



**Cover crops as a
Soil Management Practice
to Improve Nitrogen Nutrition for
Organic Vegetable Production**

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Recent cost studies documenting fertilizer costs in organically produced broccoli and leaf lettuce

- Sample costs to produce organic broccoli
- Sample costs to produce organic leaf lettuce

<http://www.agecon.ucdavis.edu/outreach/crops/cost.htm>

- go to CEMonterey and go to the publication link

Comparison of Fertilizer Costs of Organic vs Conventional Leaf Lettuce

System	Costs \$/A	Percent of growing cost
Organic¹	478	16
Conv.²	249	9

1 – Tourte and Smith, 2004; 2 – Tourte and Smith, 2001

Comparison of Fertilizer Costs of Organic vs Conventional Broccoli

System	Costs \$/A	Percent of growing cost
Organic¹	612	19
Conv.²	260	12

1 – Tourte and Smith, 2004; 2 – Smith et al. 2004

Background on Nitrogen Nutrition

- **Prior to the development of the Haber-Bosch process in 1913, growers relied on a combination of nitrogen fixation from legumes, crop residues and scavenging of animal wastes to provide the nitrogen needs of their crops.**
- **Cover crops were a key source of nitrogen fertility**

Background on Nitrogen Nutrition

- It is estimated that intensive farming operations were able to supply about 200 lbs/A of nitrogen from these sources .
- The only net input of nitrogen into the traditional farming system came from fixation of nitrogen from the air (N_2) by legumes was converted to reactive, plant-available forms of nitrogen: ammonium (NH_4) and nitrate (NO_3).

Background on Nitrogen Nutrition

- **The sources of nitrogen for organic vegetable production has changed little from the pre Haber-Bosch era**
- **However, we have improved our ability to process and transport nitrogen rich materials that are acceptable as organic fertilizers, such as meat, blood, fish and seed meals; guano from Peru; as well as manure and compostable materials**

Legumes

- Bell beans, vetches and peas
- They provide a net input of nitrogen into the crop production system by fixing atmospheric nitrogen (N_2) into a form useable by crops
- Maximize N production by flowering
- Not as good as scavenging as cereals and mustards



Cereals

- Include rye, barley, oats, triticale, etc
- Good at scavenging and cycling nitrogen
- Absorb N up to the boot stage
- Typically lower N content and release N N slower than legumes and mustards

Mustards

- White, Indian, Canola, and radishes
- Good at scavenging N and cycling it to subsequent crops
- May have biofumigation effects to reduce weeds and diseases



Cereal/legume Mix



- Provide the benefits of diverse species included [i.e. nutrient scavenging, net input of N (legume), weed control, etc.]

Nutrient Input and Cycling of Cover Crops

- **Cereals and mustards are good at scavenging N from the soil. In the Salinas Valley, there is often high amounts of residual N in the soil left over from intensive crop production**
- **Legumes have the ability to fix nitrogen. However, in high residual N soils, legume nodulation and N fixation are reduced**

Nitrogen Content of Cover Crops

Six year Average

Cover Crop	6 year mean
Cereals	131.5
Legumes	145.7*
Cereal/Legume Mix	177.1

* How much is net fixation is not known

Scavenging of N - Three Cover Crops

Chualar, 2003

Cover Crops	Biomass T/A	% N in Tops	lbs N/acre in Tops
White Mustard	2.5	3.9	194.8
Indian Mustard	2.2	4.5	199.7
Cereal Rye	3.1	3.3	203.7

Cover Crop Mix Components

Salinas, 2004

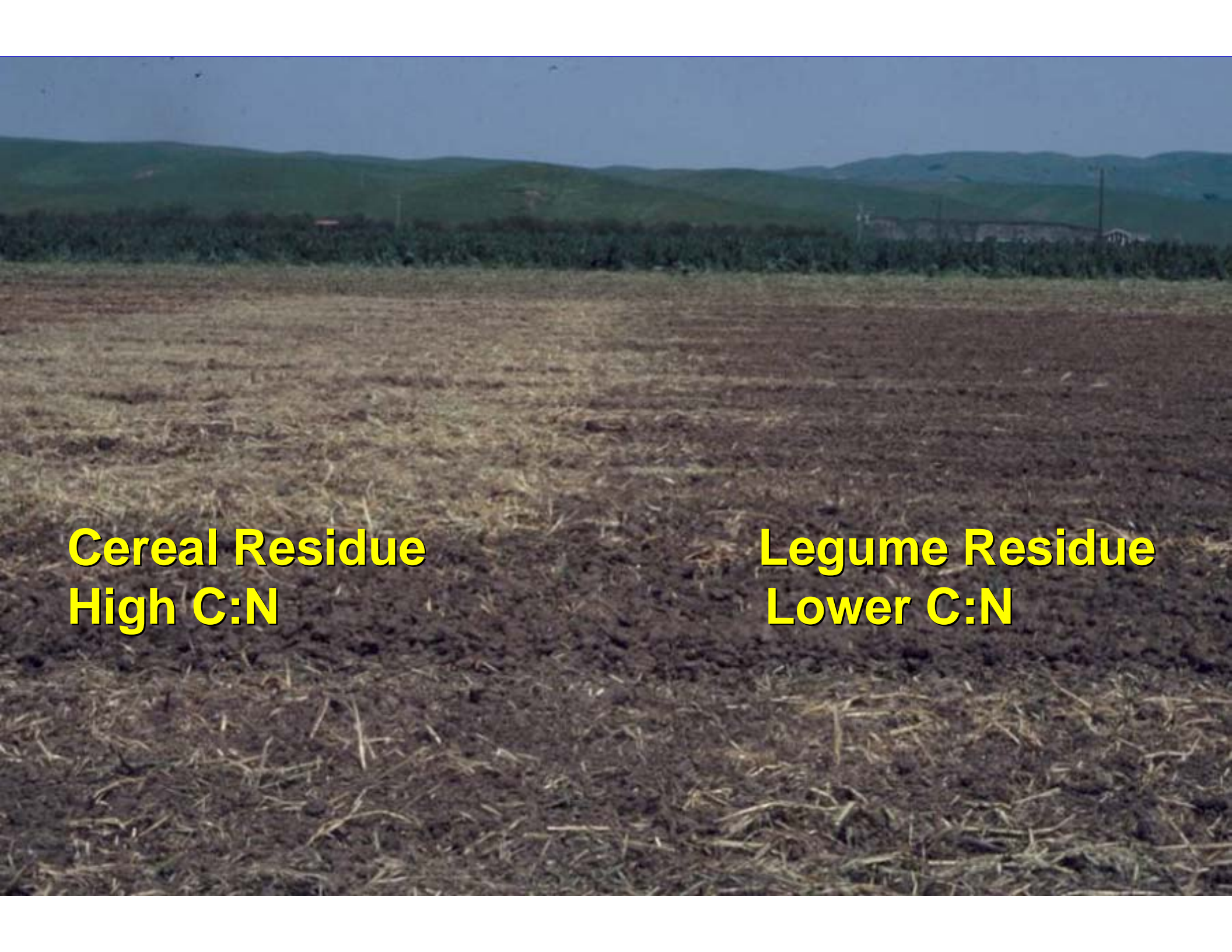
	Biomass Tons/A	Percent N in tops	N in tops Lbs/A
Oat	2.5	2.2	104
Legume	1.5	2.8	86
Total	4.0	---	190

