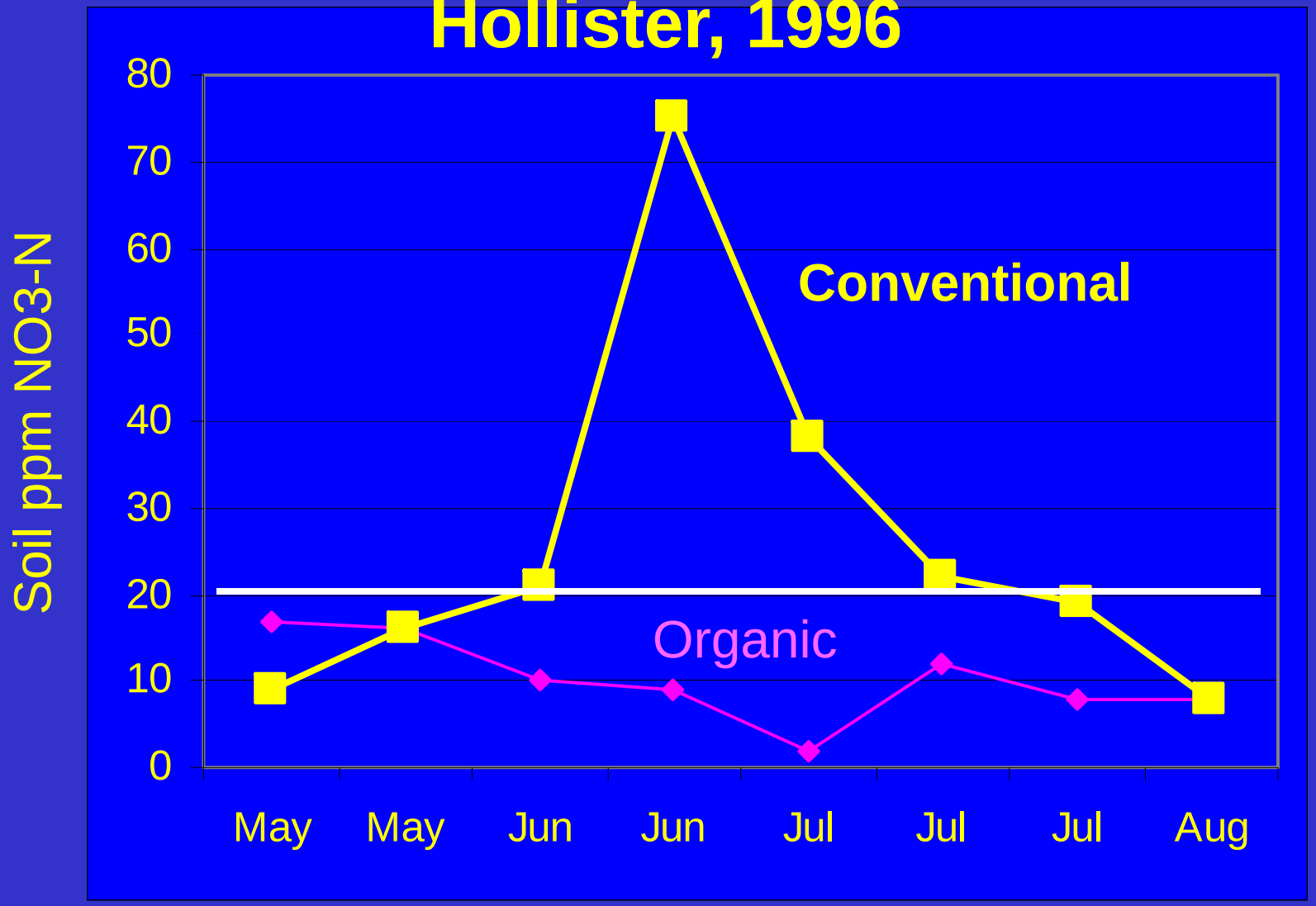
Soil Test for Nitrogen in Organic Systems

- There have been many ideas proposed to test soil nitrogen to predict crop response in conventional and organic production systems

- In conventional production the presidedress nitrate quick test measures nitrate, the dominant form of N in the soil
- In organic production nitrate is not as useful of an indicator of nitrogen due to typically low levels of nitrate encountered in soil

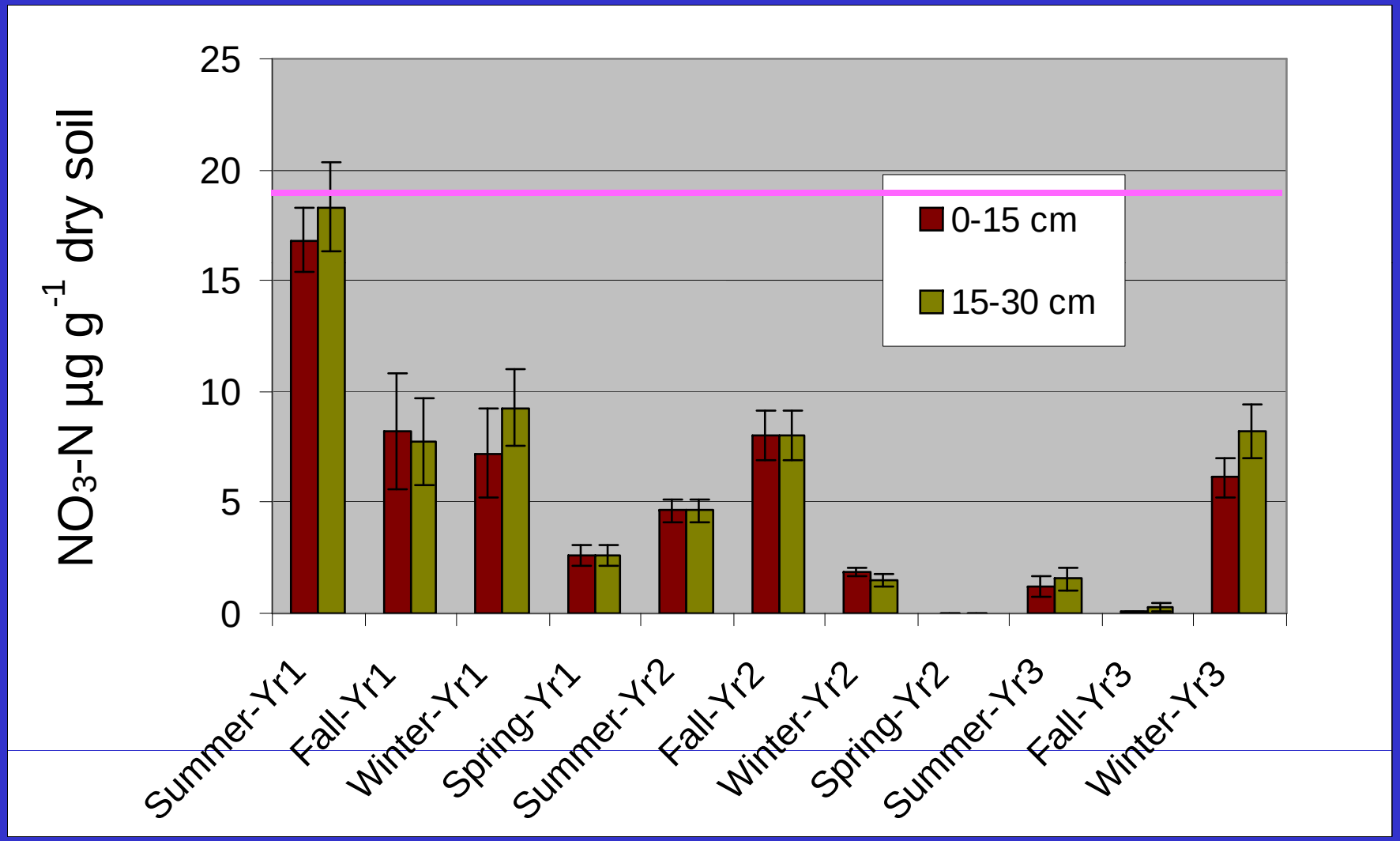
Comparison of Organic and Conventional Onions

Hollister, 1996



Smith, 1996

Soil Nitrate in Organic Vegetable Production 2001 - 2003



Jackson, 2005

Nitrogen Soil Fertility

- The amino sugar soil N test has not proved to be a good predictor of N availability to crops
- At present: the best indication of available soil nitrogen status in organic systems is with total nitrogen:
  - Soils with less than 0.07% total N mineralize limited quantities of N for rapid crop growth
  - Soils with more than 0.15% total N can mineralize significant amounts of N during the crop cycle

Nitrogen Soil Fertility

- As an example a soil with 0.07% total N contains 2,800 lbs N/A
- Incubation studies have shown that during the summer about 1% of soil organic N mineralizes/month
- For a 60 day growth cycle that would be: 2,800 lbs N x 1.0% x 2 months = 56 lbs N/A
- This is about 1 lb N/A/day

Nitrogen Soil Fertility

- The nitrogen that mineralizes from the organic matter is the “background” nitrogen level that every soil provides for plant growth
- A key goal in organic production is to build up the levels of organic matter which increases the levels of stored N which can be mineralized for plant growth

Impacts of Organic Soil Building on Nitrogen Storage in Soil

Soil Type	Management	Total Soil N %
Clay Loam	Organic	0.17
Clay Loam	Conventional	0.14
Loam	Organic	0.14
Loam	Conventional	0.11
Fine Sandy Loam	Organic	0.12
Fine Sandy Loam	Conventional	0.06

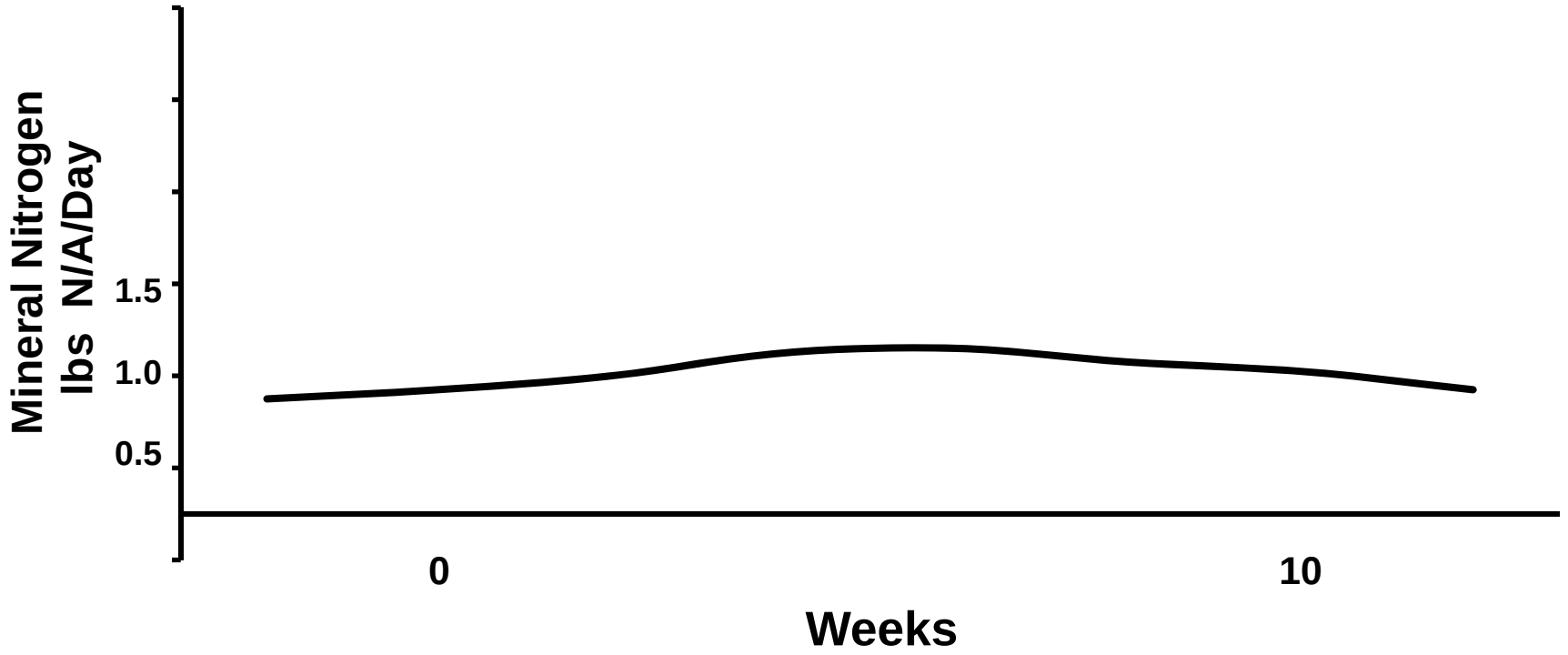
Smith, 2003

Impacts of Organic Soil Building on Nitrogen Storage in Soil

Soil Type	Management	Total Soil N %
Clay Loam	Organic	0.17
Clay Loam	Conventional	0.14
Loam	Organic	0.14
Loam	Conventional	0.11
Fine Sandy Loam	Organic	0.12
Fine Sandy Loam	Conventional	0.06

