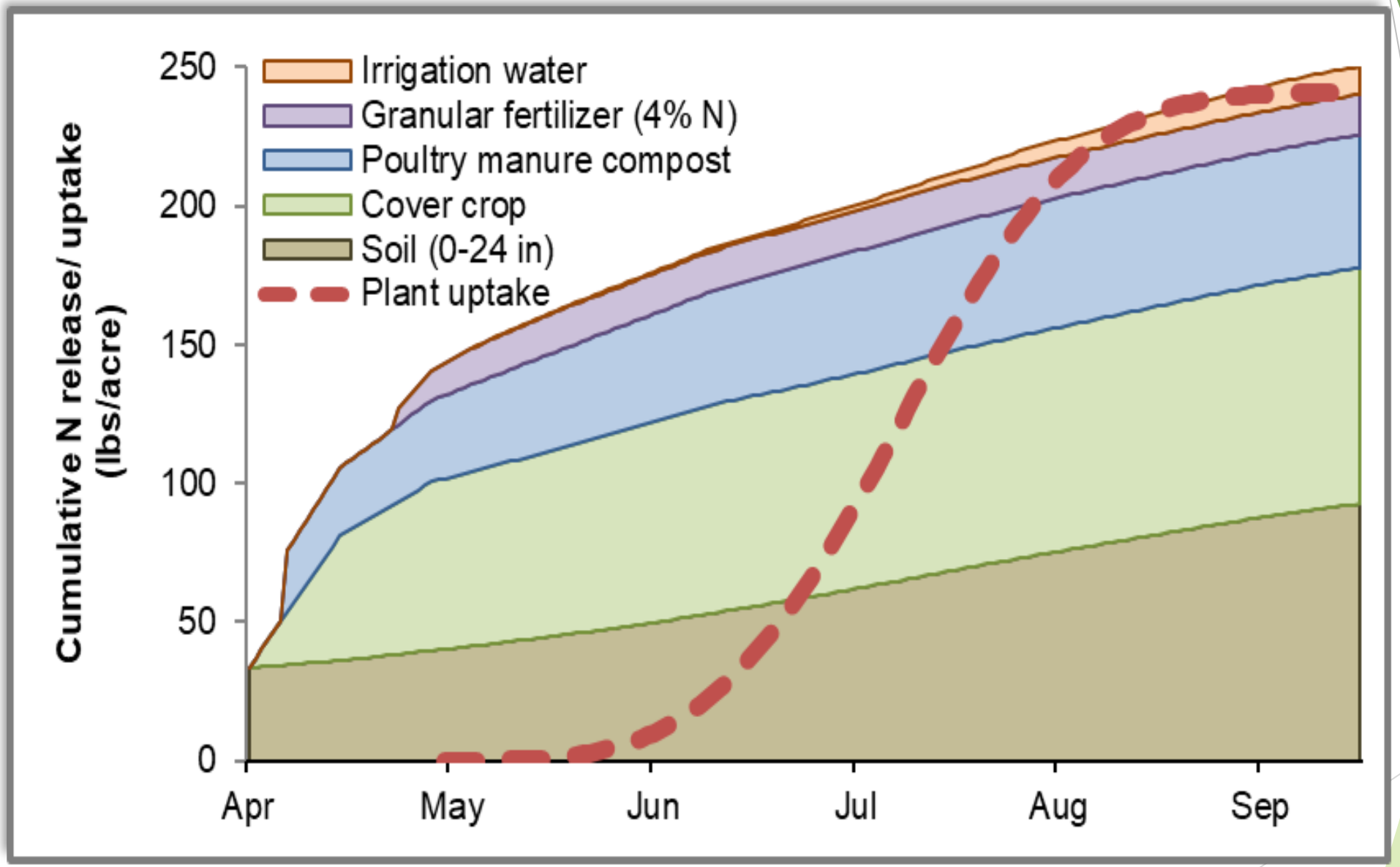
Cover Crops and Crop Residue in the Nitrogen Budget

Tuesday March 2, 2021

Margaret Lloyd

UCCE Small Farms Advisor

Yolo Solano and Sacramento Counties


Cumulative N release/ uptake (lbs/acre)
250
200
150
100
50
0
Irrigation water
Granular fertilizer (4% N)
Poultry manure compost
Cover crop
Soil (0-24 in)
Plant uptake
Apr
May
Jun
Jul
Aug
Sep

The amount of N made available from crop residues depends on:

- Biomass of the residues
- N content of the residues
- C:N ratio, total N content
- Soil moisture
- Surface or incorporated residue

Quantity Quality Availability

Biomass of the residues

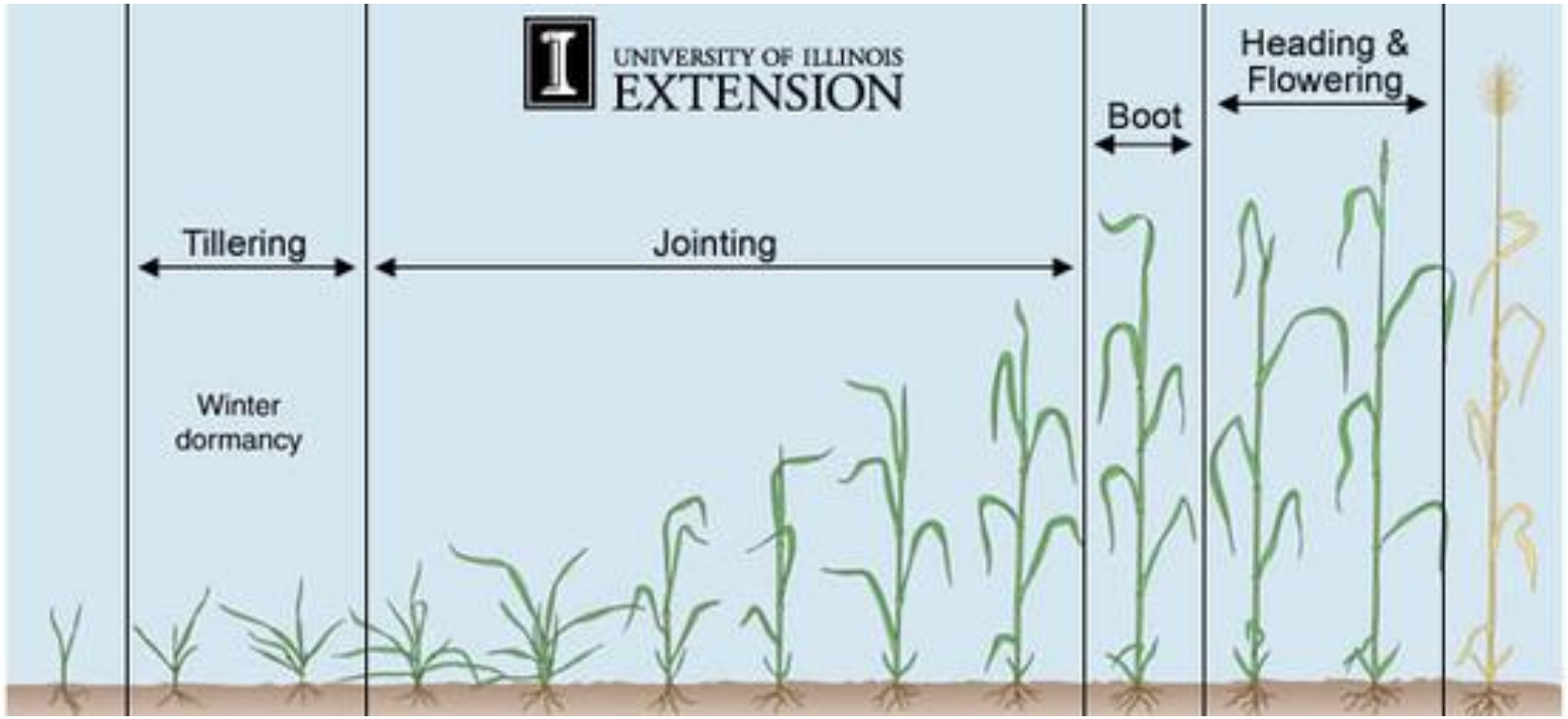
- **The vast majority of N in cover crop biomass is found in the above-ground plant biomass**

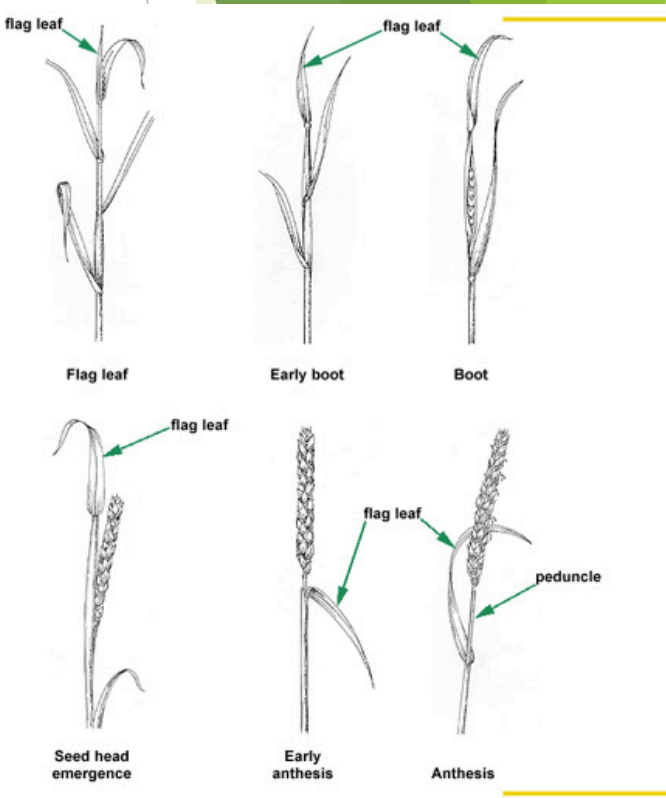

5


5
4
3
2

WHEN DOES BIOMASS ACCUMULATE?