Release of N from Cover Crops

- **When cover crops are incorporated into the soil, microbes begin to decompose the tissue and the complex forms of nitrogen that they contain (i.e. proteins)**
- **Plant available forms of nitrogen (ammonium and nitrate) are released to the soil through this process**

Release of N from Cover Crops

- **The N content of the cover crop at incorporation is an important consideration whether the cover crop will release N or whether it will be tied up in the microbial biomass (immobilized)**
- **In general C:N ratios > 25 immobilize nitrogen (i.e. cereals at heading)**
- **Leaf tissue with higher N content mineralizes quickly, while the stem tissue may take longer to break down**



Cereal Residue
High C:N

Legume Residue
Lower C:N

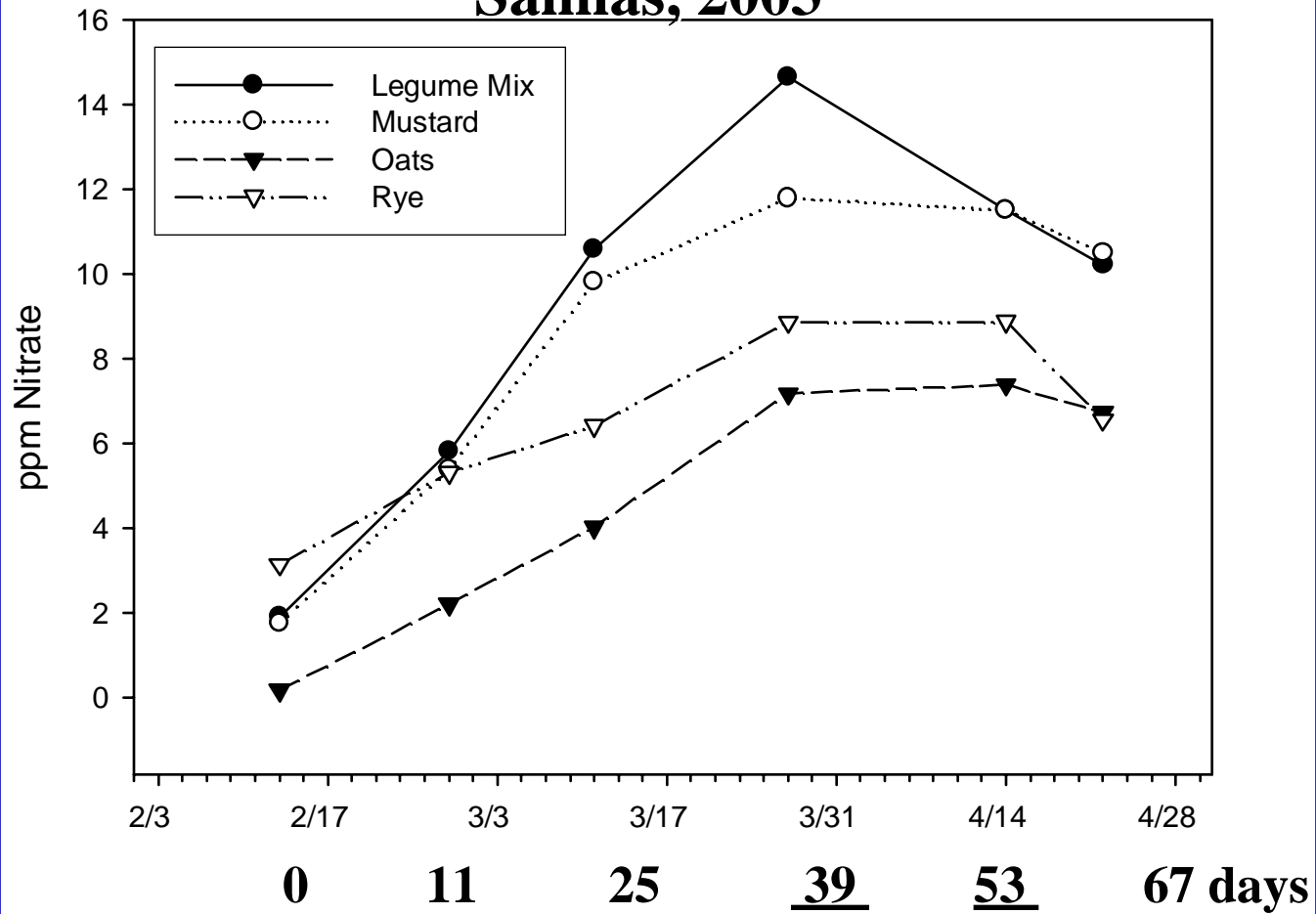
Nitrogen Content of the Cover Crop Tops, C:N Ratio and Potential N Mineralization