Smith, 2003

Generalized Trend Line: Mineral Nitrogen Made Available from Soil Organic Matter



Nitrogen Requirement of Vegetables

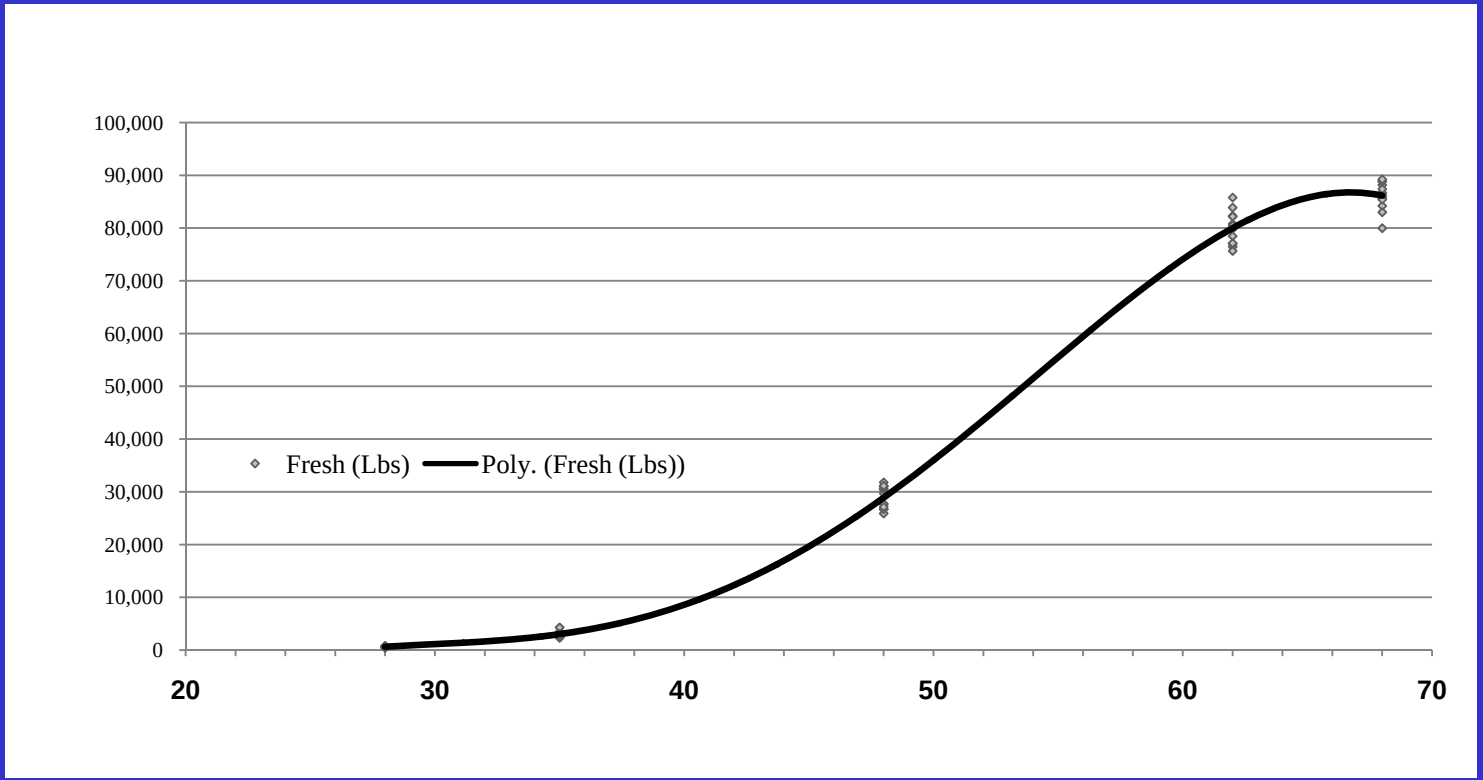
Seasonal Uptake

Low total N content < 120 lbs/acre	Medium total N content 120-200 lbs/acre	High total N content > 200 lbs/acre
Baby greens	Carrot	Broccoli
Beans	Corn, sweet	Cabbage
Cucumbers	Garlic	Cauliflower
Radish	Lettuce	Celery
Spinach	Melons	Potato
Squashes	Onion	
	Peppers	
	Tomatoes	

Nature of Vegetable Crops

- Rapid growth from 30 to 60 days following planting

- High peak demand for N
- Can be as high as 4-5 lbs Nitrogen/Acre/day

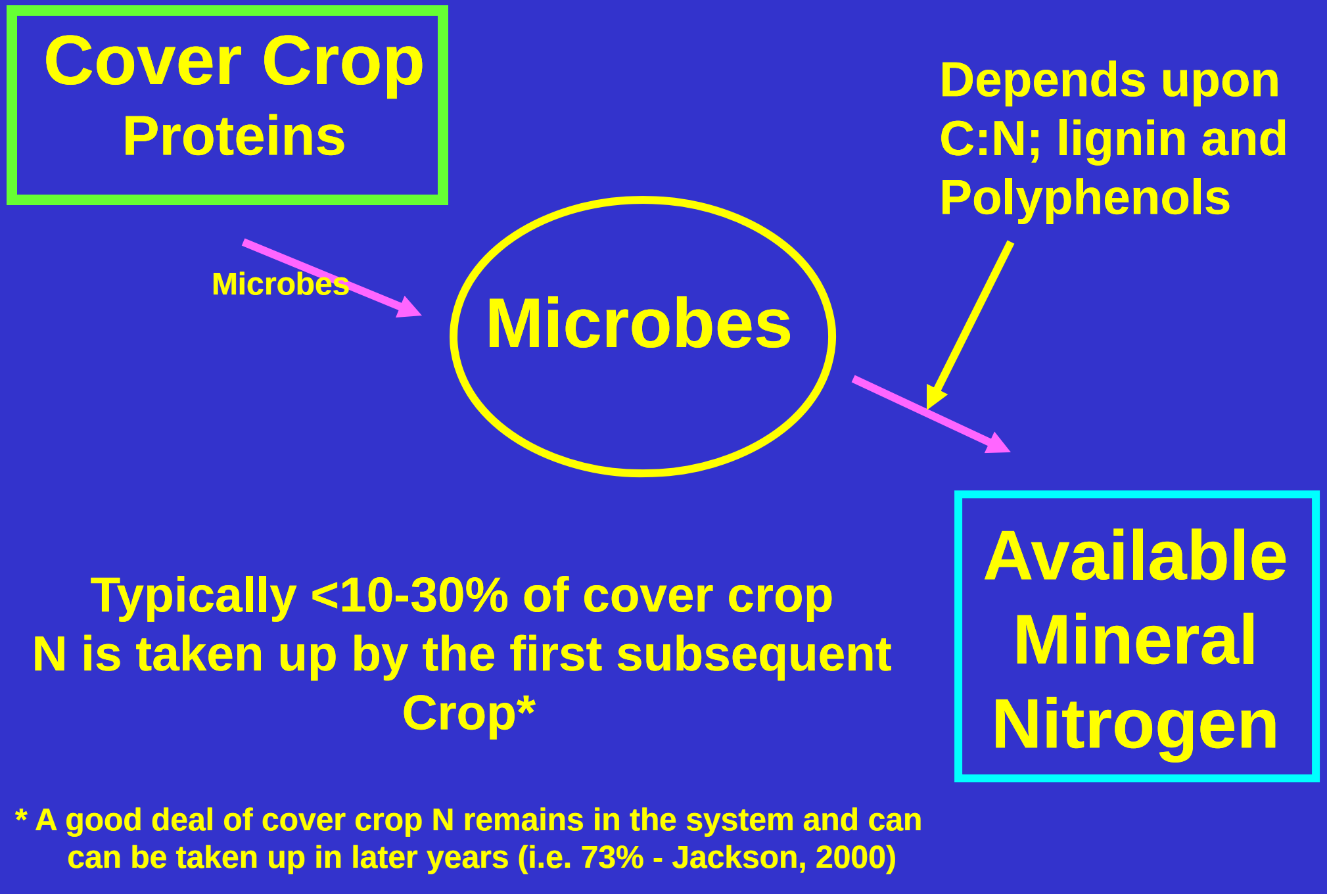


Crux of Nitrogen Fertilization of Organic Horticultural Crops

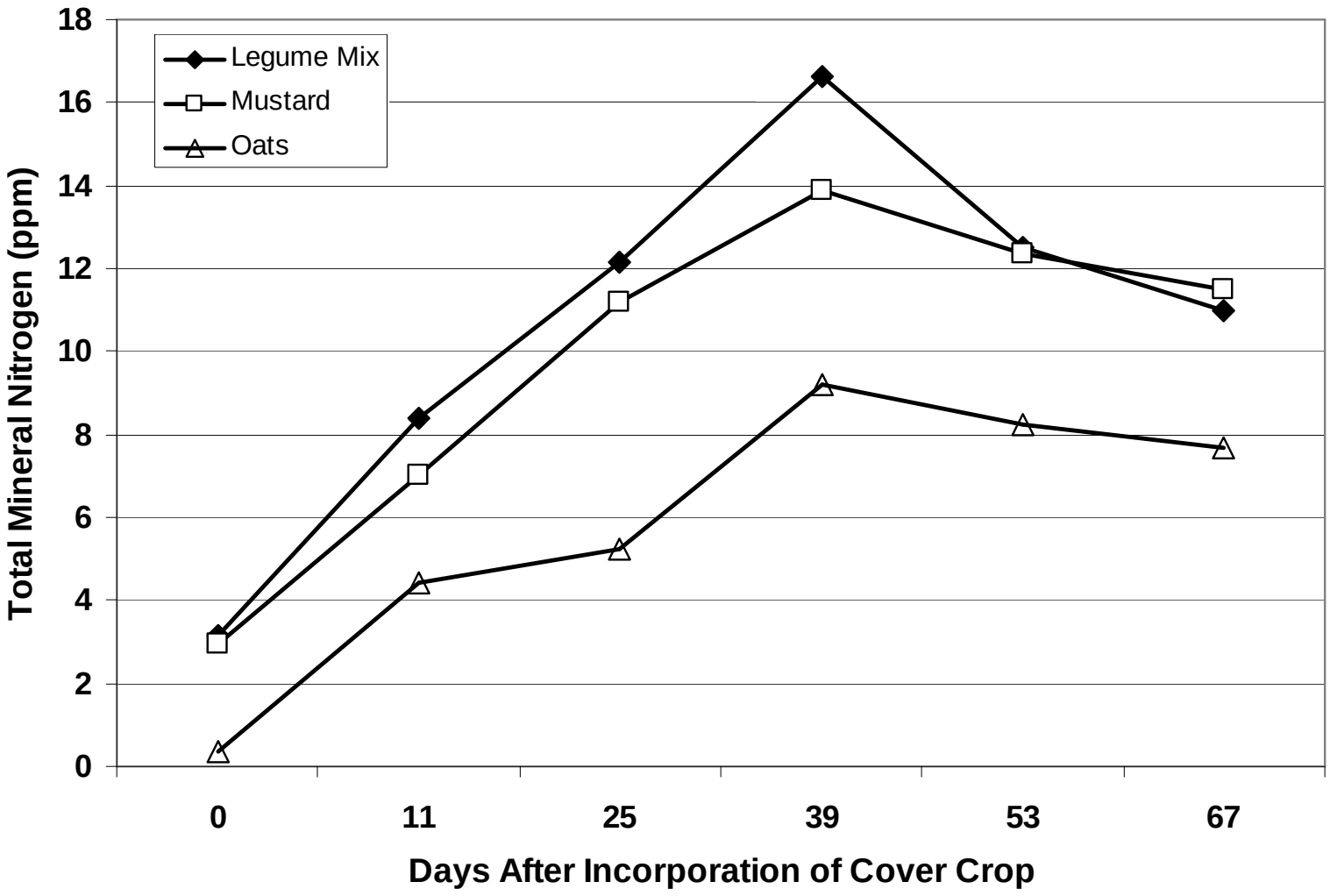
- Some crops may be able to achieve economically acceptable yield from mineralization of soil organic matter
- Most of our key crops will generally need greater quantities of available mineral nitrogen to achieve economically viable yields

Nitrogen from Green Manures

- This can be an economical source of N
- Cereal cover crops recycle and scavenge N from the soil
- Legumes fix nitrogen from the air
- There are some key issues regarding N from cover crops that needs to be kept in mind


Cover Crop
Proteins
Depends upon
C:N; lignin and
Polyphenols
Microbes
Microbes
Available
Mineral
Nitrogen
Typically <10-30% of cover crop
N is taken up by the first subsequent
Crop*
* A good deal of cover crop N remains in the system and can
can be taken up in later years (i.e. 73% - Jackson, 2000)

