Nitrogen Management in Organic Strawberries

Practical Training on Nitrogen Management in Organic Production of Vegetables and Strawberries
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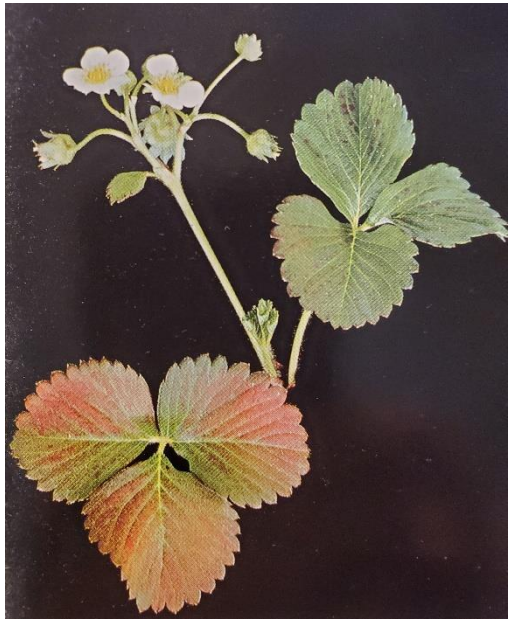
Overview

1. *Nitrogen (N) Management Basics*
   - *Roles in plants and forms in soils*
   - *Synchrony: Matching N supply with N demand*
2. *N Uptake by organic strawberries*
3. *N Supply for organic strawberries*
4. *Tools for N management in organic strawberries*
5. *Field trial: Use of high carbon amendment to reduce N loss in broccoli-strawberry rotation*