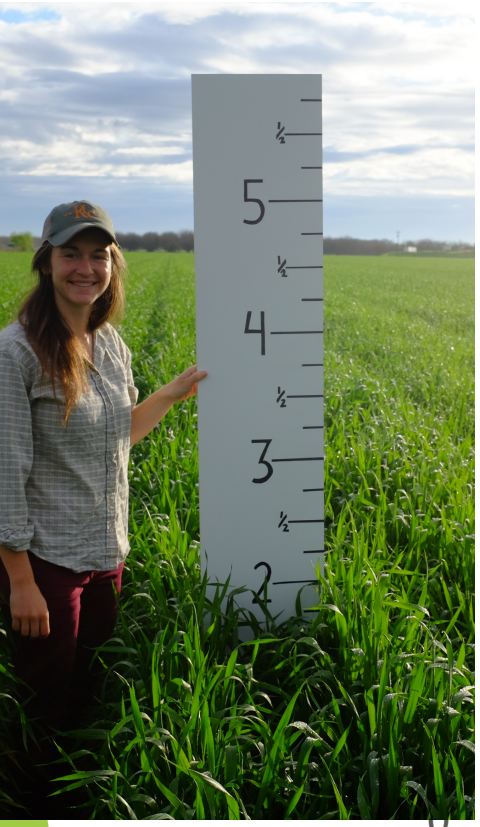
- After the boot growth stage, rye cover crops can double in biomass with little additional N

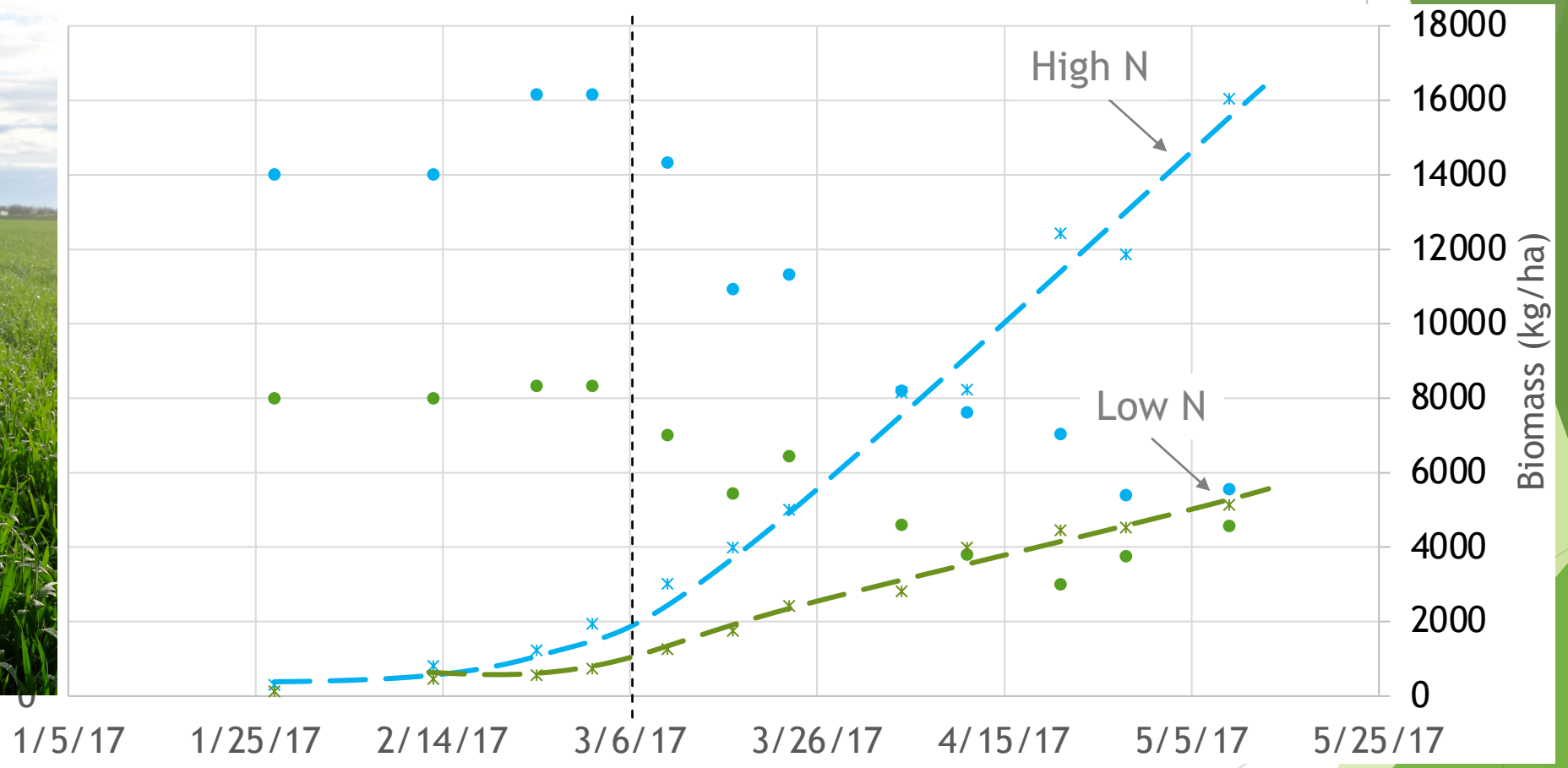




(Dabney et al. 2001, Shipley et al., 1992; Clark et al., 1994; Vaughan and Evanylo, 1998).

Biomass accumulation in wheat (Yolo Co., 2017)





Unpublished data, courtesy of Mark Lundy, UCCE Extension Specialist, Small Grains

Table 4 (p. 17)

Cover Crop	Crop Biomass (dry) (T/A)
'Cayuse' Oats	4
'Merced' Rye	3.6
Mustard[1]	3
Bell Bean	3
Cereal/Legume Mix[2]	3
'Magnus' Pea	2
Purple Vetch	2
'Lana' Woollypod Vetch	2

The vast majority of N in cover crop biomass is found in the above-ground plant biomass

…regardless of whether the N came from residual nitrate in the soil or atmospheric N fixed by bacteria in legume roots.