N Release Pattern from Cover Crops

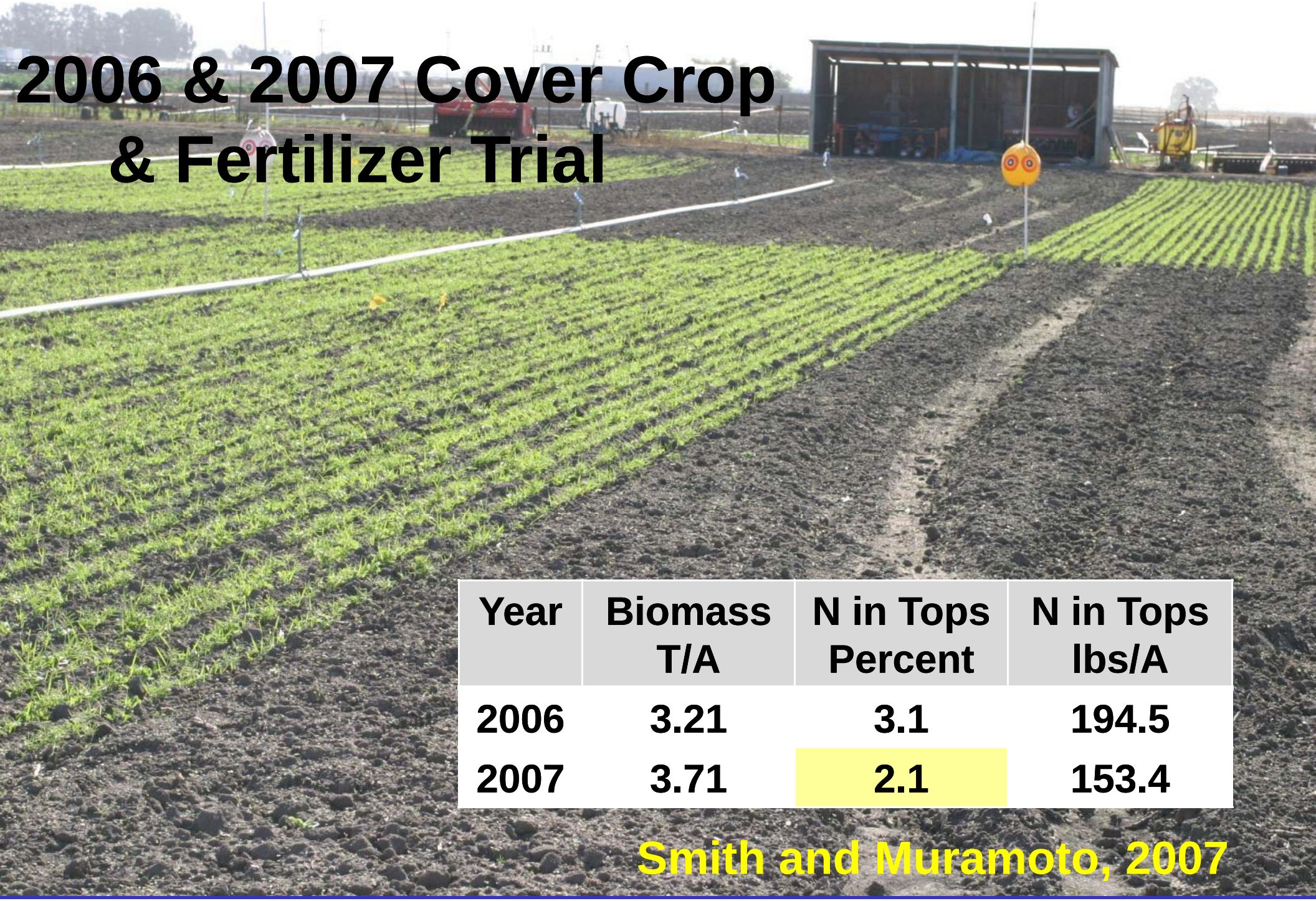


Smith & Brennan, 2003

Nitrogen release from cover crop residue based on the N content

Nitrogen Release	Percent N in Cover Crop	Examples of Cover Crops
Will Tie up N	0.5	Cereal Straw
Will Tie up N	1.0	Cereal Straw
Will Tie up N	1.5	Cereal at heading
May Tie up N*	2.0	Cereal pre heading
May Tie up N*	2.5	Mustards at heading and Imm. cereal
Will Release N	3.0	Mustards, legumes and juvenile cereal
Will Release N	3.5	Legumes and immature mustards
Will Release N	4.0	Legumes

2006 & 2007 Cover Crop & Fertilizer Trial

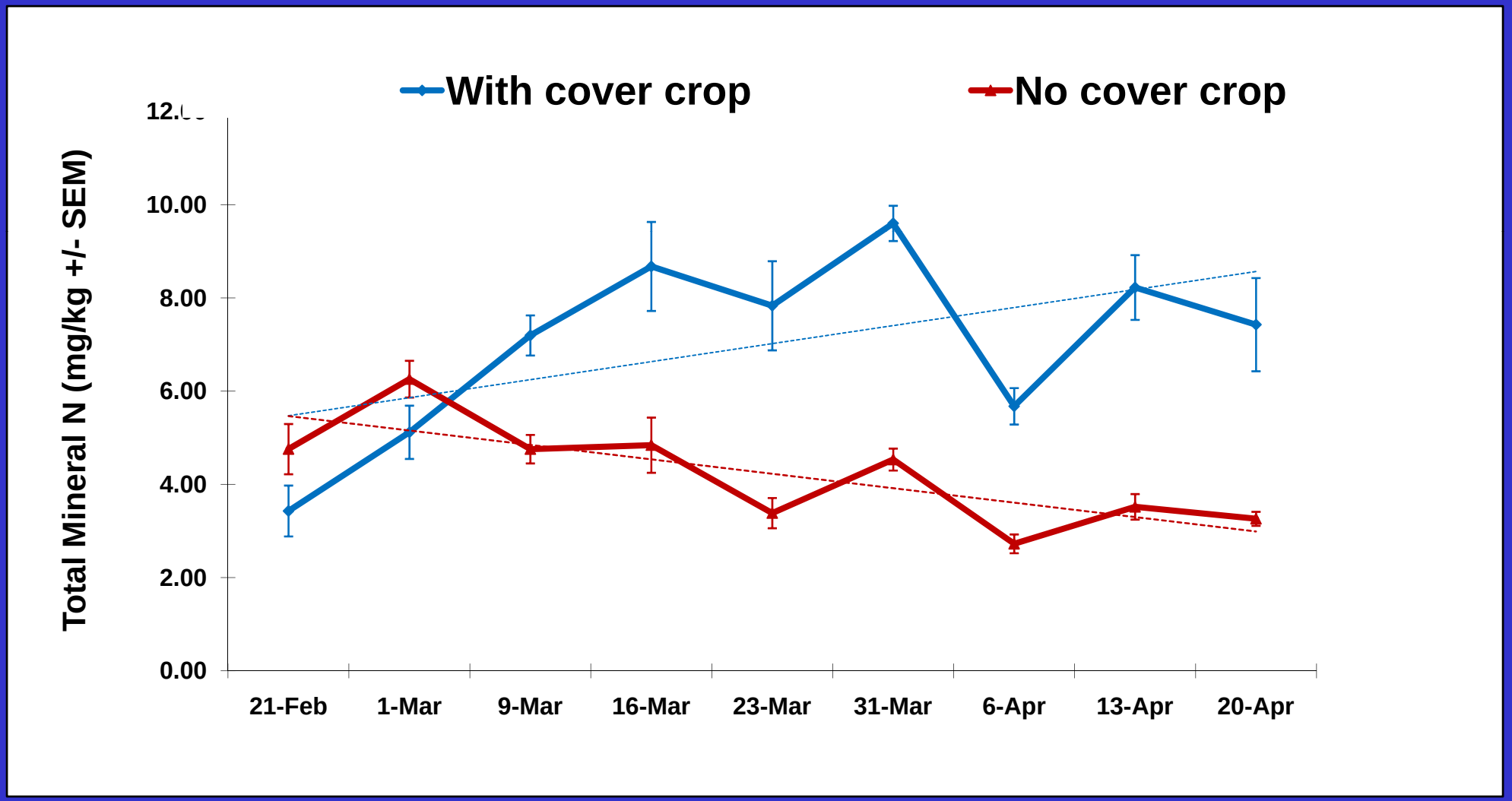


Year	Biomass T/A	N in Tops Percent	N in Tops lbs/A
2006	3.21	3.1	194.5
2007	3.71	2.1	153.4