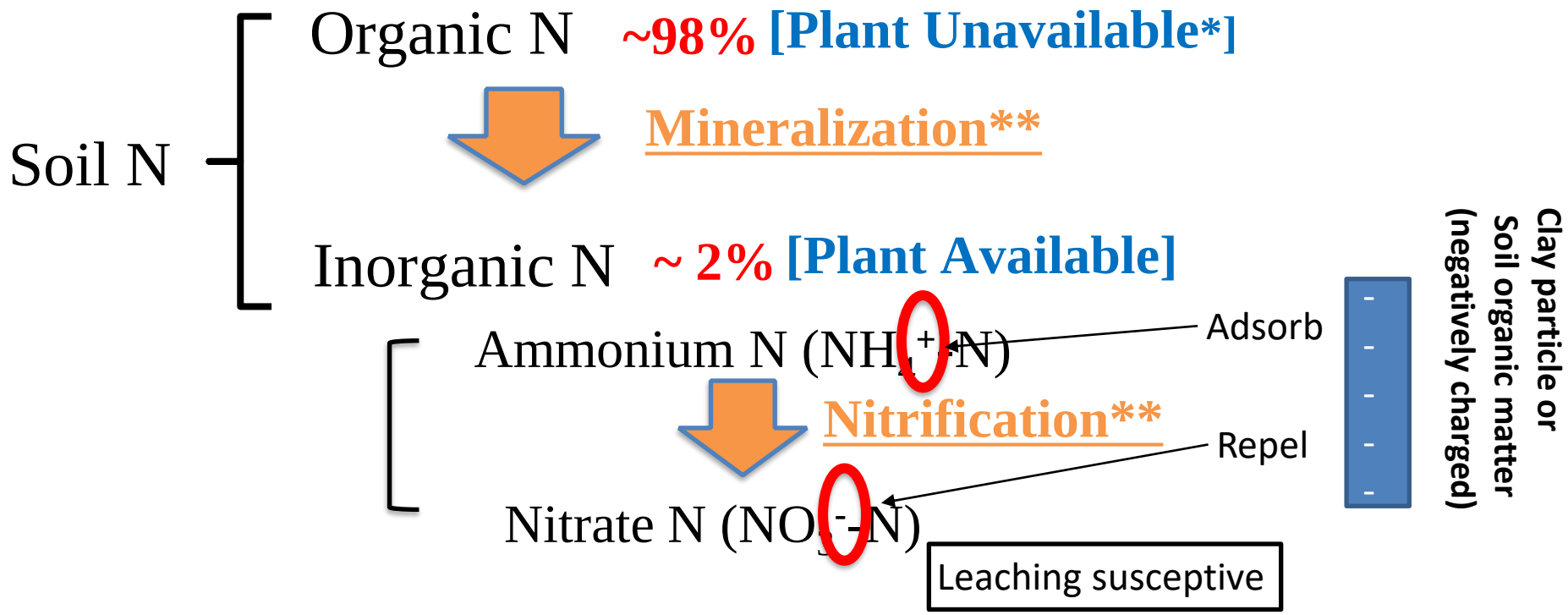
N in Plants; A Key to Crop Production

- *Primary nutrient affecting plant growth*
  - *photosynthesis (chlorophyll)*
  - *biomass structure (protein)*
  - *metabolism (enzyme)*
  - *energy production (ATP)*
  - *reproduction (DNA, RNA)*
- *N deficiency*
  - *Yellowish green leaves, smaller plants, lower yield*
- *N excess*
  - *Dark green leaves, large plants, susceptive to diseases*



N deficient strawberry plant (Ulrich et al., 1980)

N Forms in Soil and Plant Availability



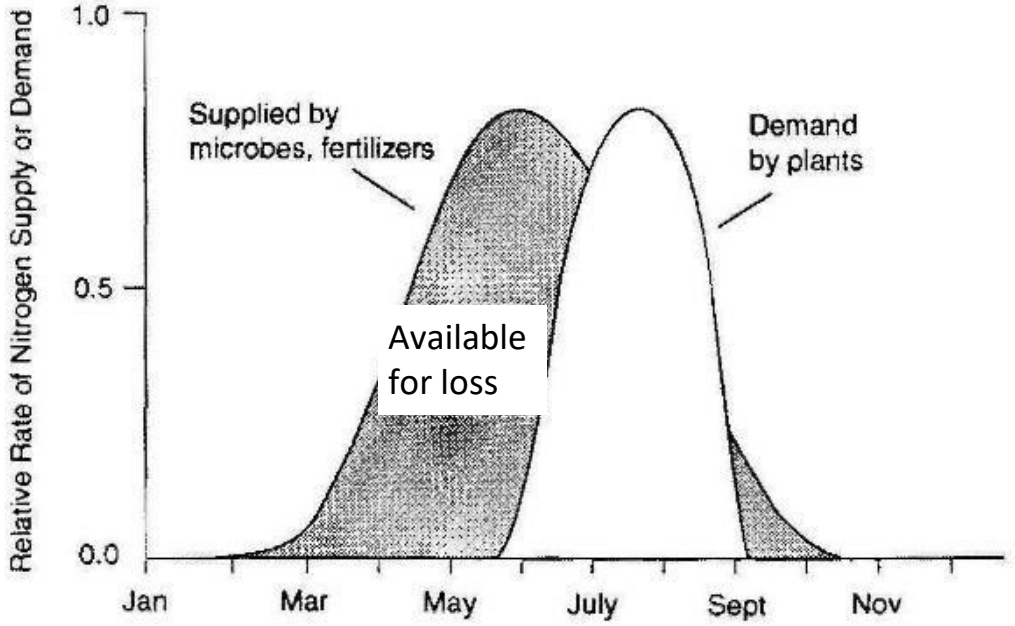
* Plants can absorb small amounts of organic N and some crop plants can do more than others

** **Biological processes** affected by ***environmental factors*** such as ***soil temperature. moisture, pH, oxygen content etc.***