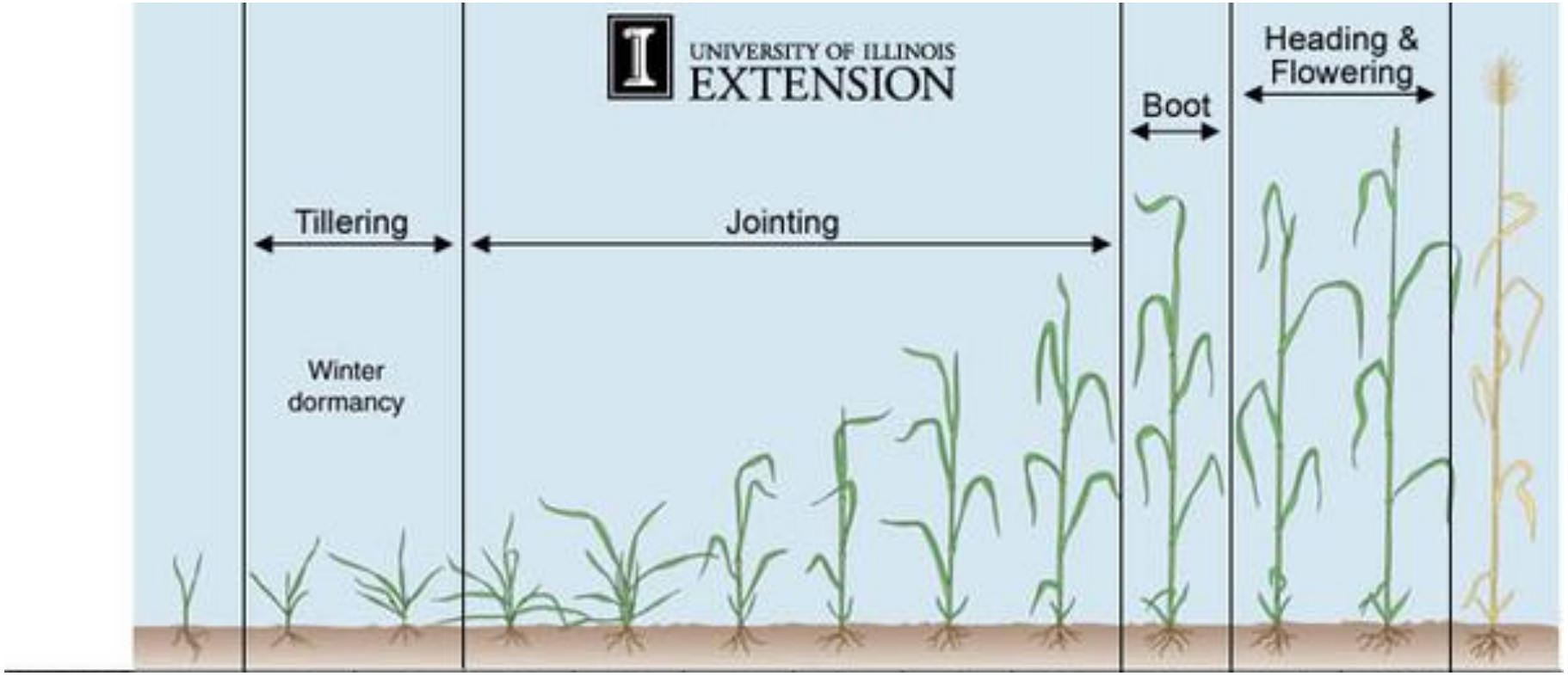
Roots from cover crop of hairy vetch and Austrian pea:
10 lb N/A
<2% N
C:N ratio >20:1
PAN release close to 0

(Kuo et al., 1997)

Legumes

- This ability to extract atmospheric N means they provide a net input of N to the soil when incorporated
- Typically have higher N content in their tissues.
- Usually accumulate N longer in the spring than non-legume cover crop

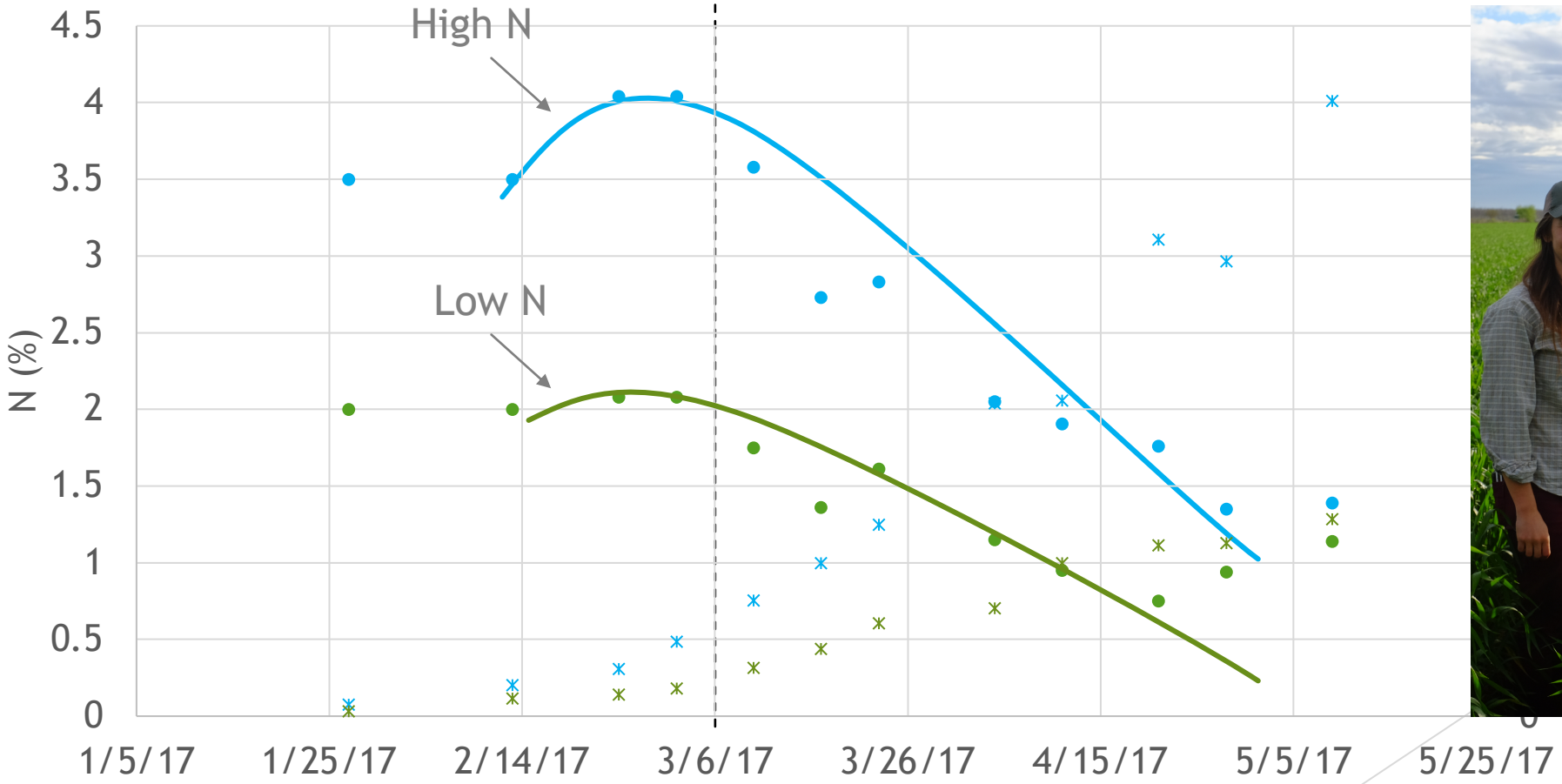
- After the boot growth stage, rye cover crops can double in biomass with little additional N

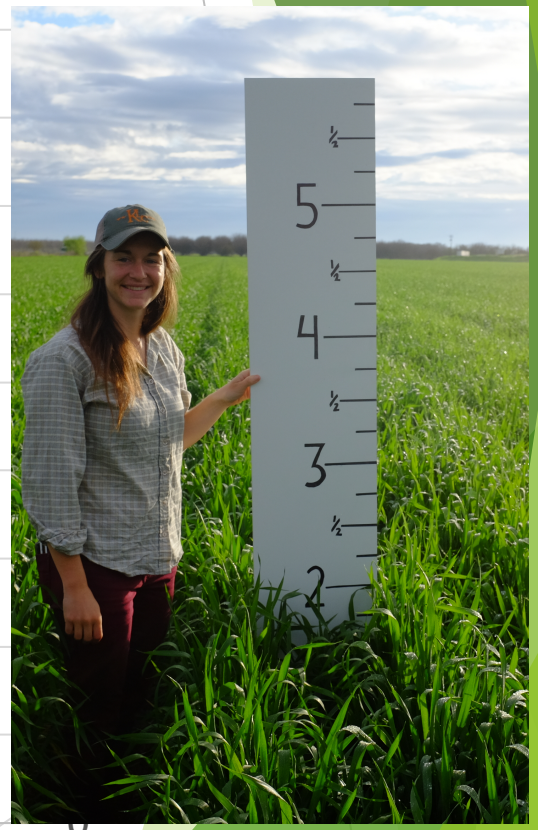


BUT, at boot stage, leaf tissue N is highest

(Dabney et al. 2001, Shipley et al., 1992; Clark et al., 1994; Vaughan and Evanylo, 1998).