Smith and Muramoto, 2007

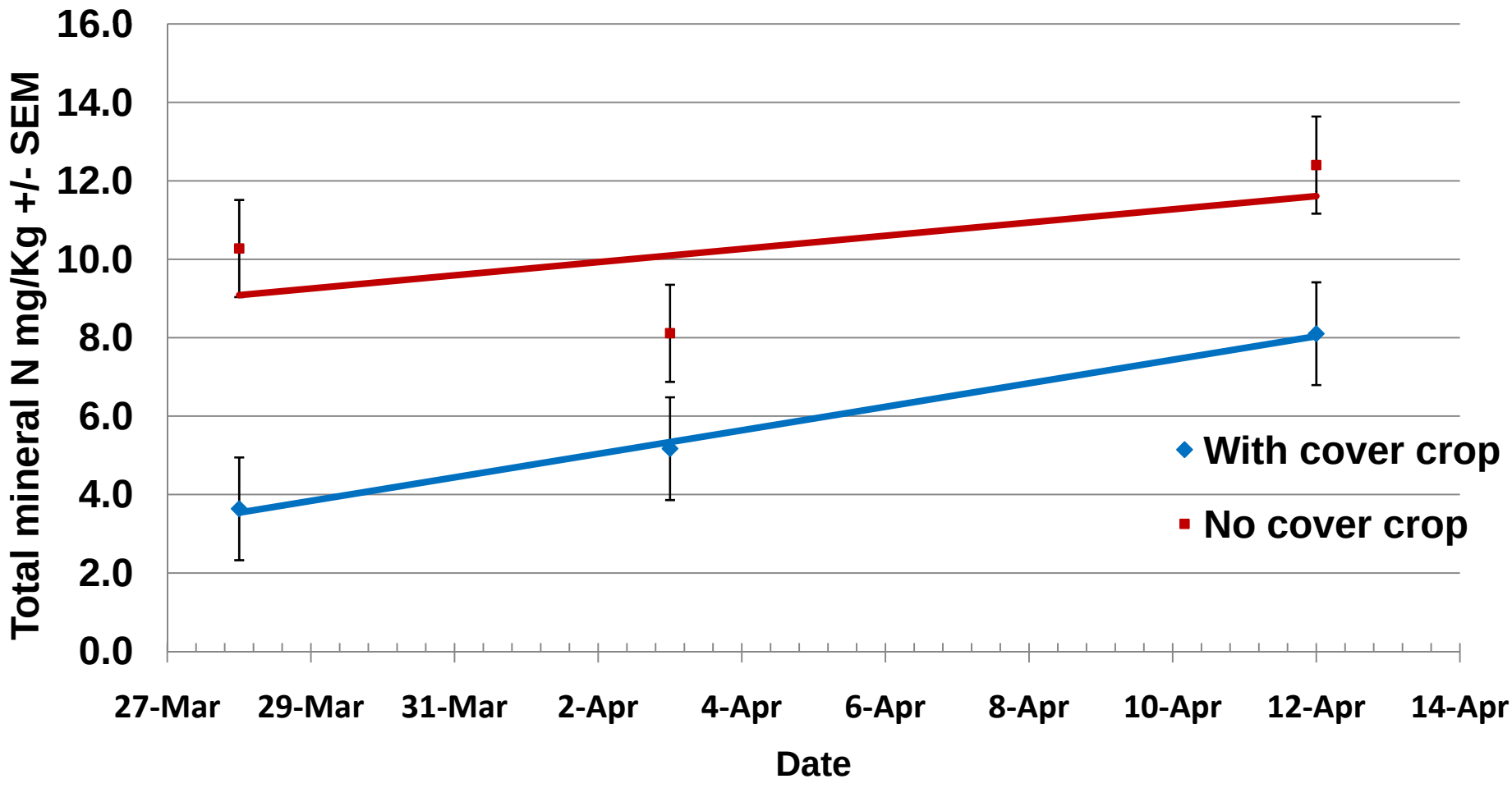
2006 Soil Mineral Nitrogen

Cover Crop Incorporation to Planting Broccoli

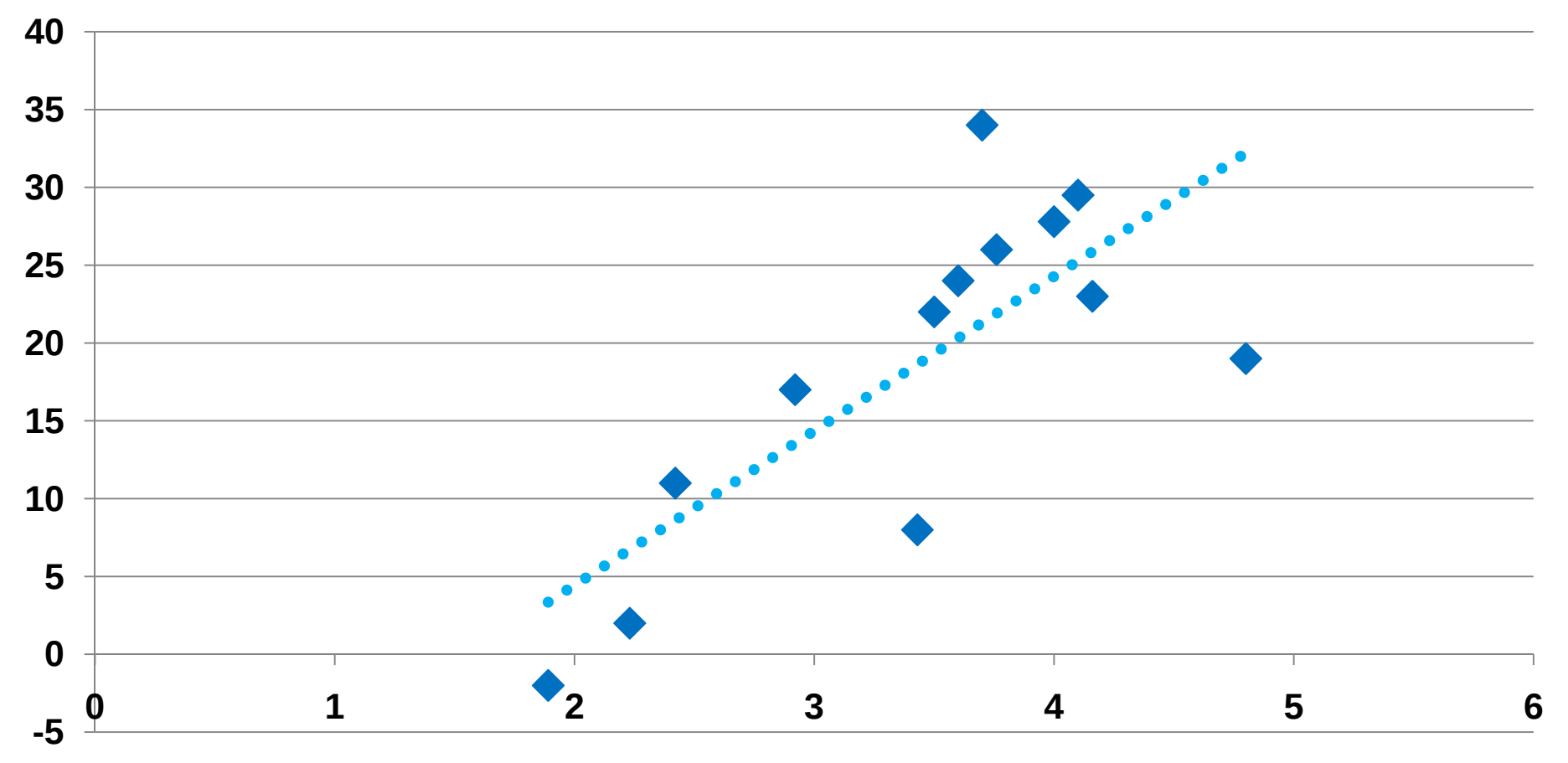


2007 Soil Mineral Nitrogen

Cover Crop Incorporation to Planting Broccoli



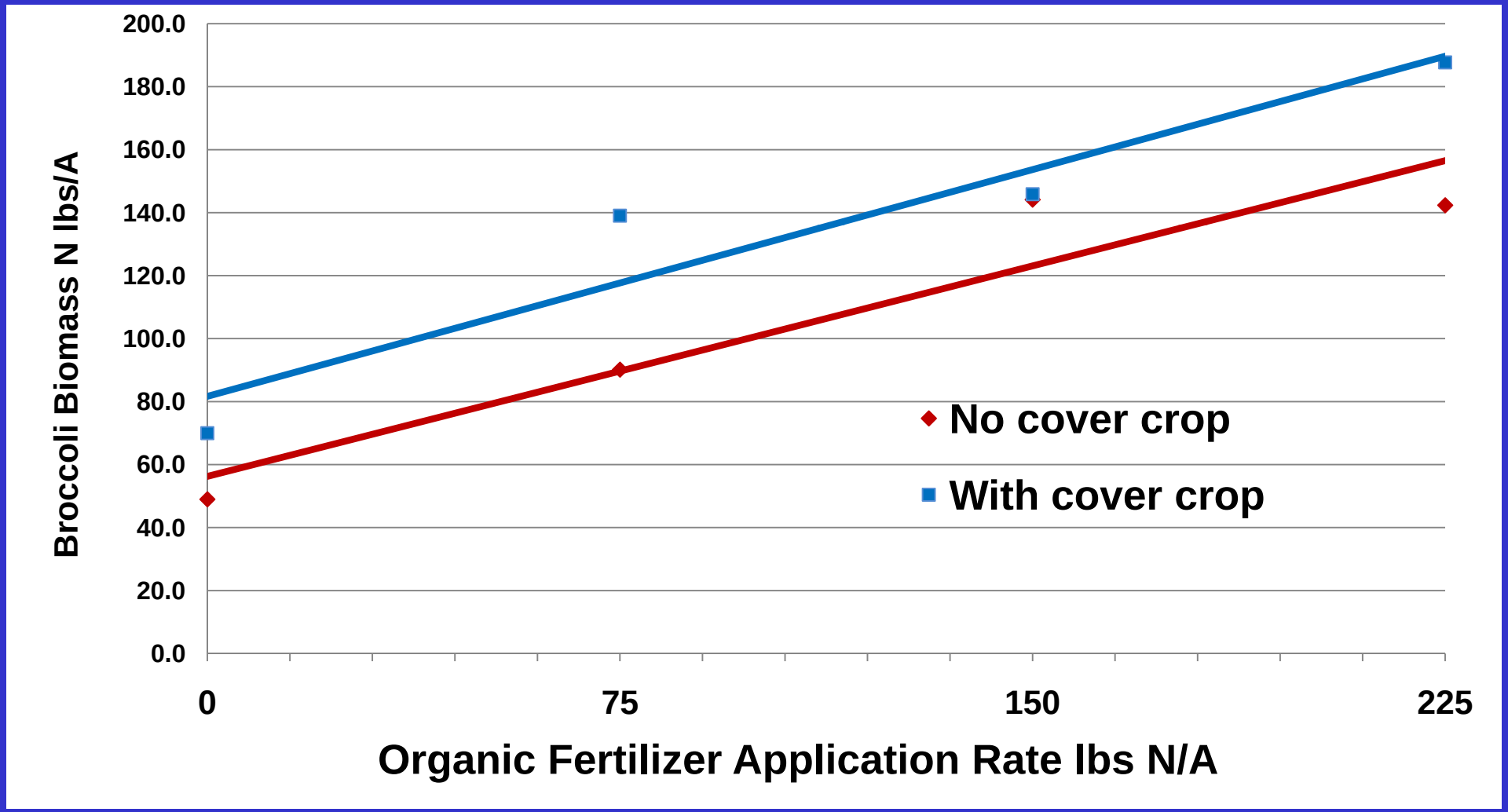
Percent of Cover Crop Nitrogen Mineralized at 8 Weeds