	Percent N in CC	C:N Ratio
Immobilize Nitrogen	0.5	1:90
	1.0	1:45
	1.5	1:30
May Release N	2.0	1:23
	2.5	1:18
Release N Immediately	3.0	1:15
	3.5	1:13
	4.0	1:11

Release of N from Cover Crops

- **The ideal scenario would be that the release of N from cover crop residue would match the N demand by crops (i.e. fast enough to match crop demand, but not so fast to leach)**

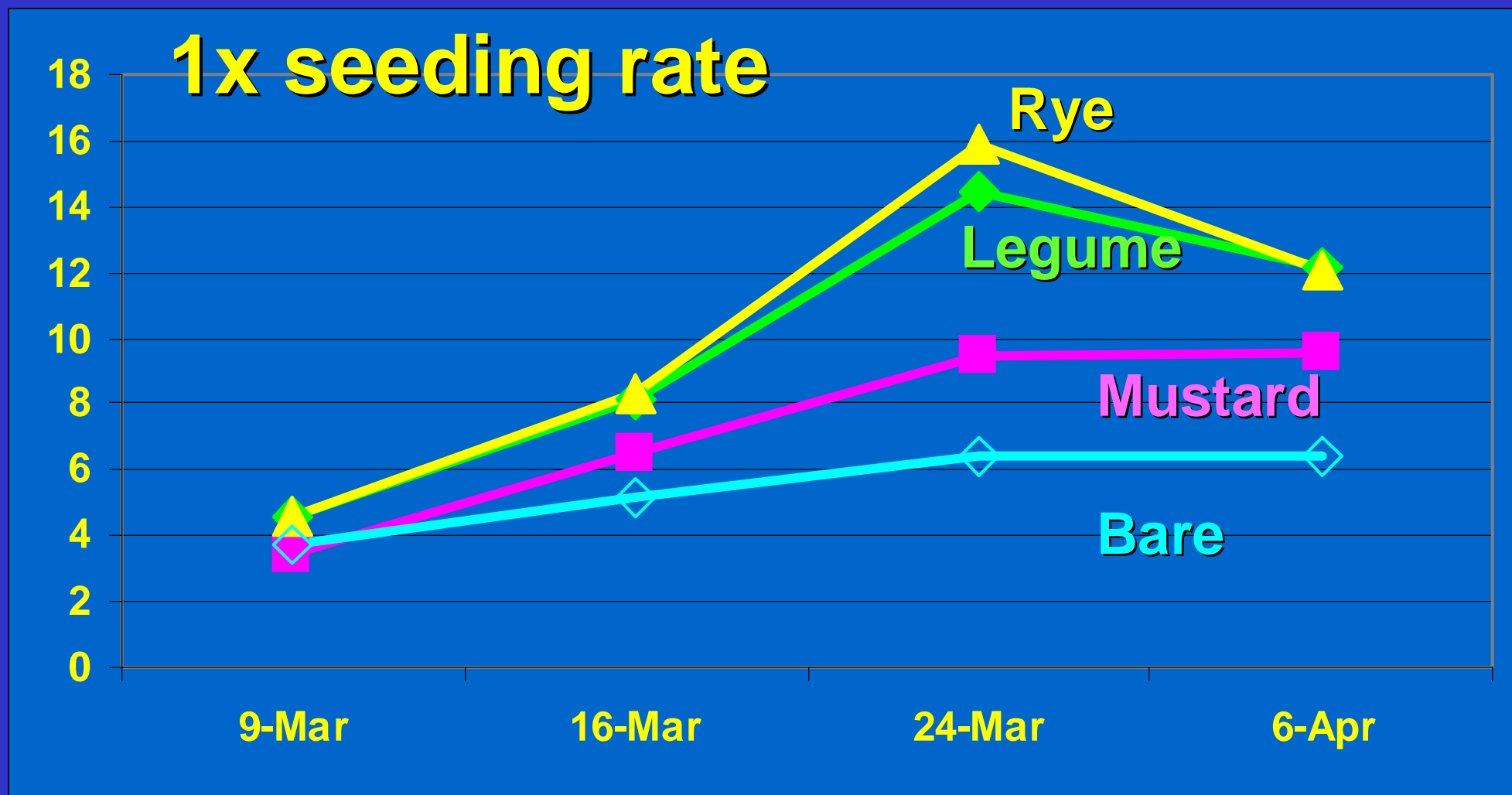
Nitrate Release from Cover Crops Salinas, 2003*