- For most crops, peak total N content occurs just before/at flower, when biomass is high and N remains in the tissue prior to use for seed production



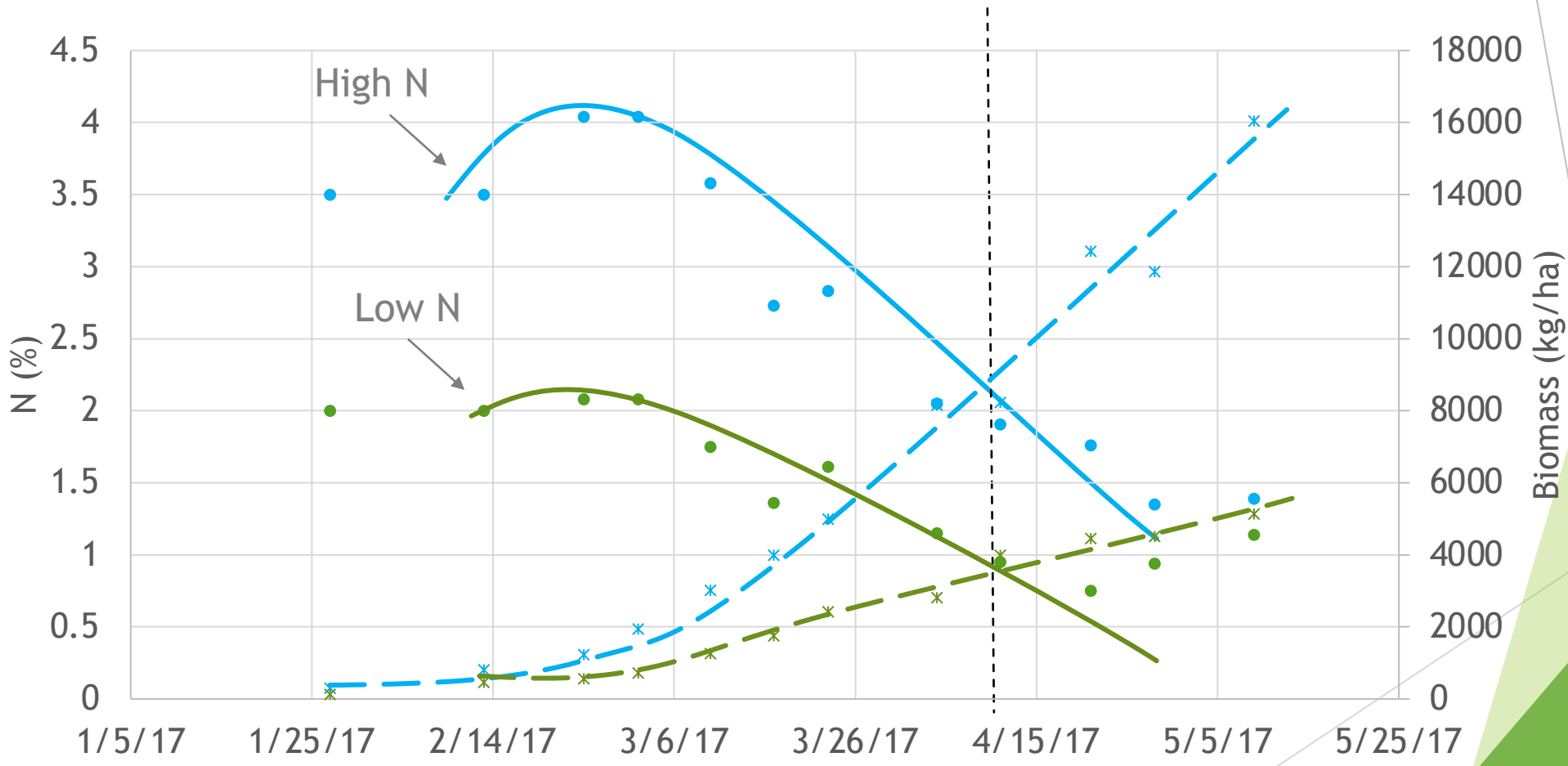


Unpublished data, courtesy of Mark Lundy, UCCE Extension Specialist, Small Grains

Table 4 (p. 17)

Cover Crop	Crop Biomass (dry) (T/A)	Tissue N Content (%)
'Cayuse' Oats	4	1.7
'Merced' Rye	3.6	1.9
Mustard[1]	3	2.6
Bell Bean	3	2.7
Cereal/Legume Mix[2]	3	2.9
'Magnus' Pea	2	3.6
Purple Vetch	2	3.7
'Lana' Woollypod Vetch	2	4.7

Relationship between %N in leaf tissue and biomass accumulation in wheat (Yolo Co., 2017)



Unpublished data, courtesy of Mark Lundy, UCCE Extension Specialist, Small Grains

Legume-Cereal Cover Crop Mixes

- Growing grass /legume mixtures typically increases total carbon inputs without sacrificing N scavenging efficiency and N contributions
- Cover crop mixes with a higher proportion of legumes, particularly when terminated before flowering will release more of their N than later terminated cover crops and grass-heavy mixes.

N content of the residues

- **Generally, cover crop age and N content drive N availability**
  - **the younger the crop and higher the N content of that species, the higher the N availability following incorporation.**
- Legumes and mustards have higher N contents in their tissue (e.g. >2%) that allows for more rapid N mineralization.
- The N content of cereals can be >2% when they are juvenile (e.g. prior to flowering), but significantly declines as they mature. As a result, the amount of N that is mineralized from cereal cover crop biomass can be less than legumes.

Cover Crop	Crop Biomass (dry) (T/A)	Tissue N Content (%)	Total N in Crop Biomass (lb/A)
'Cayuse' Oats	4	1.7	136
'Merced' Rye	3.6	1.9	137
Mustard[1]	3	2.6	156
Bell Bean	3	2.7	162
Cereal/Legume Mix[2]	3	2.9	174
'Magnus' Pea	2	3.6	144
Purple Vetch	2	3.7	148
'Lana' Woollypod Vetch	2	4.7	188

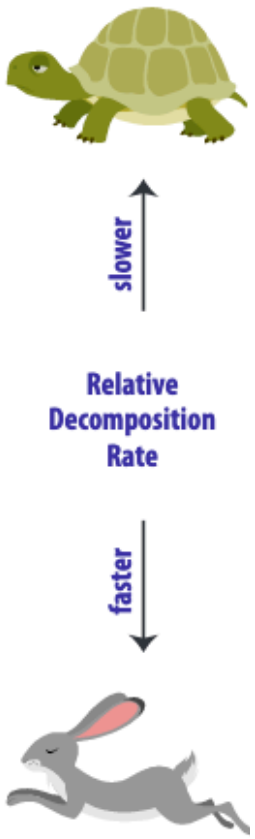
Only a portion of the total N becomes available to the following crop.

How much becomes available?

Cover crop age and the C:N ratio (Carbon to nitrogen ratio)

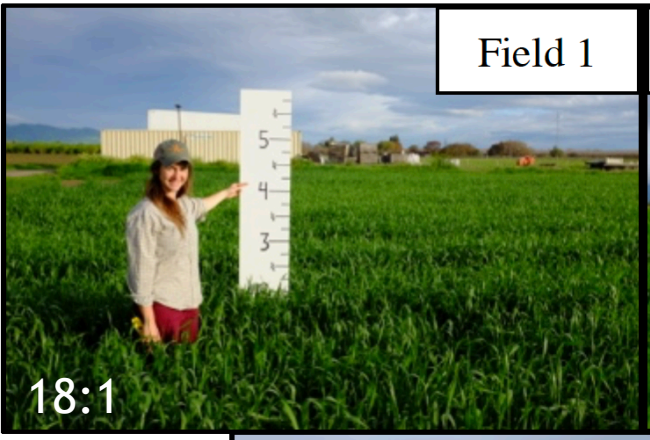
Table 1. Carbon to nitrogen ratios of crop residues and other organic materials

Material	C:N Ratio
rye straw	82:1
wheat straw	80:1
oat straw	70:1
corn stover	57:1
rye cover crop (anthesis)	37:1
pea straw	29:1
rye cover crop (vegetative)	26:1
mature alfalfa hay	25:1
Ideal Microbial Diet	**24:1**
rotted barnyard manure	20:1
legume hay	17:1
beef manure	17:1
young alfalfa hay	13:1
hairy vetch cover crop	11:1
soil microbes (average)	8:1



- Lignin, carbohydrates, and cellulose content can affect the rate of N release from the cover crop residues
- **The lower the C:N ratio, the faster mineralization and the more N becomes available for plant uptake.**
- Ex. An early spring kill of cereal grains reduces accumulation of C more than of N, so the rate of release of cover crop N into following crops is faster