Synchrony

- *Matching N supply with N demand of plants - amount and timing*

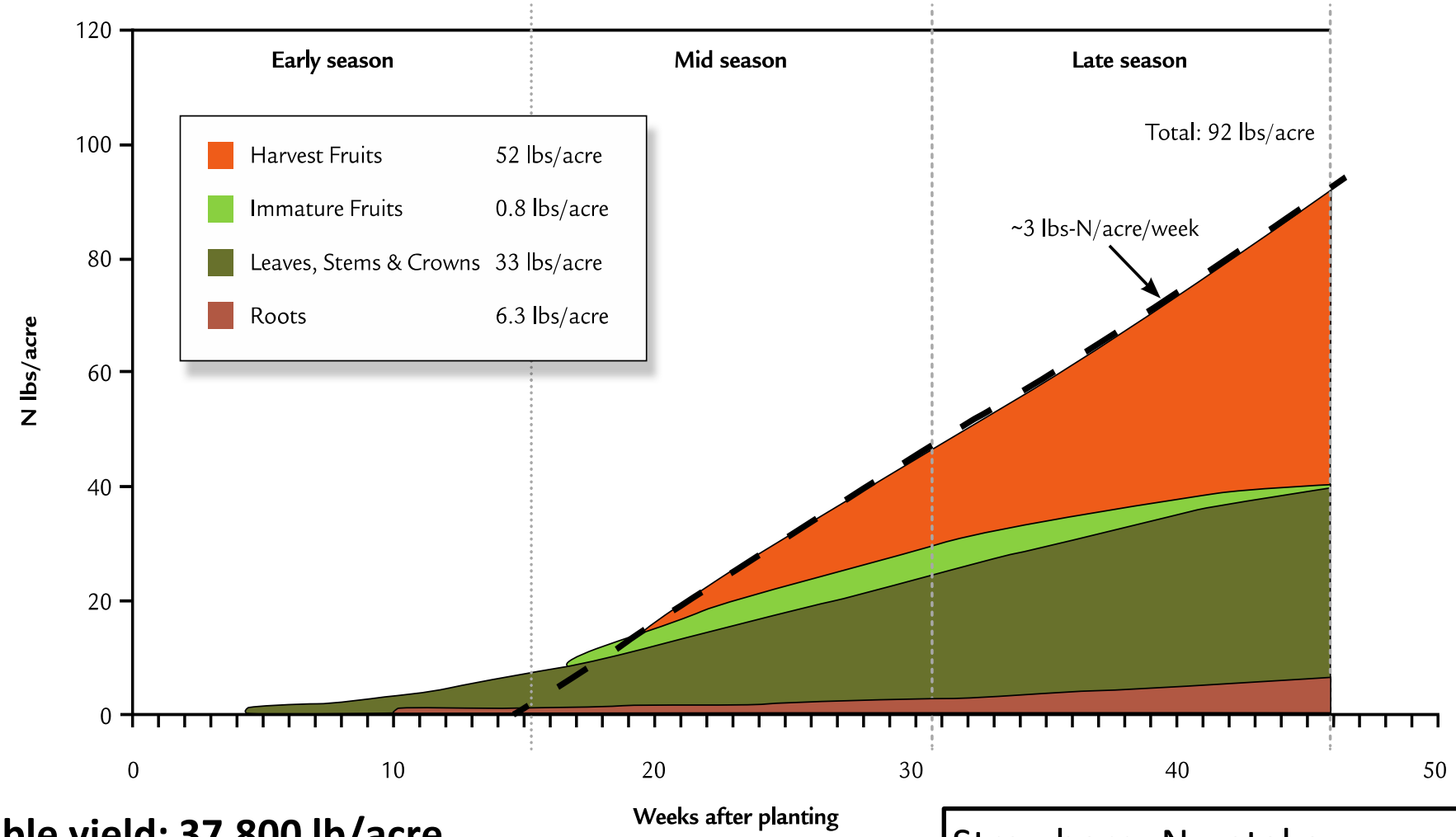
- *Important for:*
  - *Efficient use of N resources*
  - *Protecting ground and surface water from nitrate contamination*
  - *Reducing N fertilizer cost*
  - *Good fruit yield*



Asynchrony of N supply and N demand

(Robertson, 1997)

Cumulative N Uptake by Organic Strawberry in California



<u>Marketable yield: 37,800 lb/acre</u>

Moss Landing, CA. Average of 4 seasons.