* No crop present

Cover Crop Mineralization Comparison

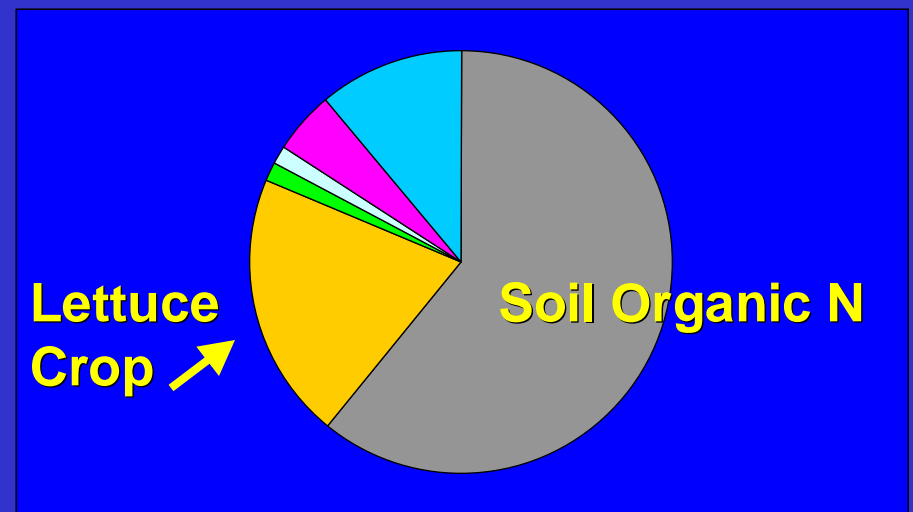
Salinas, 2004



How Much Cover Crop N is Made Available for Crop Growth

- **Cover crops can contain 100 – 200 lbs N but typically less than half of this is made available to the subsequent crop**

**Cover Crop in Lettuce
Four months after incorporation**



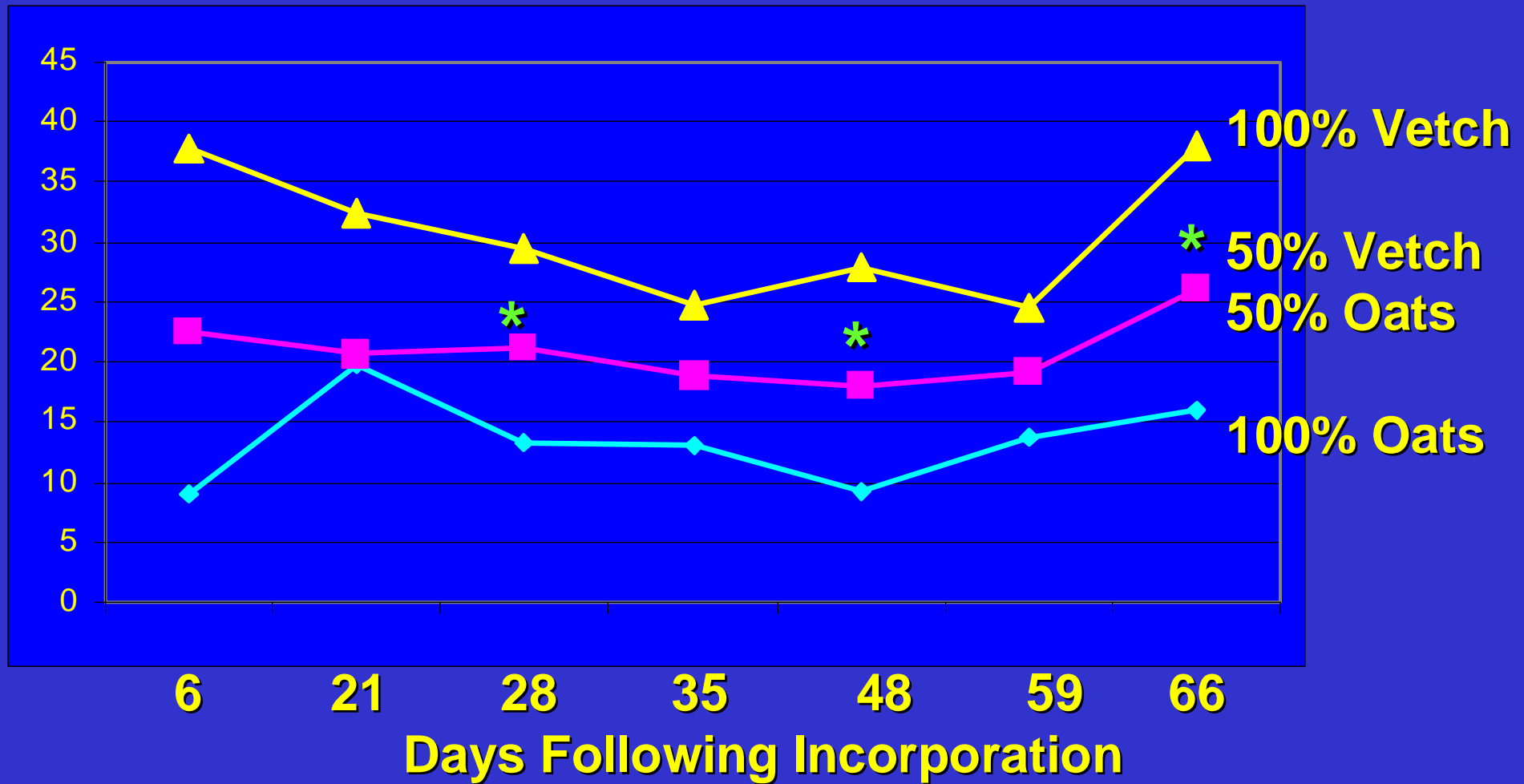
Jackson, 2000

Cover Crops and Nitrogen Nutrition

- **The synchronization of N release from cover crops with the demand by the subsequent cash crop are important for efficient use of cover crop N**
- **Release of N from cover crops depends upon the cover crop species, stage of growth and soil moisture/temperature conditions upon incorporation**