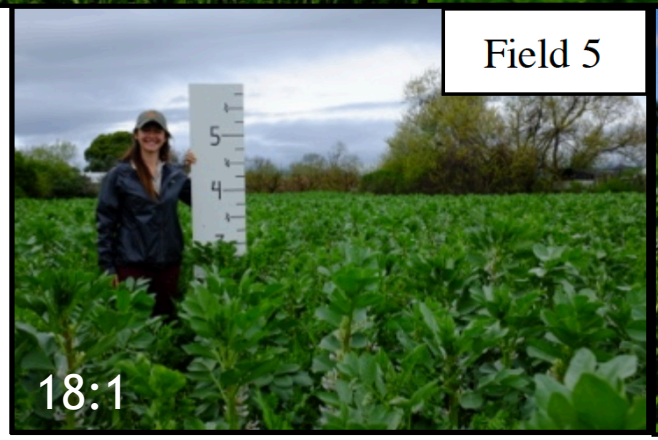
Table 1 from NRCS


Field 1
18:1

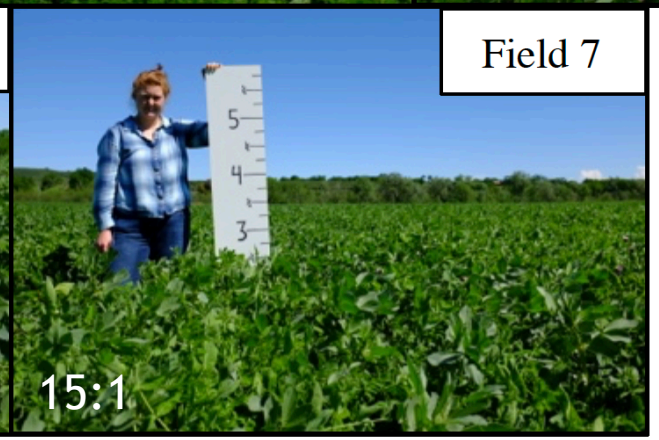

Field 2
15:1

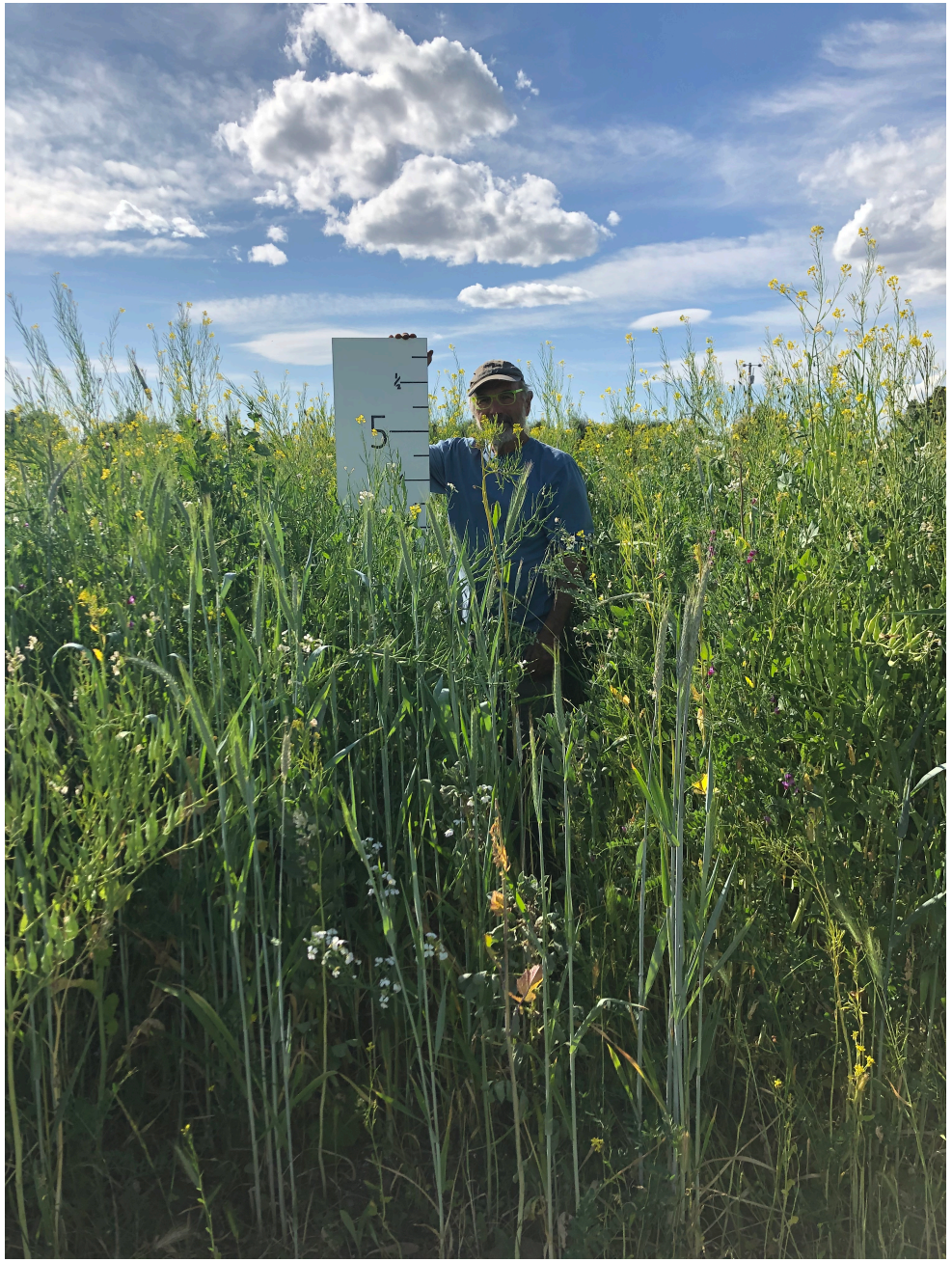

Field 3
12:1


Field 4
12:1

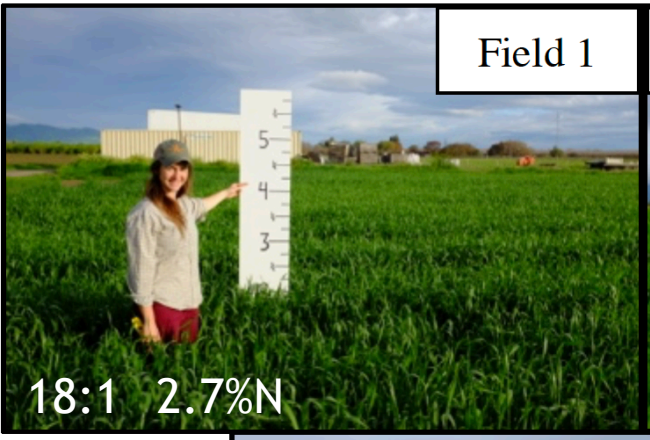

Field 5
18:1


Field 6
17:1

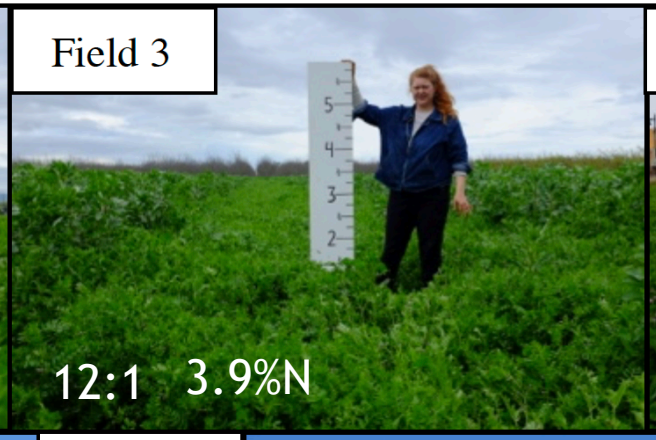

Field 7
15:1

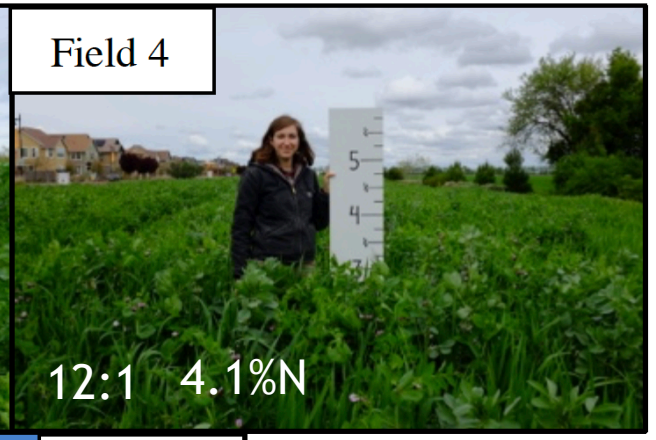


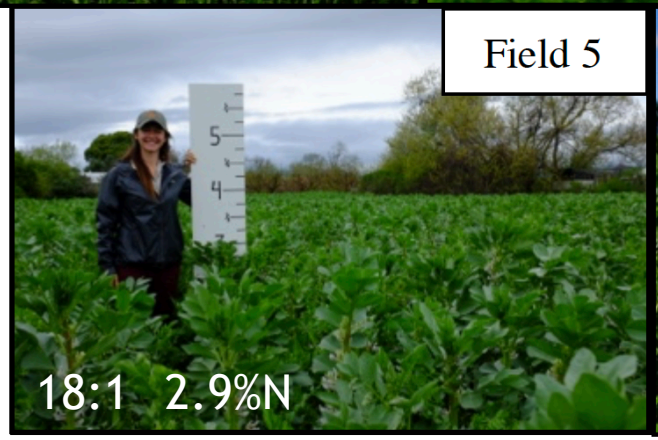
April 22, 2020
C:N 32:1


Field 1
18:1 2.7%N

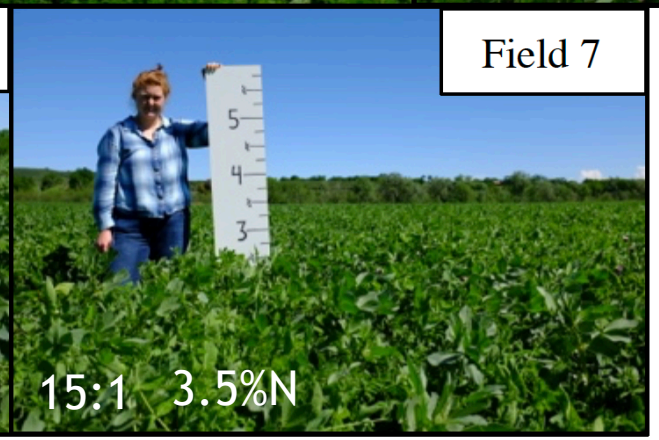

Field 2
15:1 3.5%N


Field 3
12:1 3.9%N

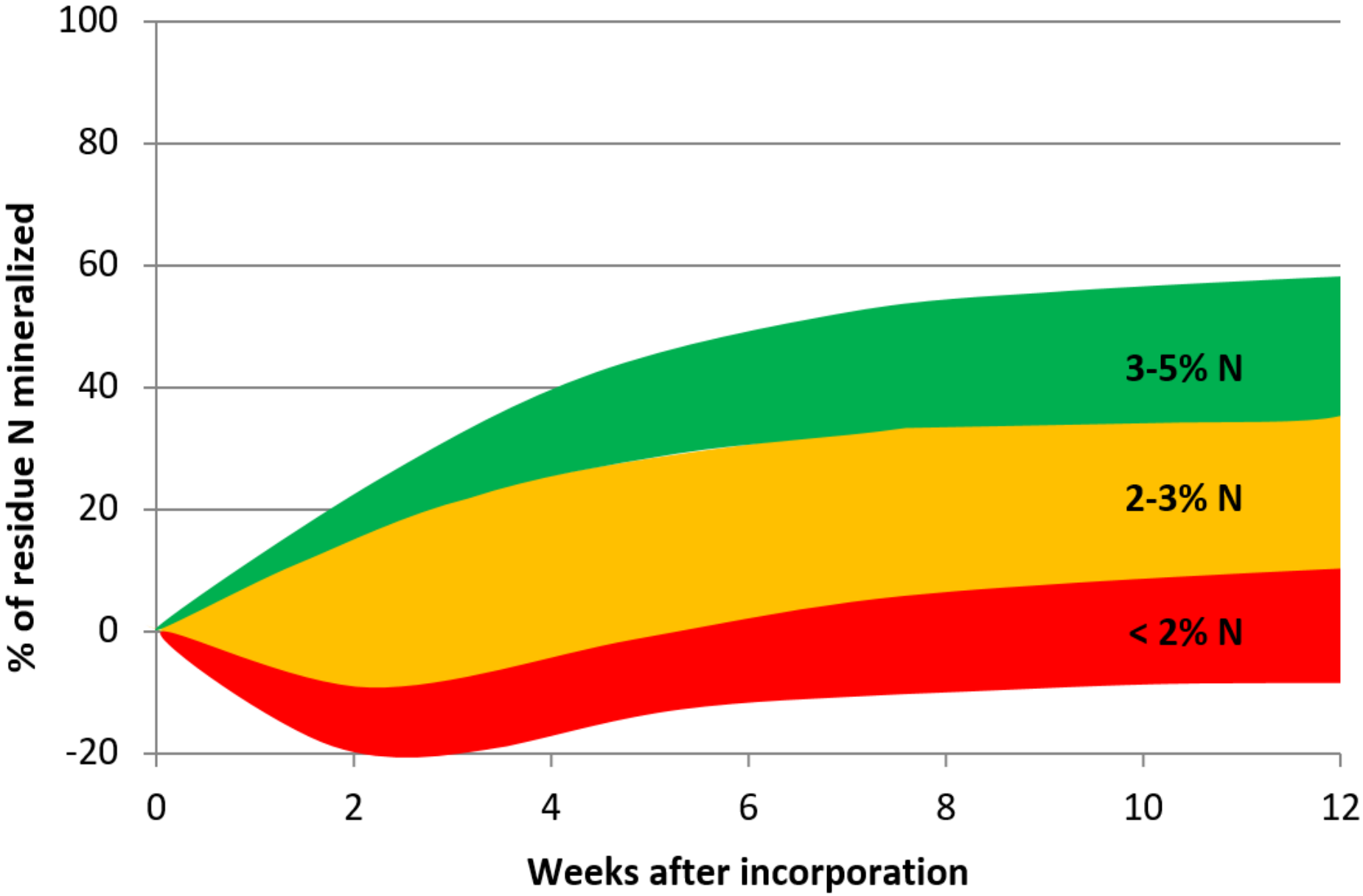