Hartz, unpublished

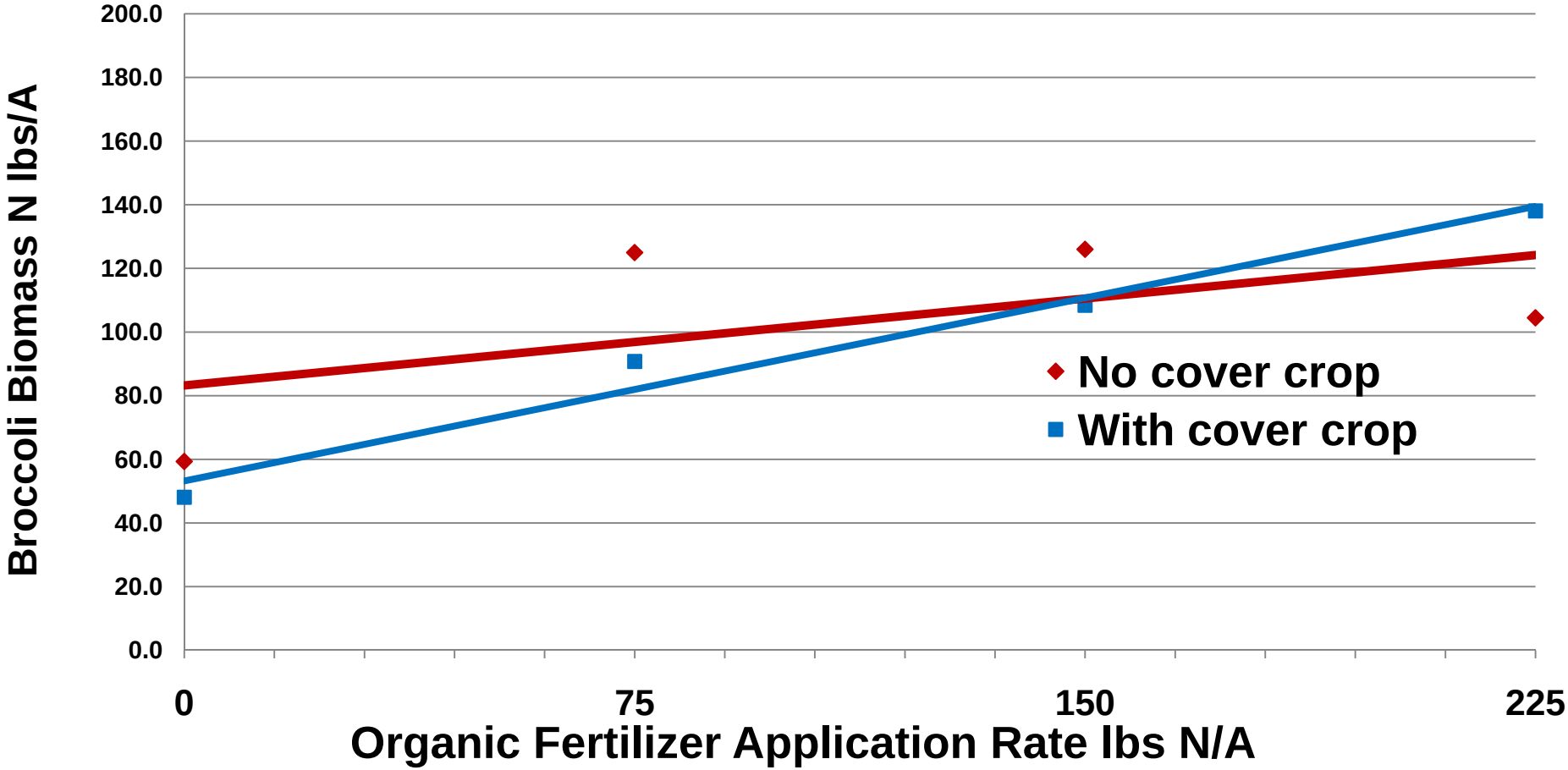
2006 Nitrogen in Broccoli Biomass lbs/A

At Harvest

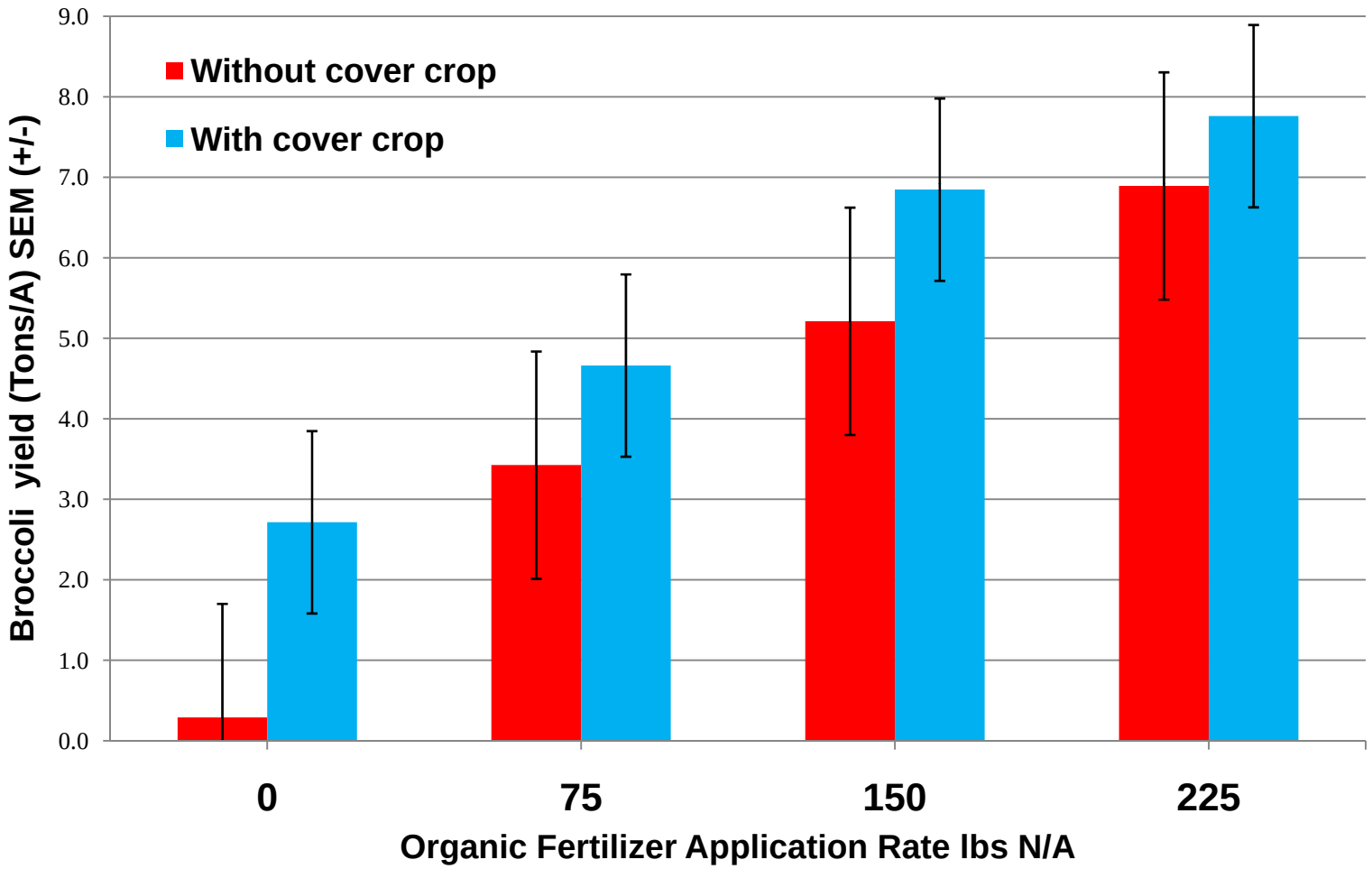


2007 Nitrogen in Broccoli Biomass lbs/A

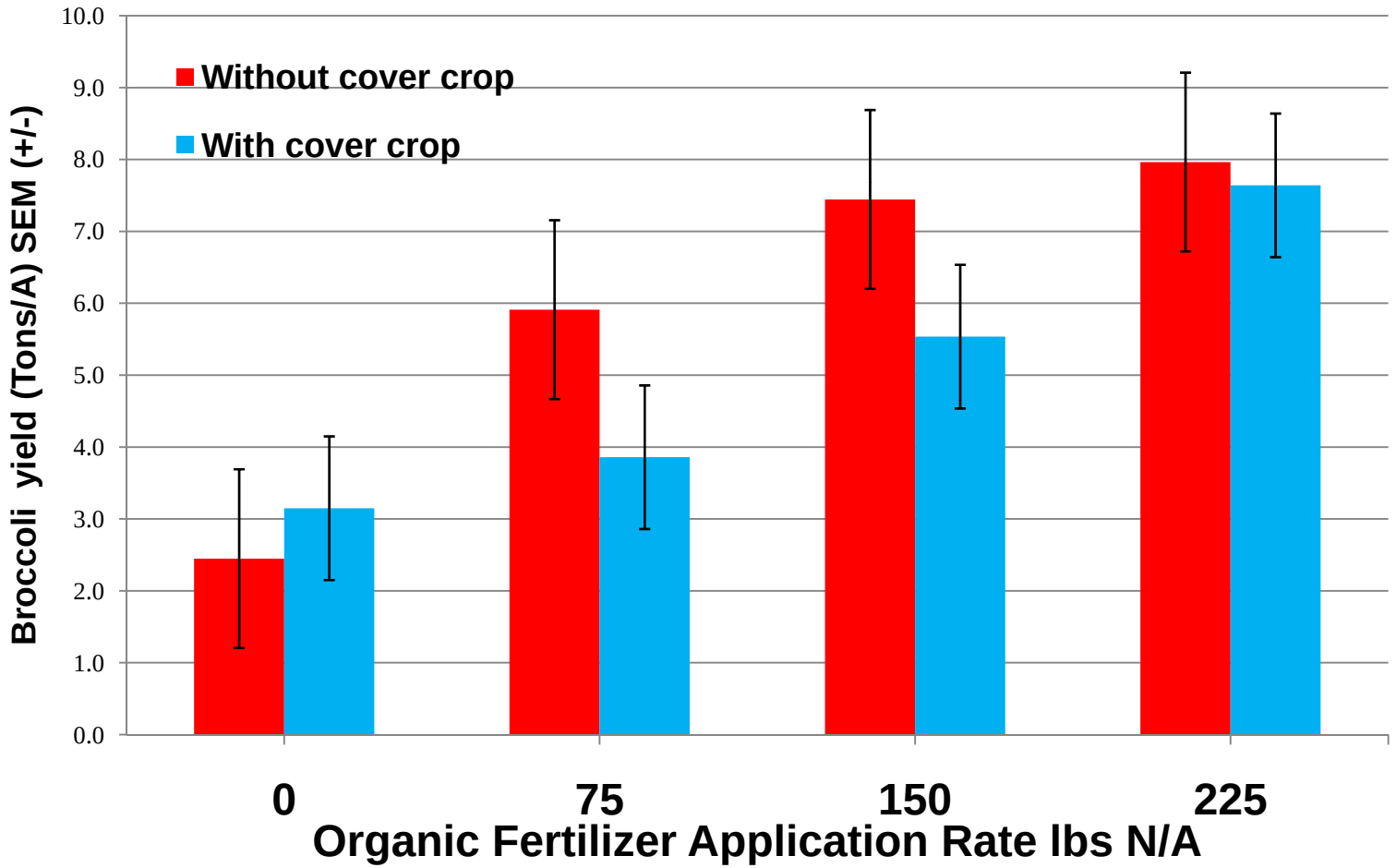
At Harvest

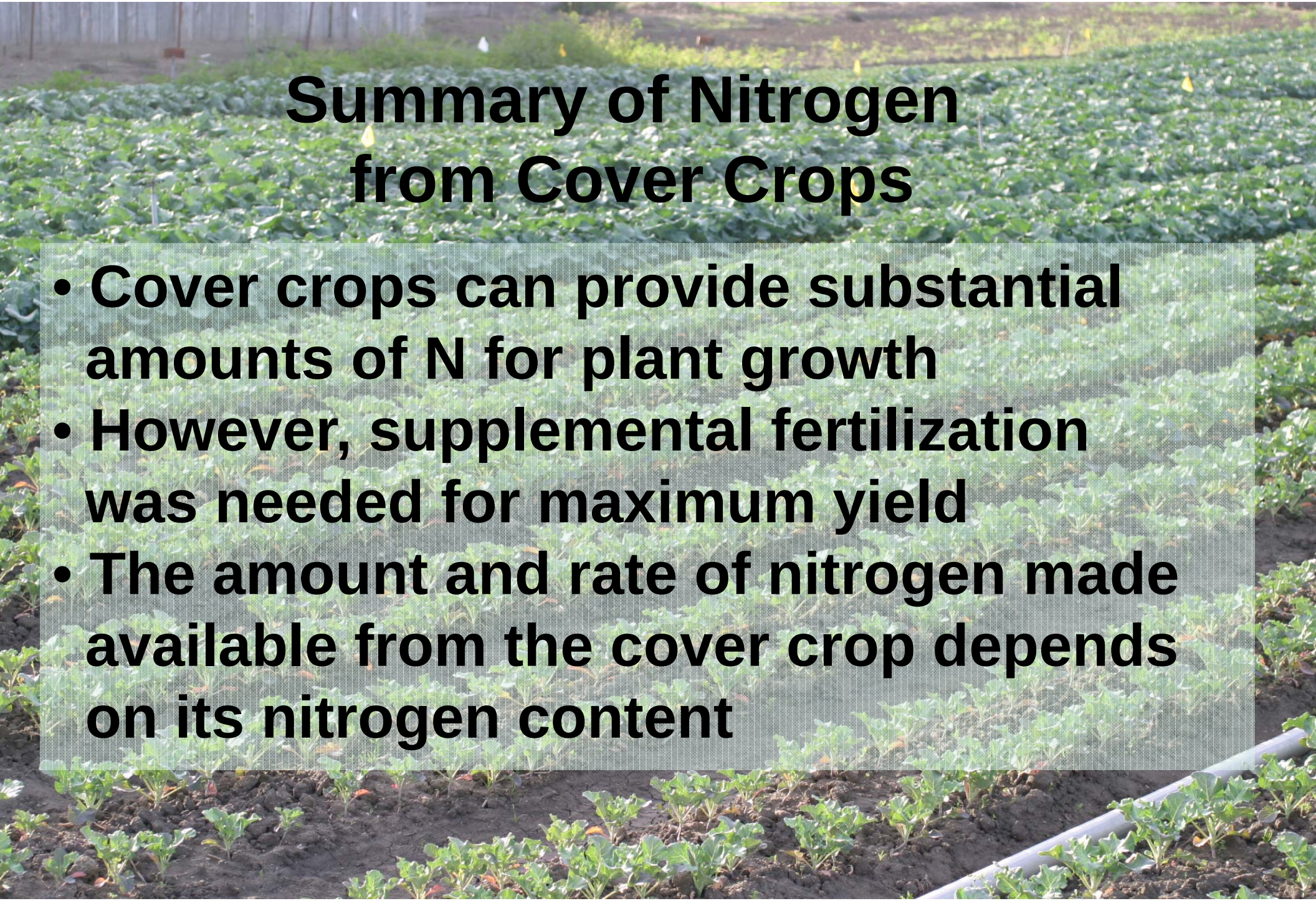


Broccoli Yield
2006 Trial



Broccoli Yield
2007 Trial





Summary of Nitrogen from Cover Crops

- Cover crops can provide substantial amounts of N for plant growth
- However, supplemental fertilization was needed for maximum yield
- The amount and rate of nitrogen made available from the cover crop depends on its nitrogen content

Mineralization of Mineral Nitrogen from Manures and Compost

Manures and composts are widely used in organic systems, but what can they provide with regards to nitrogen nutrition

Characteristics of Compost/Manures

Material	Total N	C/N Ratio
Pelletized poultry manure	4.7	4.5
Aged poultry manure	3.1	9.1
Poultry compost	3.8	5.7
Aged feedlot manure	2.0	12.4
Feedlot manure compost	2.2	11.4
Yard waste compost	1.6	14.4
Yard waste compost	1.0	12.0

Hartz et al, 2000

N Mineralization

Manures and Compost

- In a two year study of the mineralization rate of organic amendments, nitrogen was recovered in a fescue crop as follows:

Material	Mean N recovery Percent	High N recovery Percent
Manure	11	27
Composted Manure	6	15
Composted Yard Waste	2	6

Hartz et al, 2000

Mineralization of Mineral Nitrogen from Manures and Compost

Summary

- Mineralization of mineral nitrogen from manures and compost can provide limited amounts of readily available N for high N demanding horticultural crops
- These materials play a larger role in soil building and provide a long-term source of N that contributes to total soil nitrogen content and that behaves the same as soil organic matter

Mineralization of Mineral Nitrogen from Manures and Compost

Summary

- Composts and manures are good sources of phosphorus and potassium

Material	Phosphorus	Potassium
Manures and composts	1.6 – 2.6	0.5 – 3.0
Yard Waste Composts	0.2 – 0.3	0.6 – 1.4


Mineralization from
Dry Organic Fertilizers

Net N Mineralization

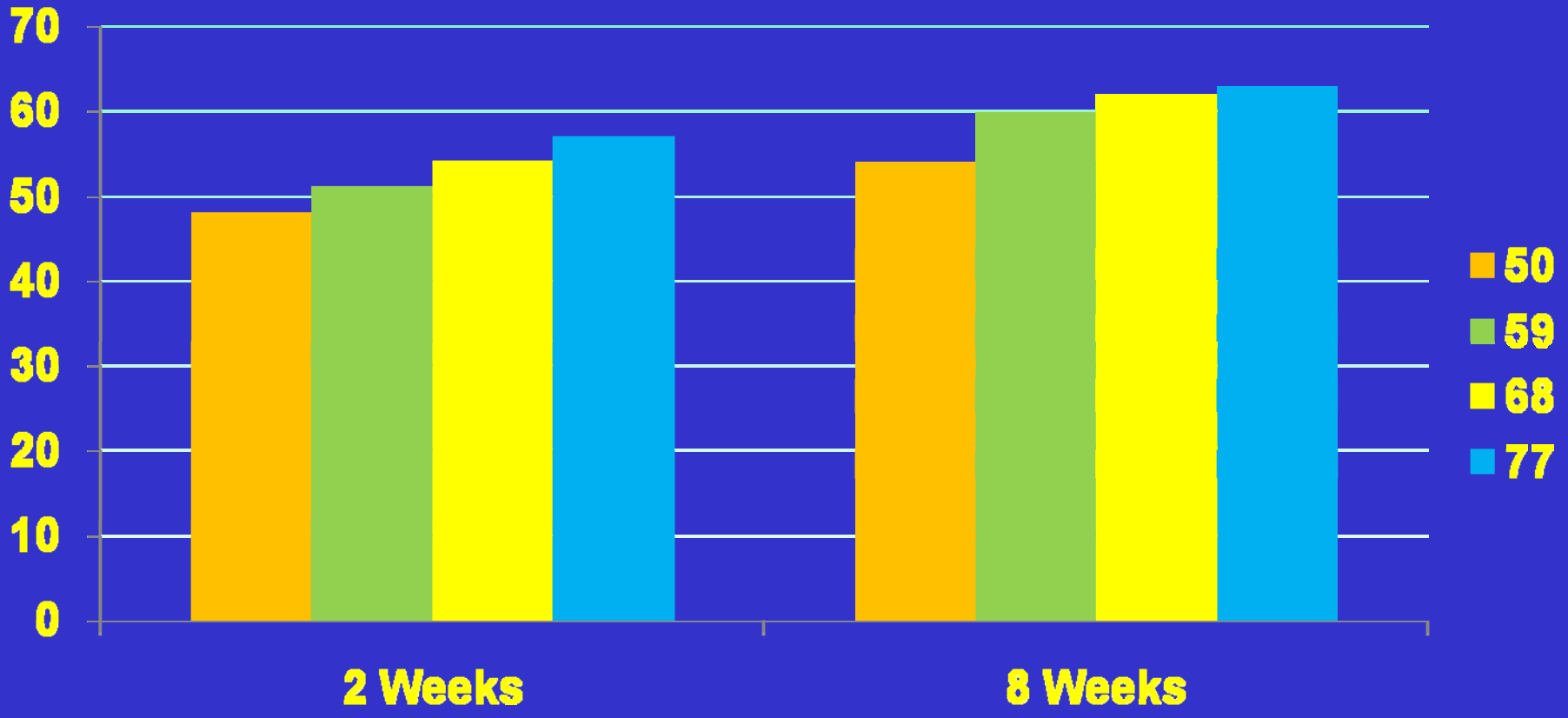
Percent of Initial

Product	Temperature °F	1 Week	4 Weeks	8 Weeks
Pelleted Poultry Manure	59	4	16	21
	77	10	23	36
Fish Powder	59	51	55	61
	77	48	60	64
Feather Meal	59	42	56	59
	77	50	64	63
Blood Meal	59	41	60	64
	77	51	67	70