Nitrogen Release from Cover Crop Mix

Salinas, 2004



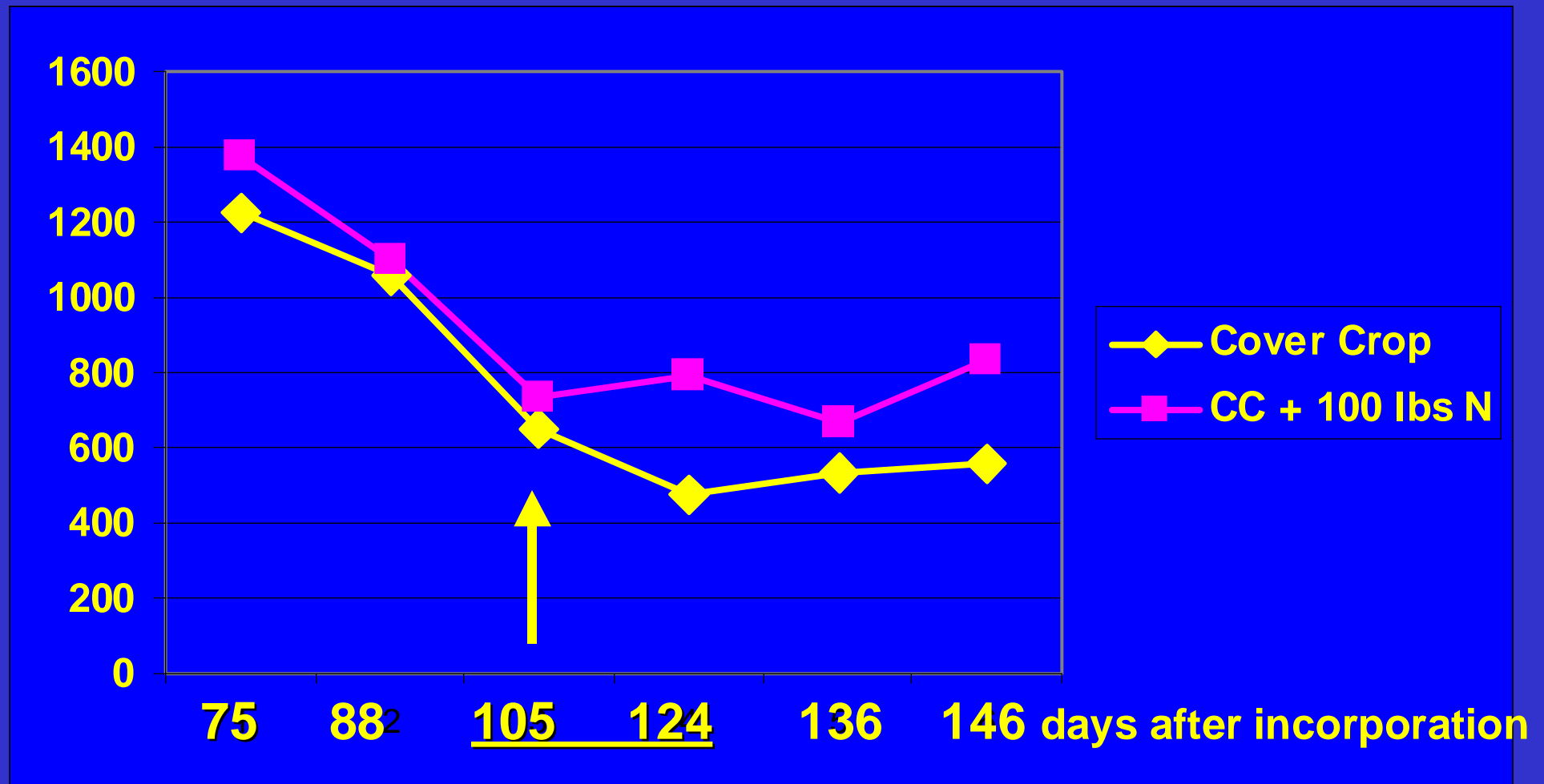
How Long is Cover Crop N Available for Crop Growth

- **Following the initial burst of mineralization soil N levels return to background levels after 6 – 10 weeks**
- **The longevity of the release of N is a concern for crops that have a growth span of >6 weeks or so**
- **Cover crop N may be sufficient for short term crops (i.e. spinach, radishes), but longer season crops will need supplemental N applications**