Field 4
12:1 4.1%N


Field 5
18:1 2.9%N


Field 6
17:1 3%N

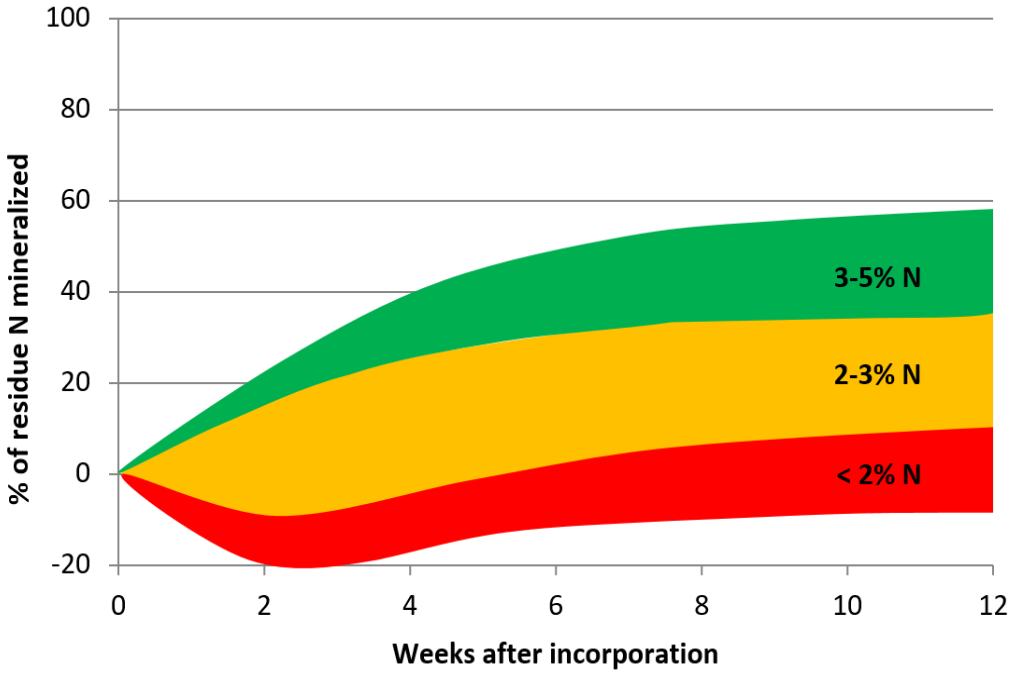

Field 7
15:1 3.5%N

Examples of N release timing from high, medium, and low-N residues

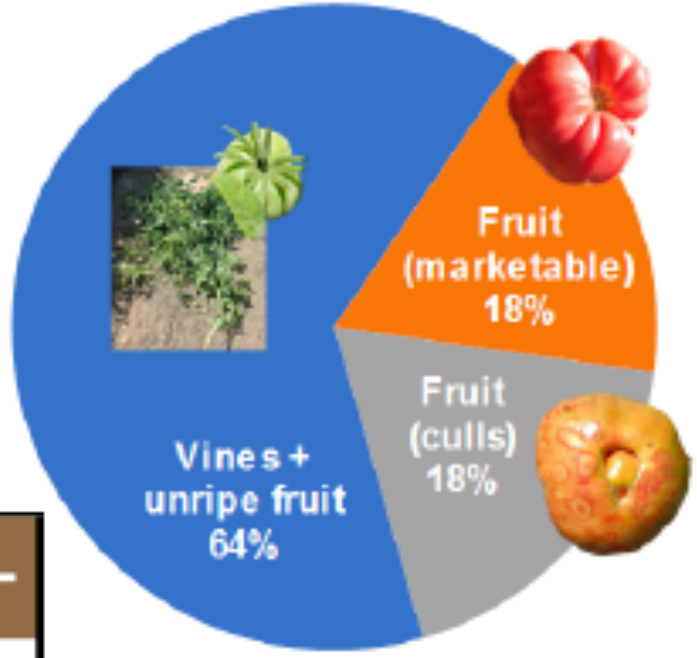


Cover Crop	Tissue N Content (%)	Total N in Crop Biomass (lb/A)		Mineralization Rate %		Available N (lb/A)
'Cayuse' Oats	1.7	136	x	10	=	13
'Merced' Rye	1.9	137		10		13
Mustard[1]	2.6	156		25		39
Bell Bean	2.7	162		25		41
Cereal/Legume Mix[2]	2.9	174		35		61
'Magnus' Pea	3.6	144		40		58
Purple Vetch	3.7	148		40		59
'Lana' Woollypod Vetch	4.7	188		55		103