Hartz & Johnstone 2006

Percent of Nitrogen Mineralized

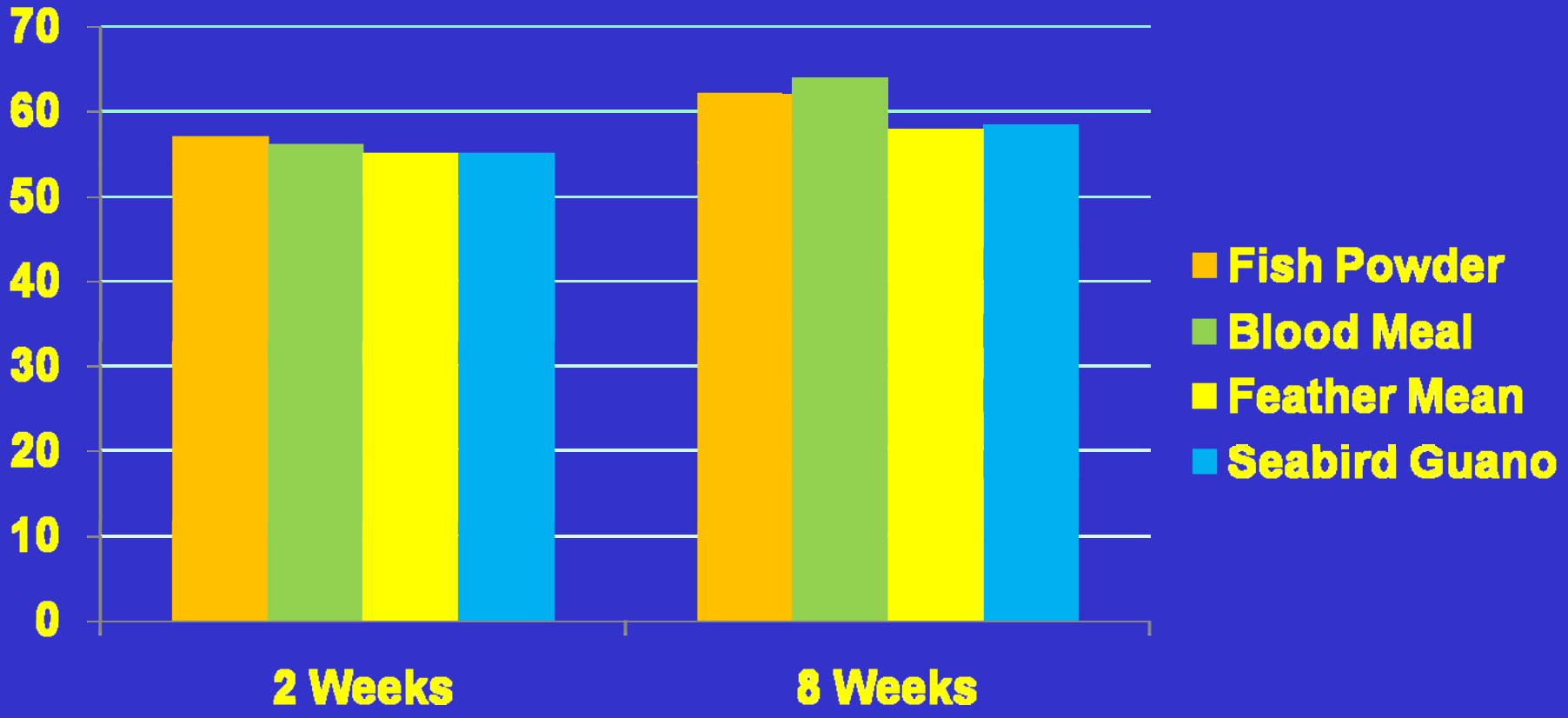
Across Fertilizers



Hartz & Johnstone 2006

Percent of Nitrogen Mineralized

Across Temperatures

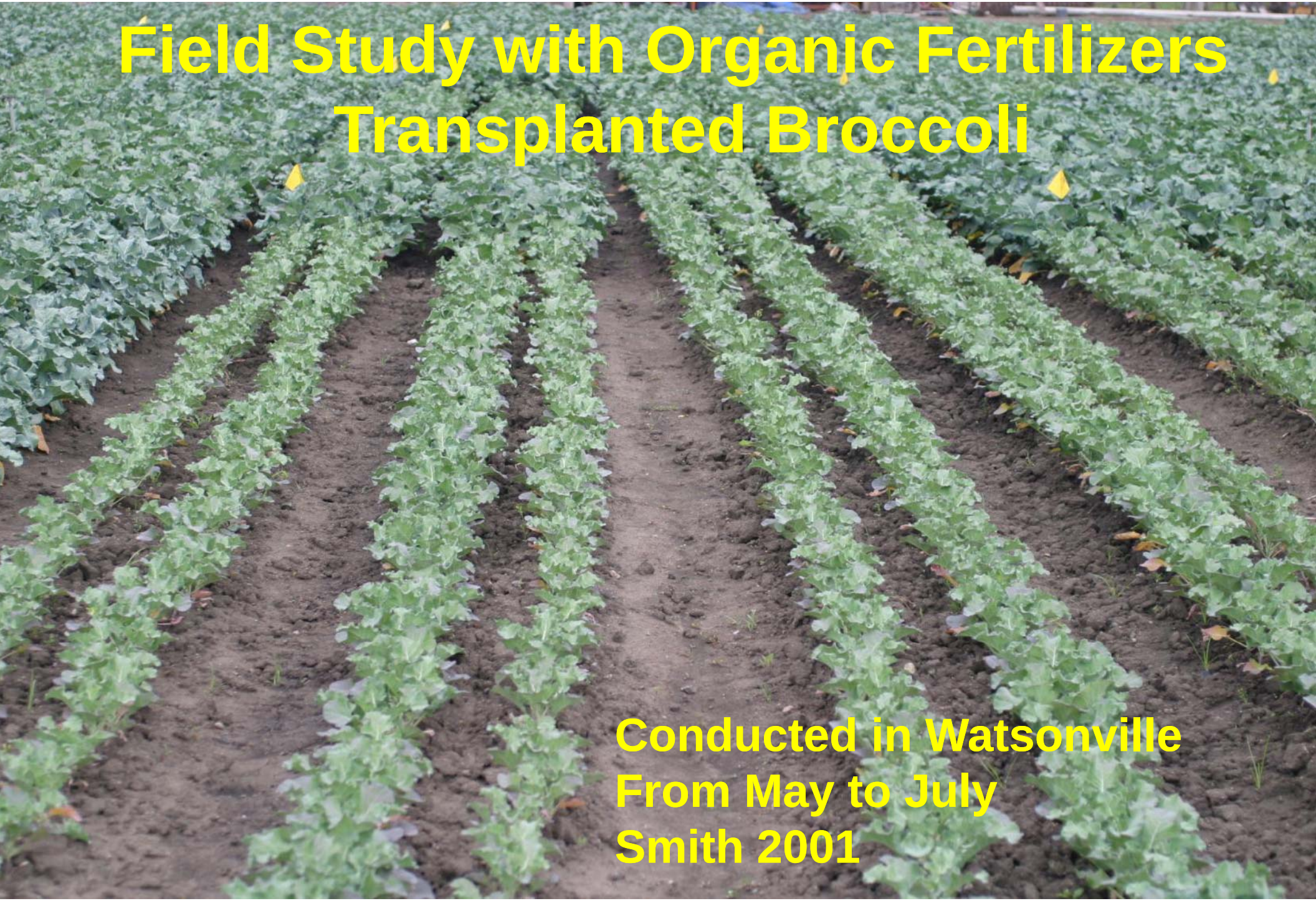


Hartz & Johnstone 2006

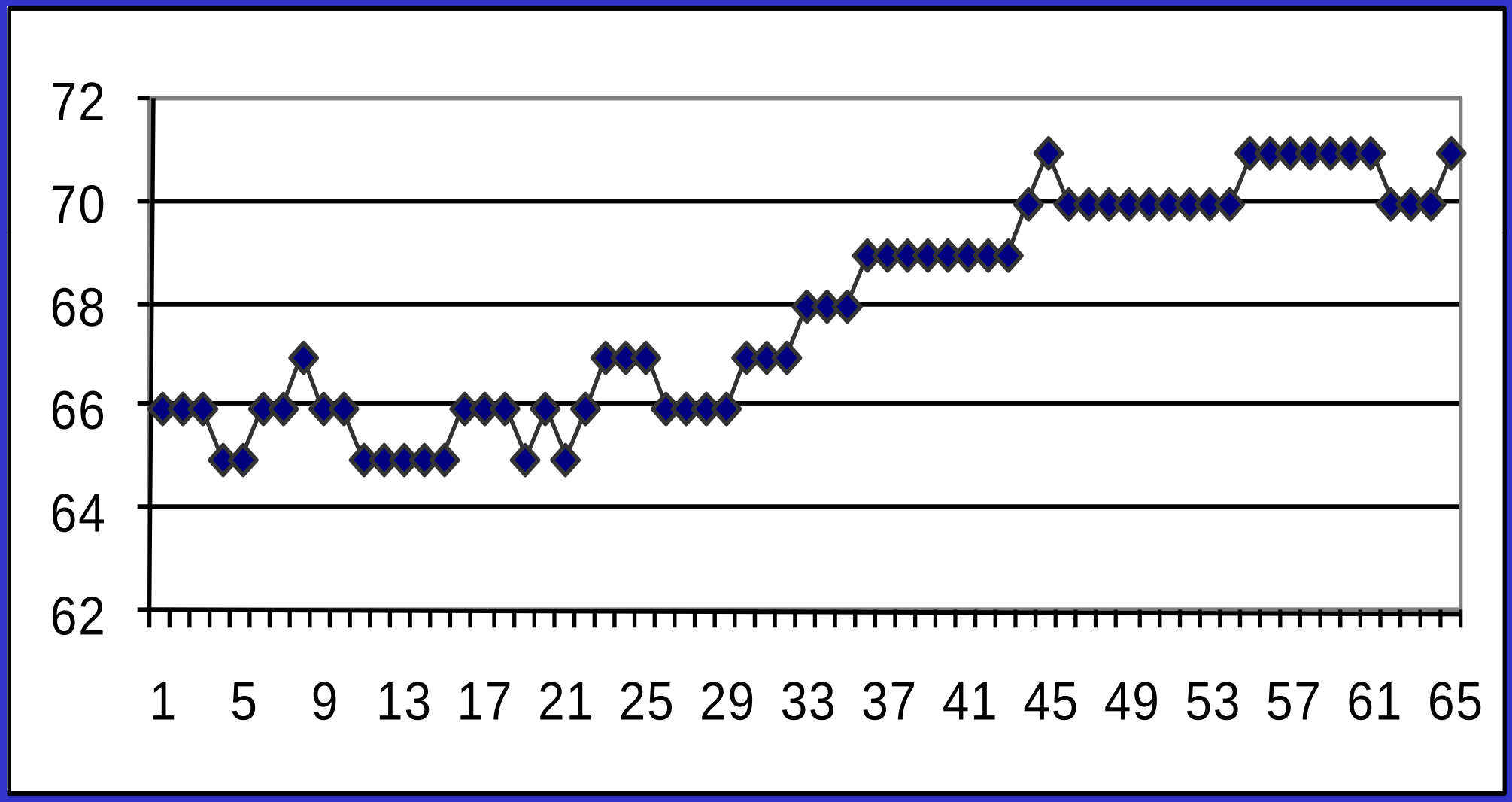
Incubation Studies of Dry Organic Fertilizers

- There was relatively rapid mineralization in the first two weeks
- This was due to enzymatic hydrolysis of urea and simple proteins (labile forms of N)

- **Even at low temperatures the labile forms of N were made available and exhausted in two weeks**
- **There was a slow rate of mineralization after two weeks that was similar to decomposition rates of soil organic matter (complex organic N forms)**


Field Study with Organic Fertilizers
Transplanted Broccoli
Conducted in Watsonville
From May to July
Smith 2001