cv. Aromas

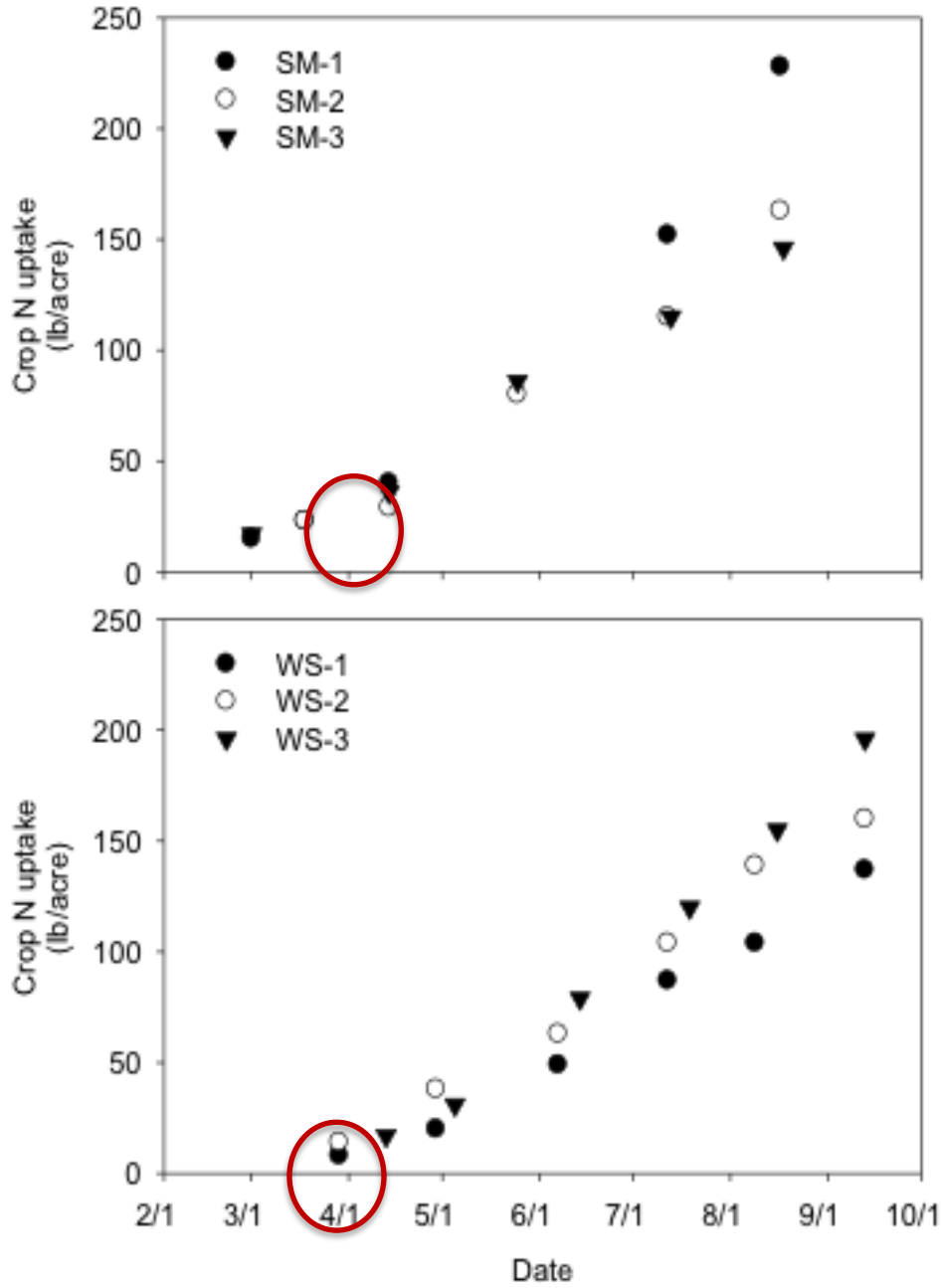
Strawberry N uptake:
Slow but constant for long period

(Muramoto and Gaskell, 2011)

Cumulative N Uptake by Conventional Strawberry in California

Santa Maria

Watsonville



Av. Yield: 73,000 lb/ac

150-220 lb-N/acre
6-8 lb-N/acre/week during the harvest season

(Bottoms et al., 2013)