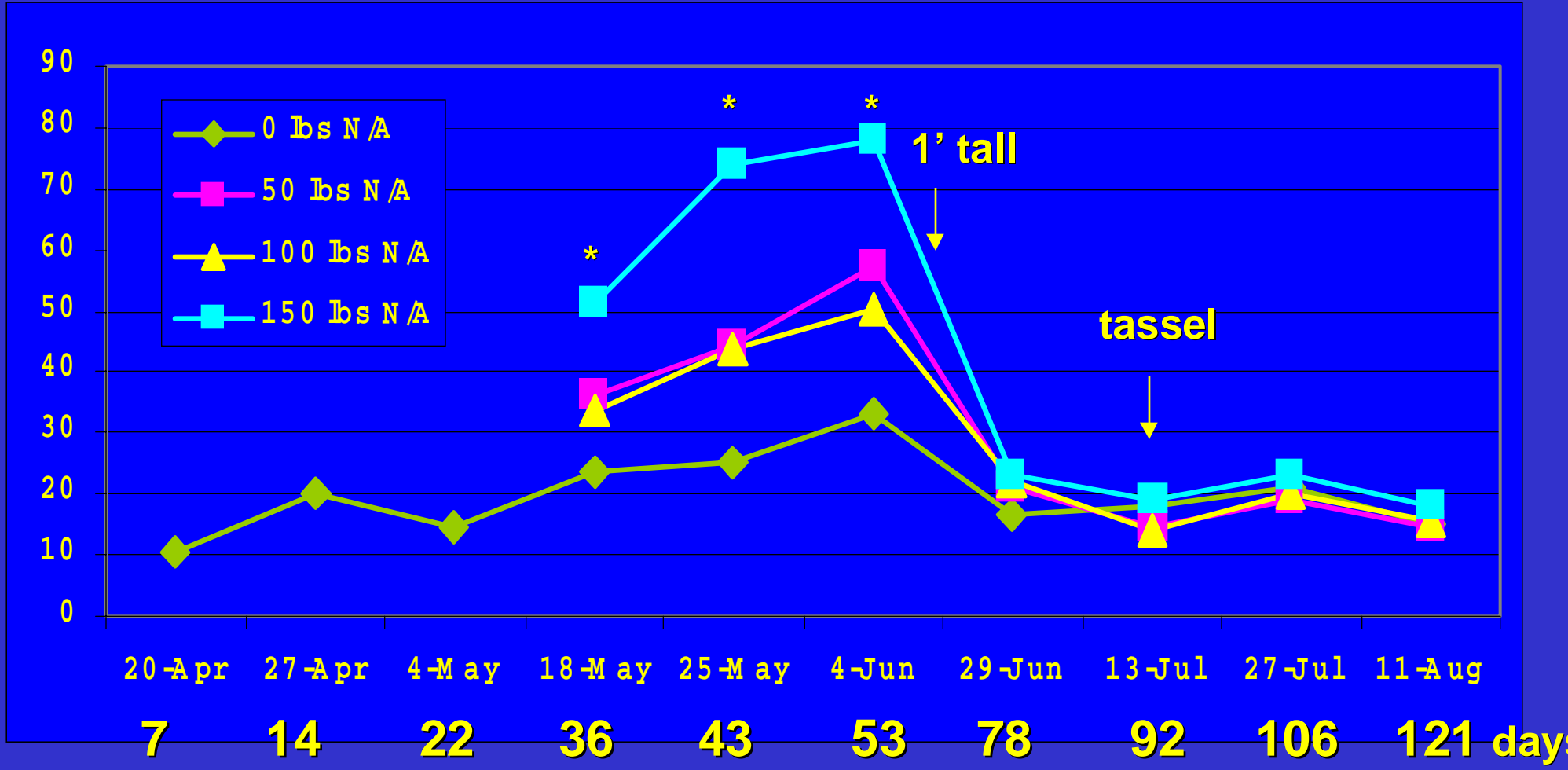
Nitrogen Release from Cover Crops

- **The difficulty in matching the release characteristics of cover crops with the nitrogen demand of horticultural crops necessitates supplemental fertilization for many crops**
- **The other difficulty is the nature of the crops: shallow rooted, high N demand and quality concerns**

Nitrate N in Pepper Petioles Following Cover Crop with and without Supplemental Application of Feather Meal

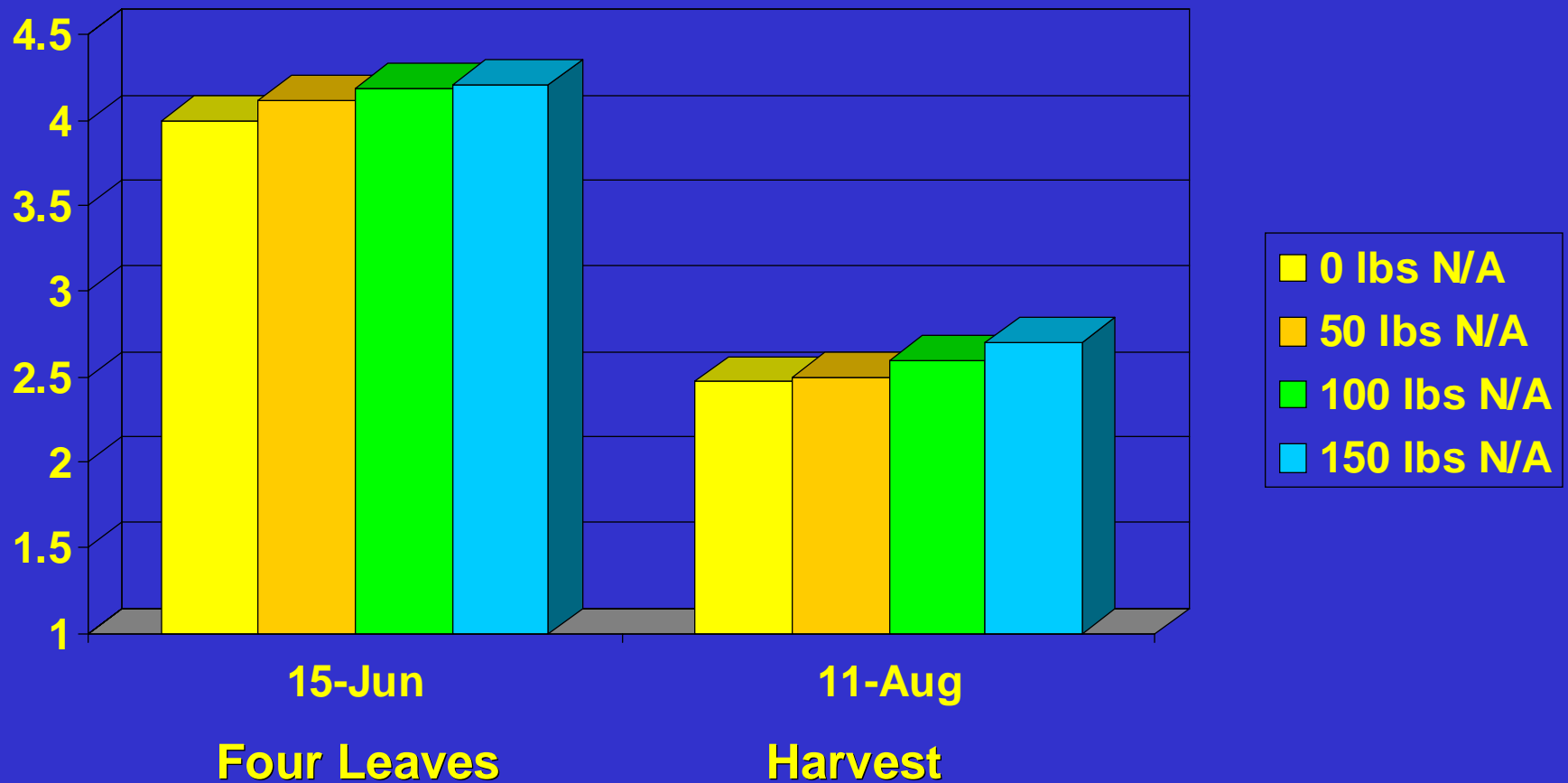


Nitrate Nitrogen in Soil of Sweet Corn Following Cover Crop and Four Fertilizer Rates, Salinas, 2004