[1]50:50 mix of Sinapis alba and Brassica Juncea; [2]Oats, bell beans, peas and vetch

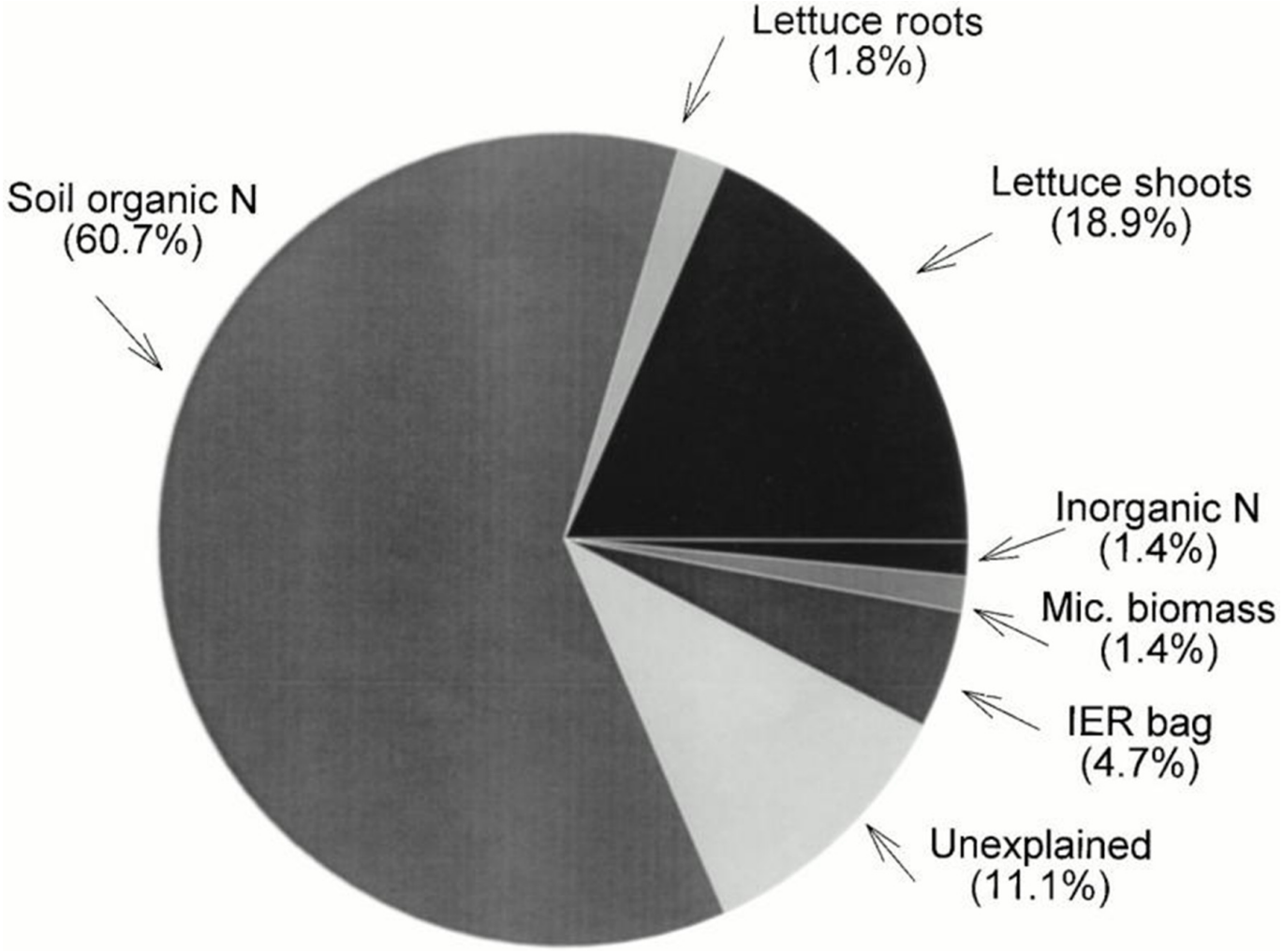


Vegetable Crop Residue



Crop	Example yield (tons/acre)	N in residues (% of total)	Expected residue N (lb N/ton yield)	Expected residue N (lb N/acre)
Lettuce	20	68	5	100
Tomato (fresh-market)	30	56	4	130
Tomato (processing)	50	46	2	100
Broccoli	10	68	24	240
Carrot	20	67	7	140
Melon	20	40	3	60
Potato	25	44	5	125
Strawberry	40	46	2	80
Spinach	15	38	3	45

Proportion of cover crop residue that was recovered in plant and soil components at harvest of the first lettuce crop at 4 months post incorporation



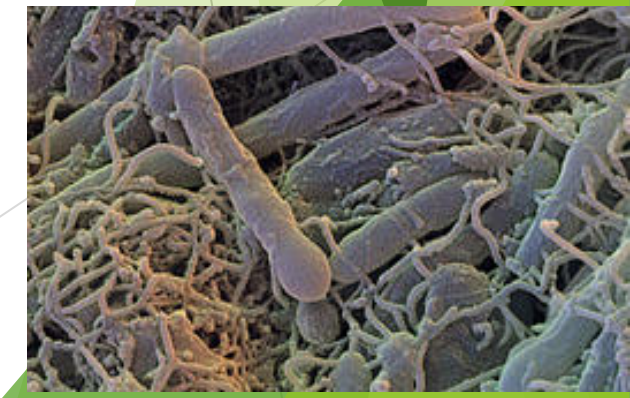
Jackson, L.E. (2000), Fates and Losses of Nitrogen from a Nitrogen-15-Labeled Cover Crop in an Intensively Managed Vegetable System. Soil Sci. Soc. Am. J., 64: 1404-1412.

Soil moisture

- Microbes and organisms decomposing plant residue need moisture
- Shoot material contains moisture—often lots, easily 50% moisture by weight.

Whether residues are left on the surface or incorporated.

- **Surface-applied residues decay more slowly than incorporated residues,**
  - …since residue decomposition is a microbial process requiring contact with microbes and moisture.
  - surface-applied residues are more vulnerable to N loss via volatilization to the atmosphere.
- The slower N release from cover crop residues left on the soil surface is more pronounced in dry than in wet years, is most evident during the first 4 to 8 weeks after killing, and differences due to tillage in accumulative N release disappear after 16 weeks (Varco et al., 1989)



How to sample for biomass, C:N and nitrogen content

Images 8-11. Quadrat (3’ x 3’) used for measuring a cover crop subsample. Pruners were used to cut debris to ground level.

Images 12-13. Biomass drying in an oven (left). Dried material after 48h (right).

Weigh

Send small sample to lab for tissue N content ($15)

Cover Crop	Tissue N Content (%)	Total N in Crop Biomass (lb/A)		Mineralization Rate %		Available N (lb/A)
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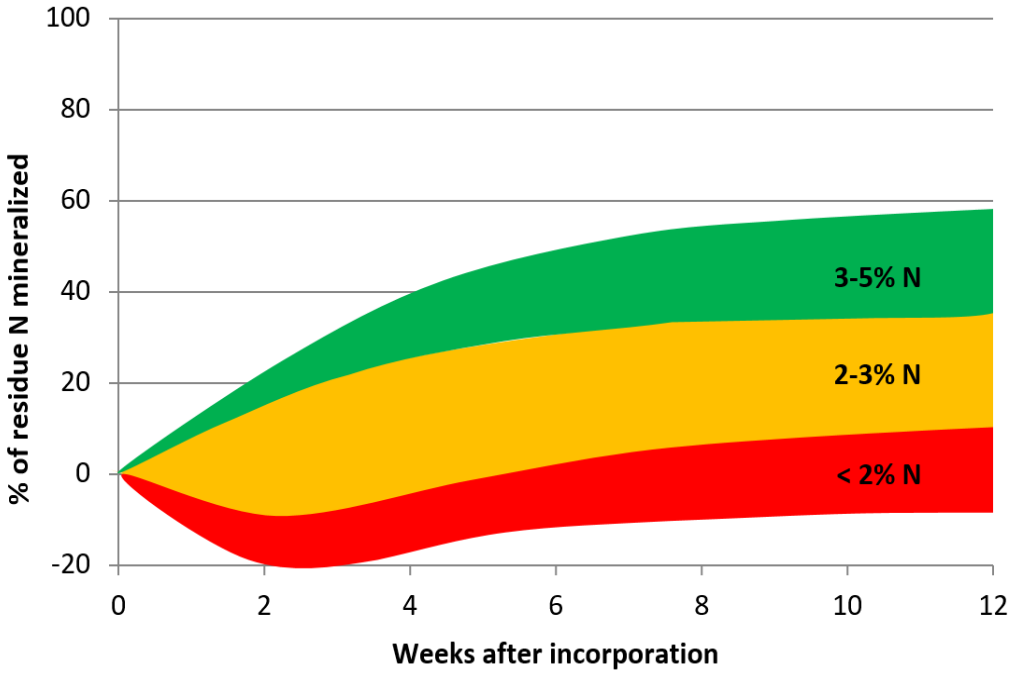


The amount of cover crop N that is made available for vegetable crop growth varies widely, and estimates range from less than 0 to 50%.