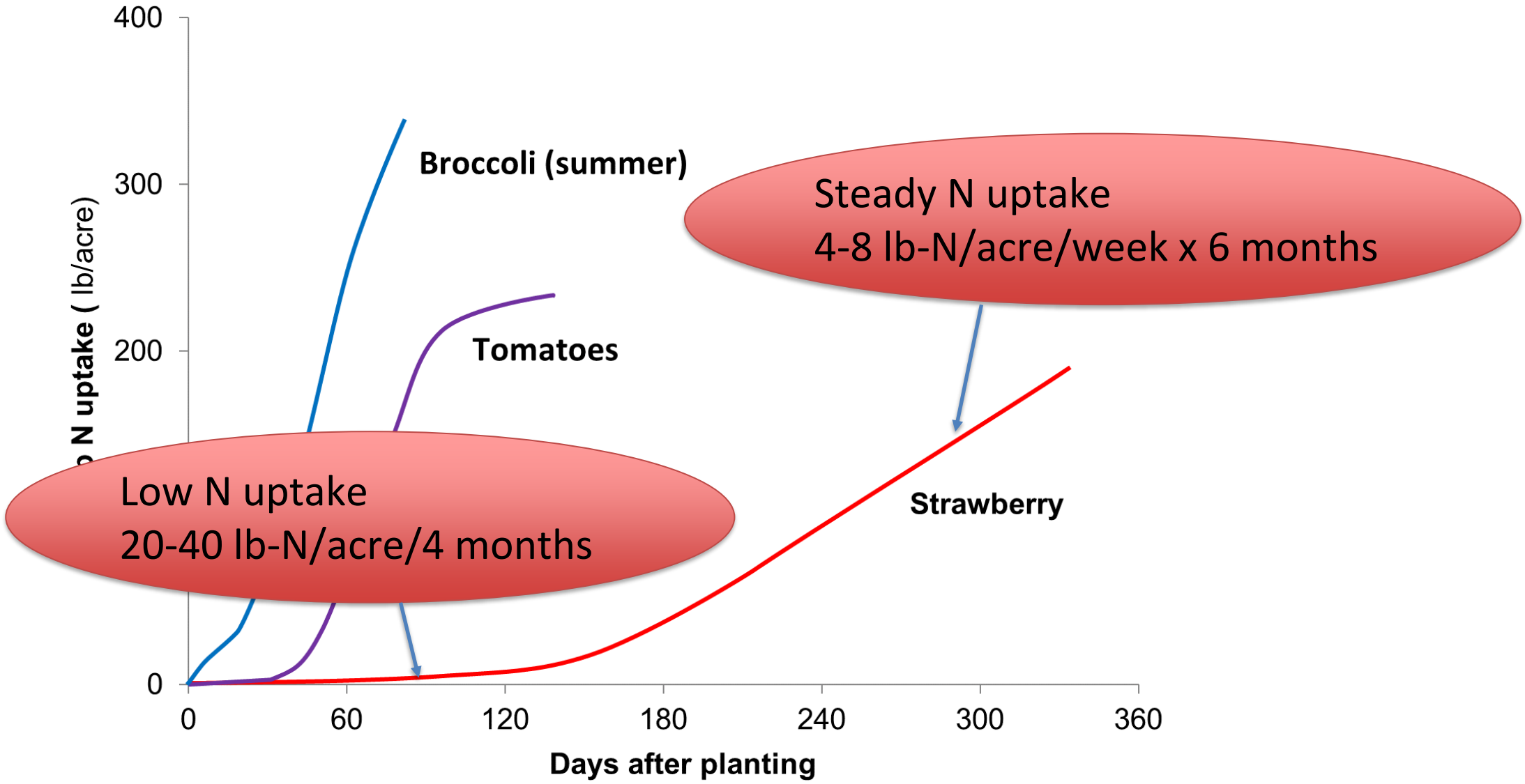
Approximate N Uptake by Strawberry during Harvest Season

Marketable yield lb/acre	Total yield (20% cull) lb/acre	Cumulative plant N uptake lb-N/acre	N uptake during harvest season lb-N/acre/week
40,000	50,000	110	4
50,000	62,500	138	5
60,000	75,000	165	6
70,000	87,500	193	7
80,000	100,000	220	8

Assumptions:

- Each ton of fruit: 2.2 lb-N (N: 0.98% d.w., Fresh moisture 89%)
- N uptake by Fruits vs. Shoots: 1 to 1
- Harvest period: April to September (26 weeks)

Unique N Uptake Pattern of Strawberry



N Supply: Organic N sources

- *Traditionally, organic growers concentrate on soil organic matter (SOM) management as basis for organic production program*

N Mineralization from SOM During the Pre-Harvest Season (Nov. – Mar.)

Month	Central Coast	
SOM	1.5%	3.0%
lb N acre^{-1} month^{-1} (top 12 ")		
January	3	6
February	3	6
March	4	7
April	5	9
May	6	11
June	6	12
July	7	14
August	7	15
September	7	13
October	6	11
November	4	8
December	3	6

(Geisseler, 2021)

SOM 1.5%

N = 4+3+3+3+4= **17 lb-N/acre/foot**

SOM 3.0%

N = 8+6+6+6+7 = **33 lb-N/acre/foot**

N Supply: Organic N sources

- *Traditionally, organic growers concentrate on soil organic matter (SOM) management as basis for organic production program*

- *Nitrate from irrigation water*

Nitrate-N from Irrigation Water during the Pre-Harvest Season (Nov. – Mar.)