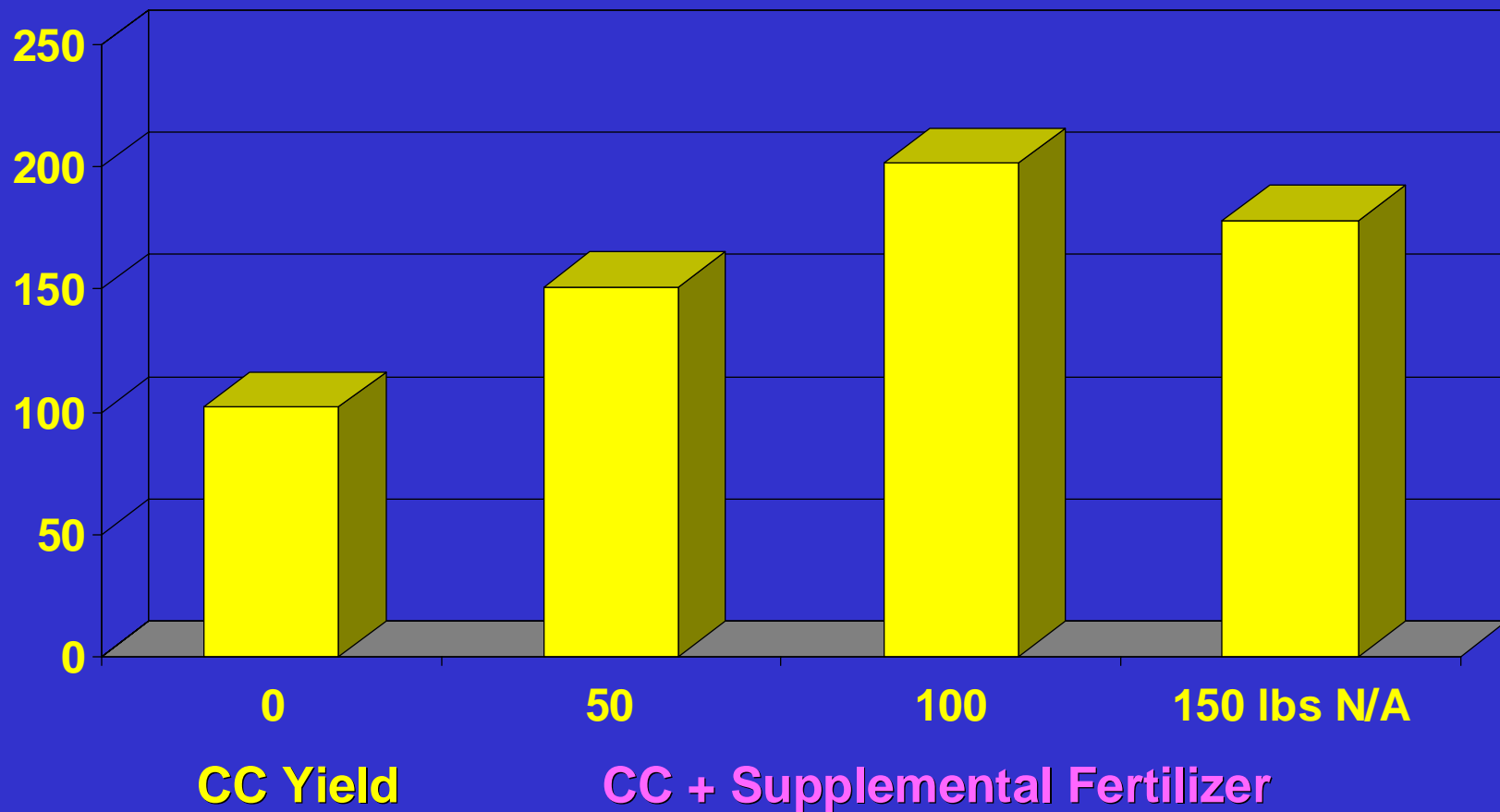


Total Nitrogen in Corn Tissue

Two Growth Stages



Yield of Sweet Corn Fertilizer Rates Following Cover Crop



Cover Crop and Long-term Soil Fertility

- **Cover crops are key for soil building as resistant forms of the plant biomass are converted to organic matter that then serves as a reservoir for slowly available nitrogen for future crops**
- **The nitrogen in organic matter is stored as amino acids and sugars that must be microbially processed to be made into plant available forms of N**