Soil Temperatures



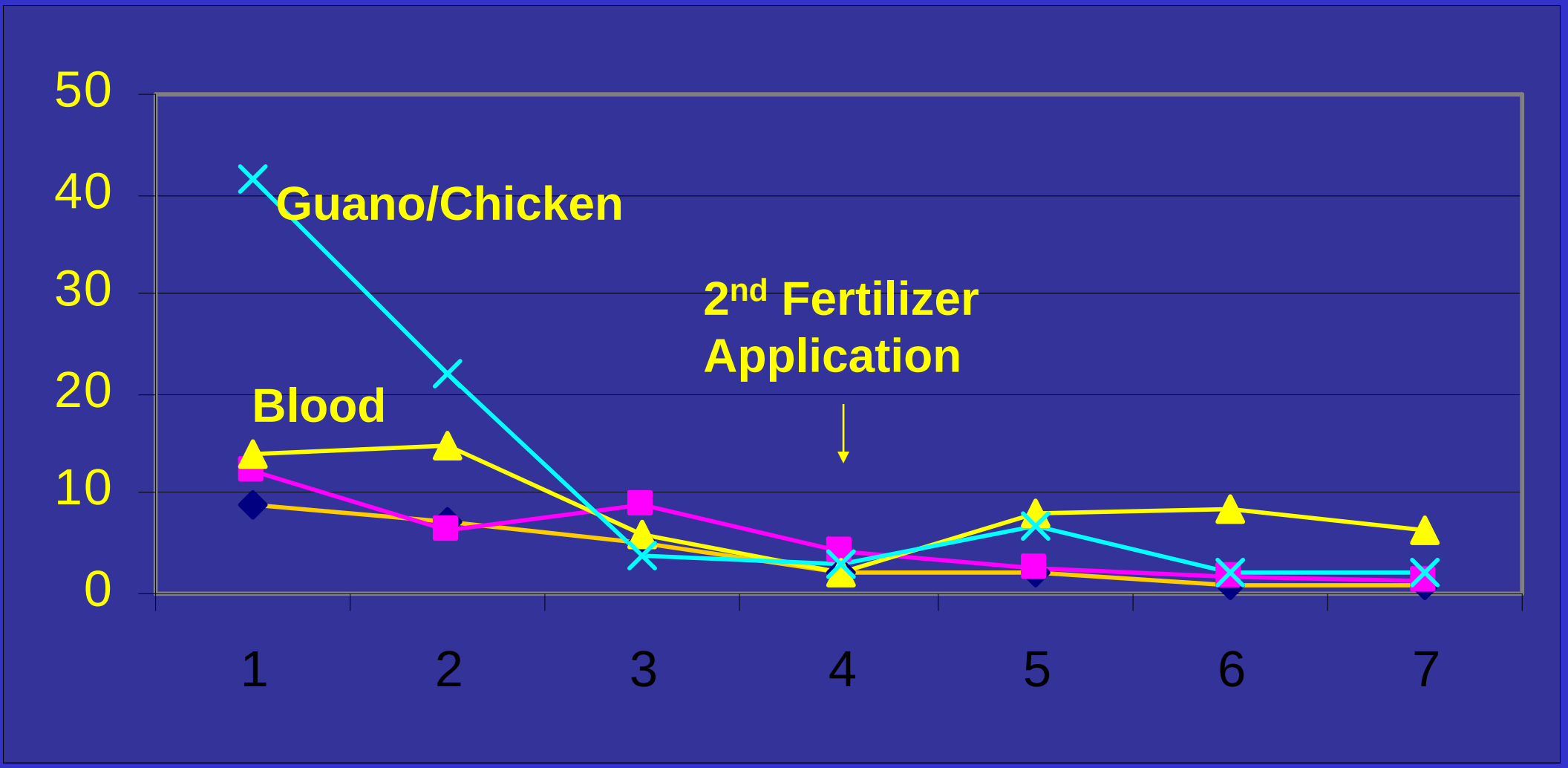
Organic Fertilizer Treatment Application Timing

Treatment	Preplant May 8	Top dress May 31	Top dress June 7	Top dress June 14	Total
Untreated	0	0	0	0	0
Fert Treat No. 1	45	45	45	45	180
Fert Treat No. 2	90	0	45	45	180
Fert Treat No. 3	135	0	0	45	180

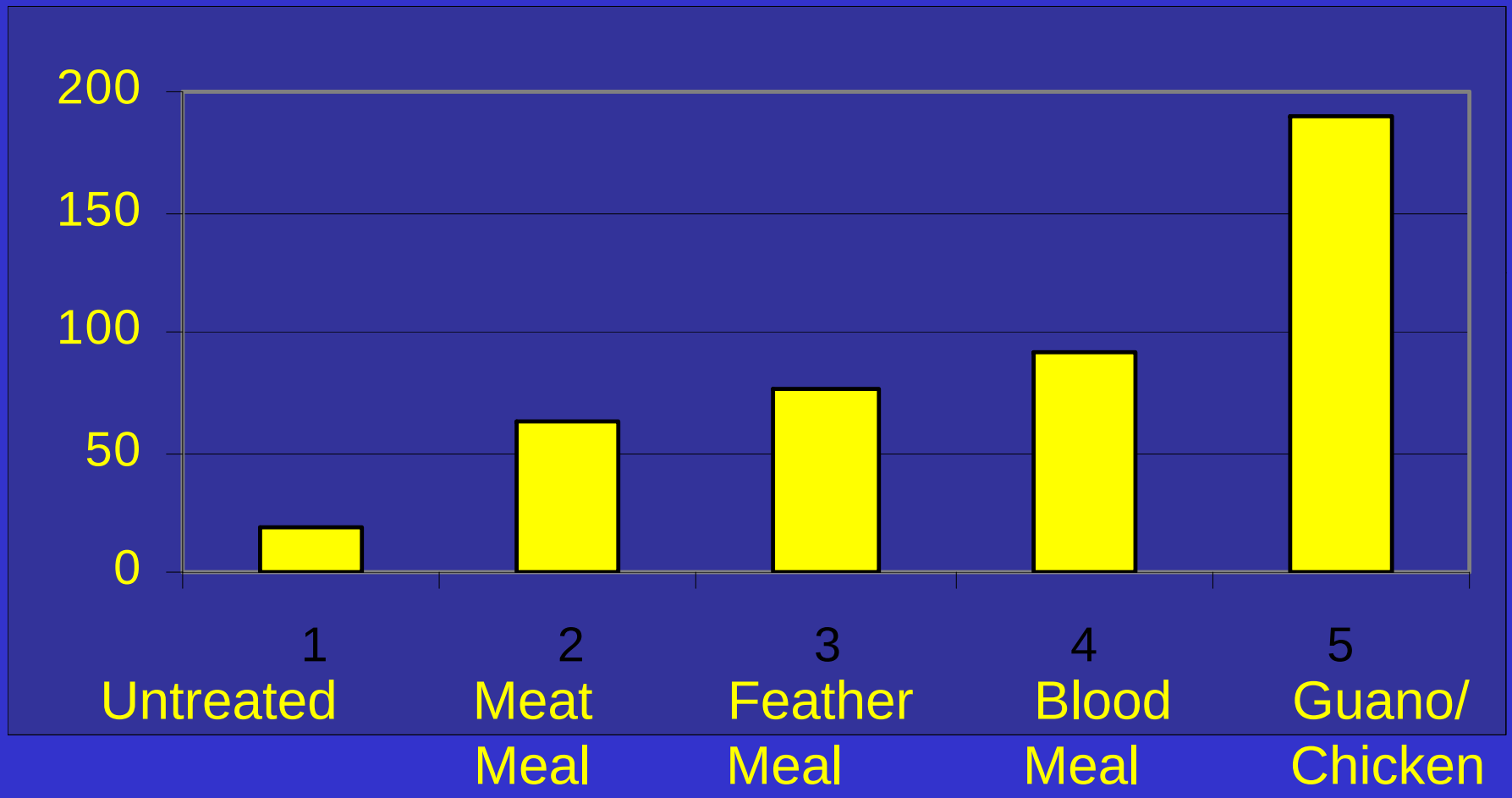
----------Fertilizers----------

1) Meat Meal 8-5-1
2) Feather Meal 12-0-0
3) Blood Meal 13-0-0
4) Guano/Chicken 7-0-0

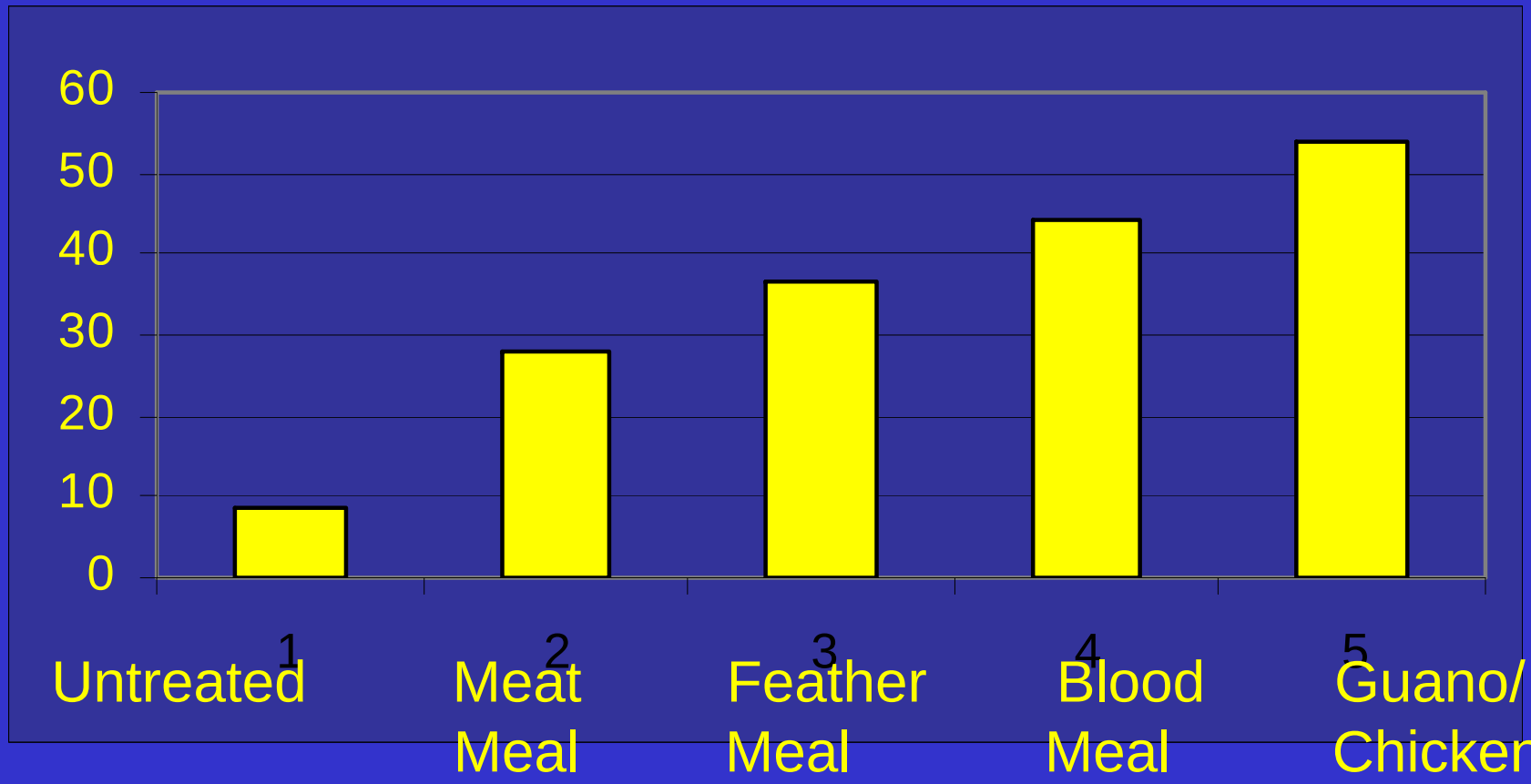
Nitrate-Nitrogen in the Soil of 135-45 Fertilizer Treatments