- Unmineralized N from crop residue and cover crops contributes to the total N in the soil organic matter and long-term soil fertility.

Example Scenarios

- Cover crop mixes with a higher proportion of legumes, particularly when terminated before flowering will release more of their N than later terminated cover crops and grass-heavy mixes.
- An early spring kill of cereal grains reduces accumulation of C more than of N, so the rate of release of cover crop N into following crops is faster
- In a cover crop mix, low residual soil N will limit cereal growth and promote legume growth
- A wet winter will encourage more rapid cover crop decomposition, which will lead to earlier availability and higher availability of early nitrogen
- Following a cover crop with a transplanted crop (as oppose to seeded) helps reduce the potential for N loss, better timing the N availability with crop N demand.

Summary

The amount of cover crop/crop residue N that is made available for vegetable crop growth varies widely, and estimates vary from <0 to 50%

- **C:N ratio and % N are good predictors of plant-available N (PAN)**
  - the younger the crop and higher the N content of that species, the higher the N availability following incorporation
  - Legumes and mustards tend to have higher %N tissue than cereals
    - With similar amounts of biomass, they may contribute more N to the following crop
- Grasses will scavenge N, keeping N in the system (reduce loss to leaching)
- More biomass leads to more total N contribution (no necessarily PAN)
  - The age (tissue N content) of that biomass influences PAN
- Soil moisture determines when/how much decomposition occurs
- Residue incorporation vs surface mulch determines when/how much decomposition occurs

(PAN – plant available nitrogen)

RESOURCES

UC University of California Cooperative Extension

How much nitrogen is in your cover crop?

Yolo/Solano County Cover Crop Sampling Results from Seven Organic Fields

Margaret Lloyd, UCCE Small Farms Advisor

In April 2019, I visited seven organic fields around Yolo and Solano County to check on the status of the cover crops in an effort to gauge the nitrogen contribution. The cover crops ranged from all wheat to all legume, and several legume-oat mixes (Field image 1-7) To do so, from April 2-15, I removed two samples per field using a quadrat (Image 8-11). These samples were dried, weighed and used to estimate biomass in lb/A (Image 12-13). Next, the samples were sent to a lab where they were ground and analyzed for total N (%) and the carbon-to-nitrogen ratio (C:N). Using the subsample of material taken in the quadrat to estimate biomass, along with the total N (%) from the lab, I was able to calculate the total N in lb/A (Table 2). Results from the seven fields are summarized in Table 1.

Table 1. Summary of Cover Crop Nitrogen and Biomass from Seven Fields.

Field[a]	Cover Crop[b]	Approx. Planting date	Seeding Rate (lb/A)	Biomass (lb/A, dry)	Total N (%)	Total N (lb/A)	C:N	Plant-available N[c] (lb/A)
1	Wheat			5562	2.7	150	18:1	6-53
2	Common Vetch	11/15/2018	60	4786	3.5	166	15:1	7-58
3	Common Vetch	11/15/2018	100	4221	3.9	166	12:1	7-58
4	Mix 1 (legume only)	11/15/2018	100	4550	4.1	188	12:1	8-66
5	Mix 2 (legume + oats)	10/20/2018	100	5628	2.9	160	18:1	6-56
6	Mix 3 (legume + oats)	11/1/2018	118	5872	3	179	17:1	7-63
7	Mix 3 (legume + oats)	1/15/2019	118	3590	3.5	124	15:1	5-43

a. *Field number corresponds to images 1-7.*

b. Mix 1 45% Bell Beans 35% Dundale Peas Mix 2 30% Bell Beans Mix 3 35% Bell

Cover Crop Chart

----------Cool Season---------- ----------Warm Season----------

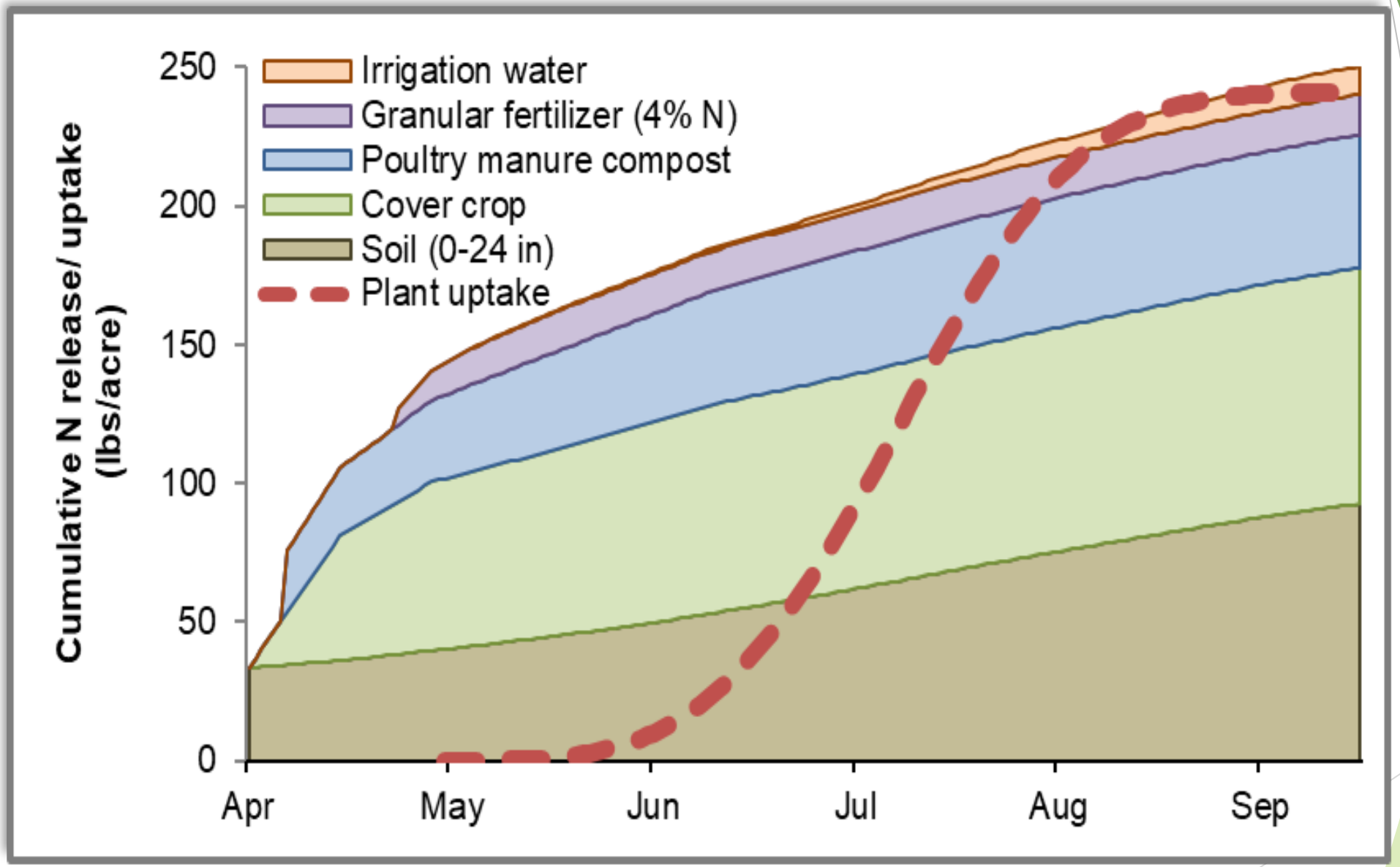
---Grass---

---Grass---

----------Broadleaf----------

----------Legume----------

								Corn
	Brassicas	Fava bean						Japanese millet
	Flax	Field pea	Balansa clover	Red clover	Common vetch	Chickpea	Amaranth	Proso millet
	Phacelia	Lentil	Berseem clover	Rose clover	Hairy vetch	Cowpea	Buckwheat	Sorghum
	Radish	Lupine	Crimson clover	Sweetclover	Purple vetch	Soybean	Safflower	Sudangrass
	White mustard	Medic/burr clover	Persian clover	Subterranean clover	Woollypod vetch	Sunnhemp	Sunflower	Teff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Thank you for your interest!

Margaret Lloyd

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