Types of Cover Crops to Build Soil Organic Matter

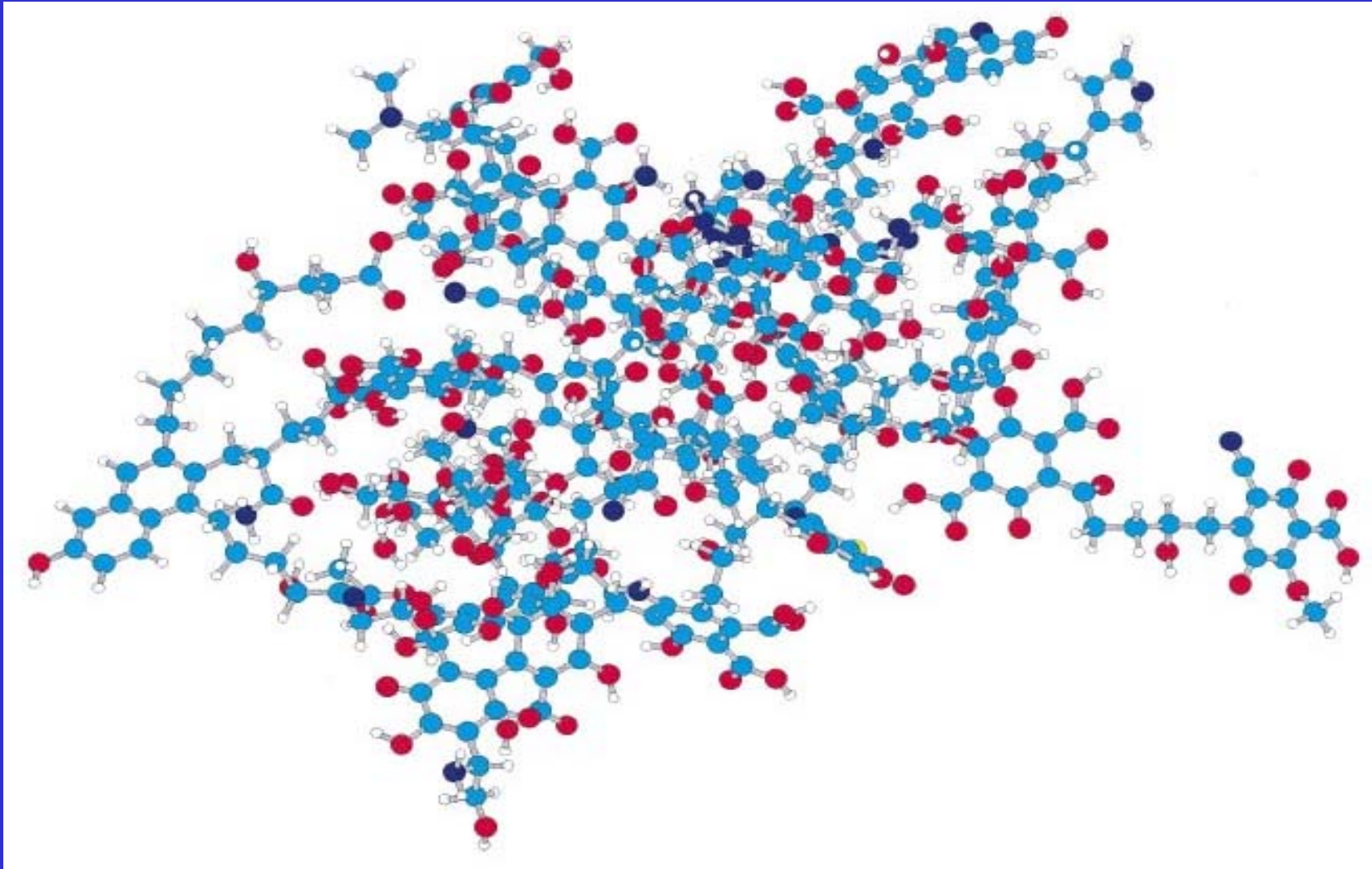
- **Cereals and legumes have different impacts on building soil organic matter**
- **Cereals contain phenolic compounds which are the building blocks of soil organic matter**
- **Legumes are richer in nitrogen, but provide less of the building blocks for building organic matter**

Phenolic Acids (PA) in Soils after Plant Residue Additions

Plant species	Day	Total PA (mg g ⁻¹)
Corn	0	729
	9	433
	29	345
	84	220
Soybean	0	68
	9	30
	29	32
	84	31

(Martens 2002)

Soil Organic Matter



Soil Mineralization

- In general, about 2% of the organic matter will mineralize over 60 days with soil temperatures at 77 F
- Soil containing 1-2% organic matter, approximately 30-60 lb N/acre would be expected to mineralize during a 60 day summer crop (0.5 to 1.0 lbs N/A/day)
- The higher the organic matter content, the more N that will be released

Comparison of Organic vs Conventional Soils

Salinas, 2003

Soil Type	Management	Organic Matter Percent	Total Soil Nitrogen Percent	Stored Nitrogen Lbs/A
Clay Loam	Organic	2.24	0.17	6,800
Clay Loam	Conventional	1.78	0.14	5,600
Loam	Organic	1.74	0.14	5,600
Loam	Conventional	1.37	0.11	4,400
Sandy Loam	Organic	1.31	0.12	4,800
Sandy Loam	Conventional	0.66	0.06	2,400

Ten Year Comparison of Management on Nitrogen in Soils (1989-1998) - UCD

Treatment	Organic Matter	Nitrogen Storage kg N/ha	Nitrogen Loss kg N/ha
Short Rotation Conventional (Low Biomass)	1.10	0	452
Organic (High Biomass)	1.46	901	90

Poudel et al. 2001

Soil Mineralization – Organic Soil Management

- **However, the increased mineralization of N from cover crops and soil mineralization did not lead to comparable yields in the SAFS project at UC, Davis**
- **This was partially attributable to the poor synchronization between the N release and crop demand**
- **Necessitating careful supplemental fertilization**

Case example:

Other organic amendments

Summary of Nitrogen Impacts of Cover Crops on Crop Production

- **Cover crops are a basic component in building up the organic matter levels in soils**
- **On light soils, cereal based cover crops will be an important part of the soil building process**
- **On heavier soils, higher proportions of legumes can be added to the cover crops to achieve the same level of organic matter**

Summary of Nitrogen Impacts of Cover Crops on Crop Production

- **Cover crops mineralize useful amounts of nitrogen that can be an important source for subsequent crops**
- **For high yield and quality, supplemental applications of N are needed for long-season crops**
- **Over a period of years, as the soil organic matter levels build up from the use of cover crops and compost, the amounts of supplemental nitrogen fertilizer needed for high yields may decline**

Thank you for your attention