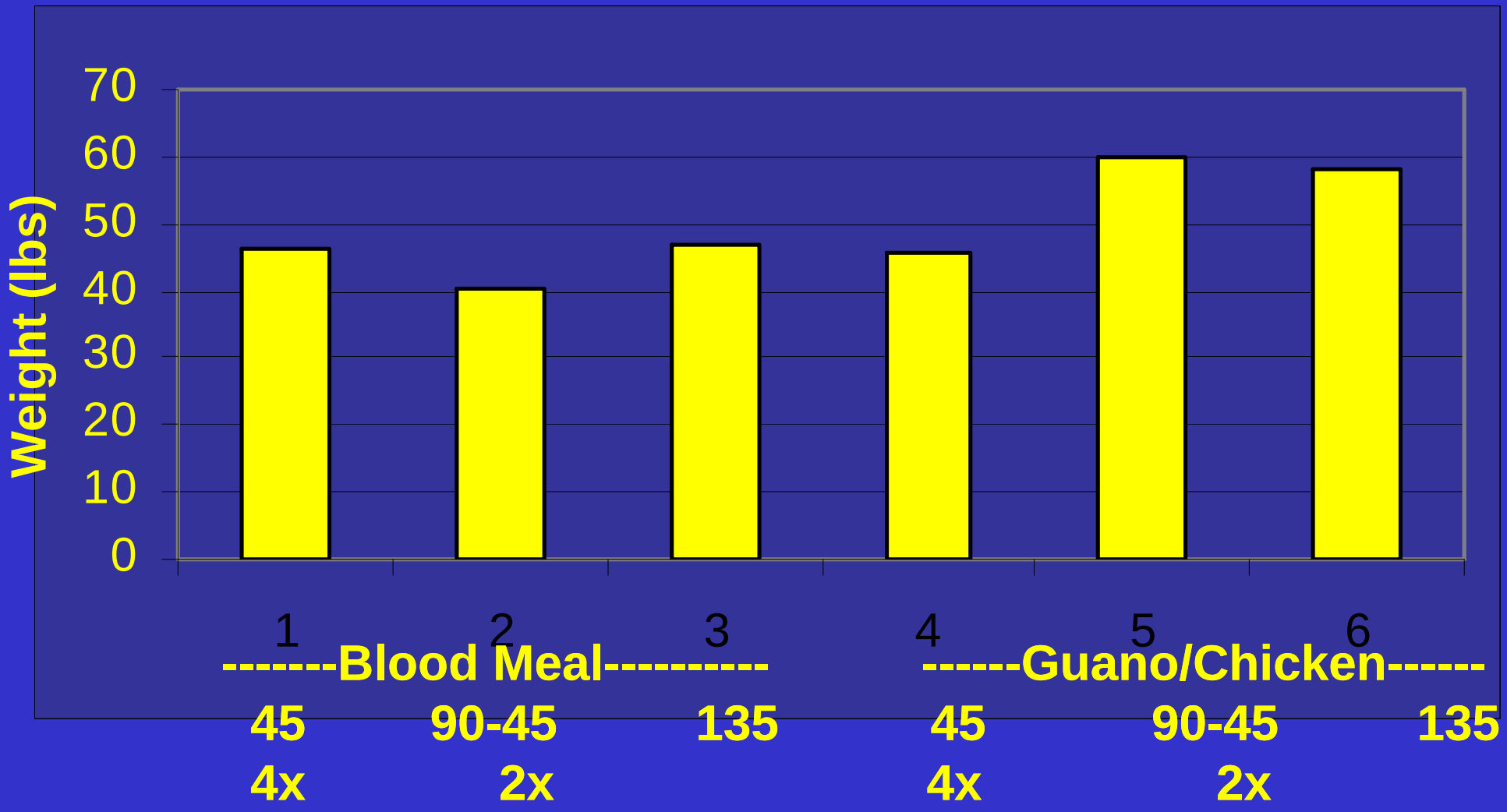
Yield Evaluation: Total Number of Heads



Yield Evaluation: Total Weight of Heads



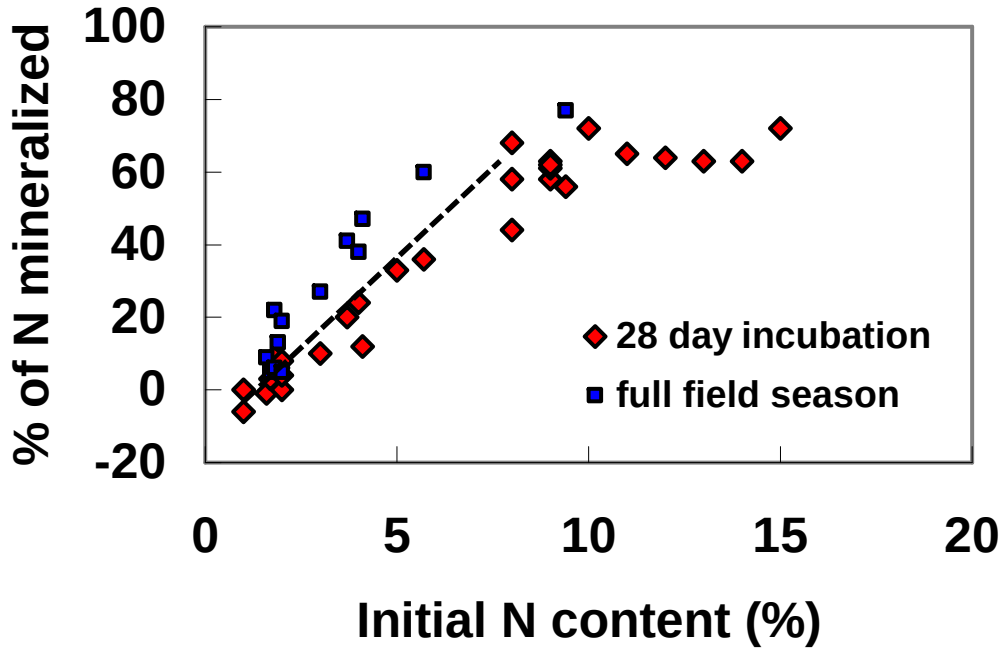
Comparison of Materials and Timing
Total Weight of Heads

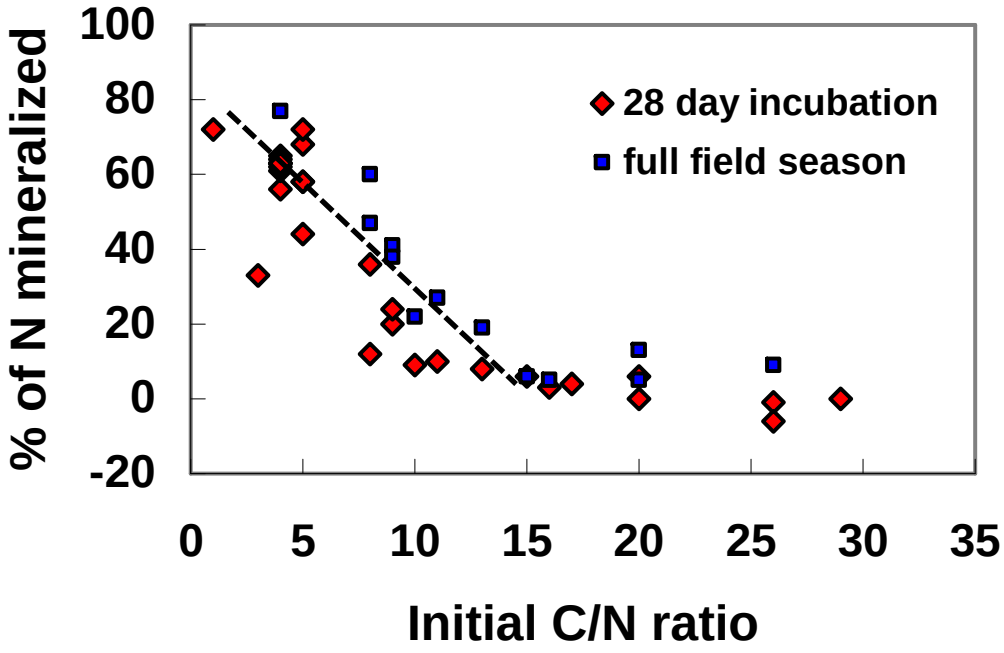


Summary of Field Study with Organic Fertilizers Transplanted Broccoli

- Guano Chicken gave the most rapid release of nitrogen
- Other forms of nitrogen apparently released nitrogen too slow to meet N demand by broccoli
- Applying nitrogen early in the growth cycle gave the highest yield
- This was due to providing sufficient time for the nitrogen to mineralize and meet the demand for N by the broccoli crop

- **The initial nitrogen content greatly affects the speed of mineralization of nitrogen from organic fertilizers**





Mineralization Characteristics of Liquid Organic Fertilizers

Liquid Organic Fertilizers

- Liquid organic fertilizers are convenient to use and can be injected through drip systems
- They have challenges in applying through drip systems (plugging and losses)
- They are expensive per unit of nitrogen ($4-70/lb of N)

Net N Mineralization Liquid Fertilizers

Percent of Initial @ 59 °F

Product	Material	% mineral N @ time zero	1 week	2 week	4 week
Agrolizer 5.12 actual N	Fish 6.0 label N	70	69	75	83
Biolyzer 2.59 actual N	Grain Fermentation 2.5 label N	12	34	40	50
Phytamin 434 3.48 actual N	Guano, Fish 4.0 label N	63	74	78	79
Phytamin 421 3.96 actual N	Soy Meal Plant Extracts 4.0 label N	24	62	71	78

Hartz, unpublished

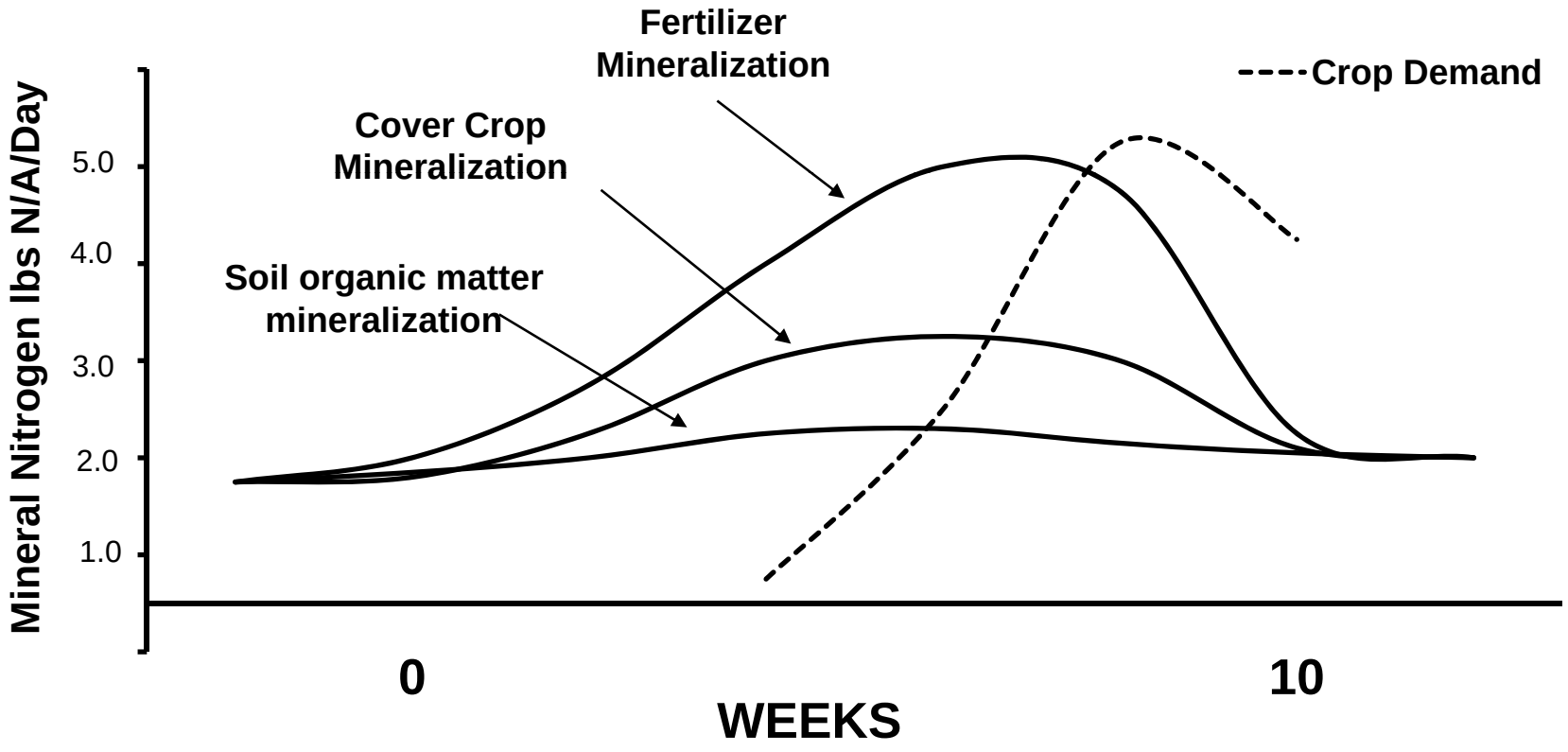
Liquid Organic Fertilizers
Summary

- These materials are unique in the amount of mineral nitrogen immediately available
- They mineralize quickly and can rapidly meet crop nitrogen needs

Effectively Fertilizing with Organic Fertilizers

- Organic soil management is complex
- To do a good job it is important to be aware of the interaction between the mineralization characteristics of soil organic matter, soil amendments, crop residues and fertilizers, as well as crop N demand
- Understanding the impacts of soil temperatures, soil moisture and irrigation practices on the above is critical

Effective Synchrony Between Mineralization from the Various Sources and Crop Demand



Effective Organic N Fertilization Programs

- Soil building practices can provide useful amounts of N
- Supplemental N must be provided in most cases to supply the peak N needs of shallow-rooted, high-N demanding cool season vegetable crops

Effective Organic N Fertilization Programs

- Understanding the release characteristics of N sources is key
- Understanding the influence of temperature and moisture on N mineralization is essential
- These two factors must be considered in conjunction with crop demand

Effective Organic N Fertilization Programs

- At present there is no effective soil N test in organic systems
- Growers have settled on N fertilizer programs by years of trial and error
- The fertilization programs that they have settled on probably have a cushion built in to assure sufficient N for crop growth

Effective Organic N Fertilization Programs

- The costs of organic sources of N are pushing growers to greater efficiency
- Cost per pound of nitrogen in organic fertilizer:
- Dry organic fertilizers – typically >$2.00
- Liquid organic fertilizers – $4-70

For Further Information

- **Organic Soil Fertility Management Symposium January 15, 2009, UC Davis**
  - **vric@ucdavis.edu**

Publications

- **Nitrogen sources for organic vegetable crops**
  - Mark Gaskell and Richard Smith, 2007
  - http://vric.ucdavis.edu/slectnewtopic.organic.htm

- **Soil fertility management for organic crops**
  - Mark Gaskell, Richard Smith and others, 2006
  - http://anrcatalog.ucdavis.edu/OrganicVegetableProductioninCalifornia/7249.aspx

- http://cemonterey.ucdavis.edu/

Thank you for your attention