- Typical Irrigation rate: ~12 inches (Cahn, Per. comm.)

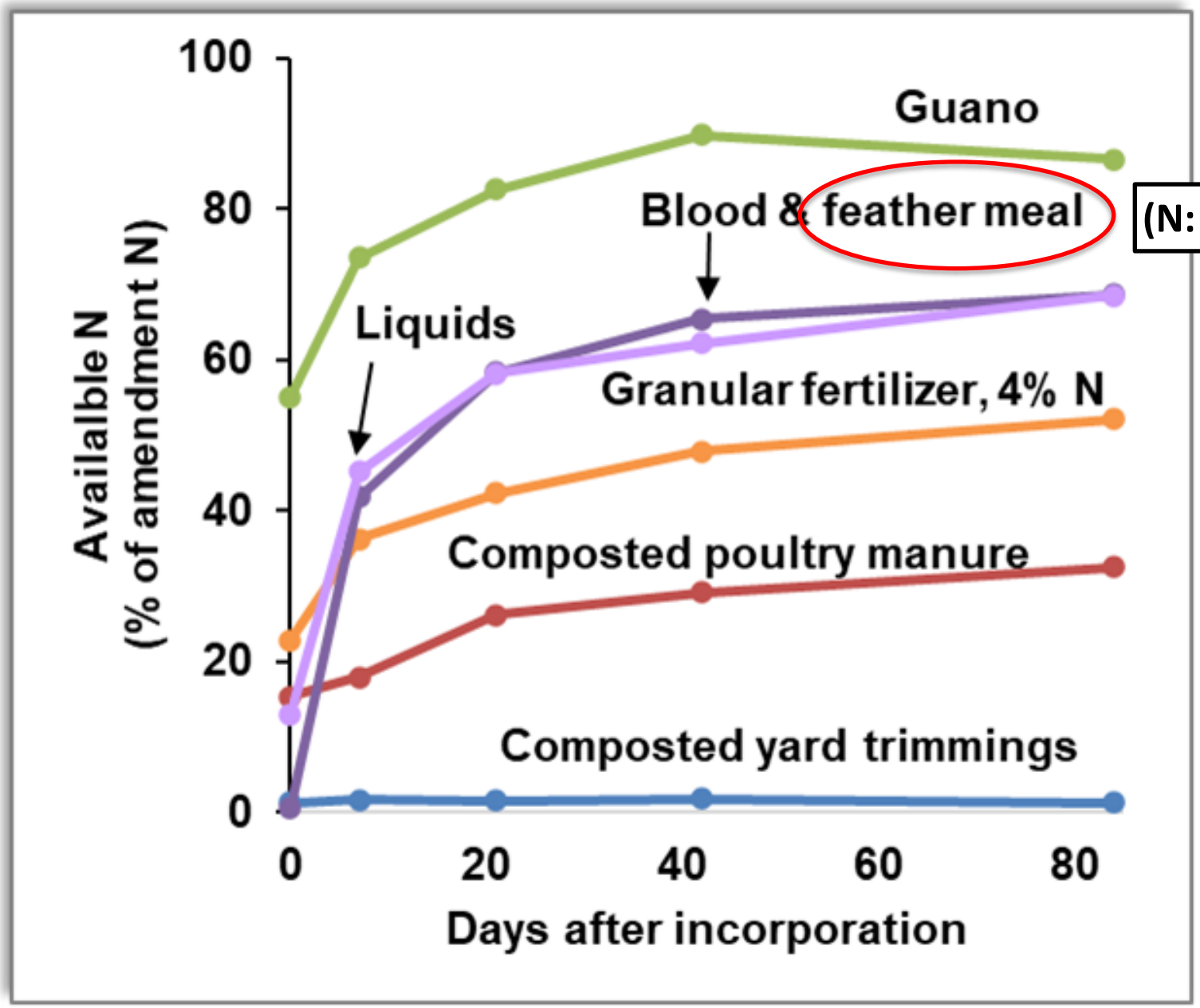
5 ppm NO_3-N

- NO_3-N lb-N/acre = 5 x 12 x 0.23 = **14 lb-N/acre**

10 ppm NO_3-N

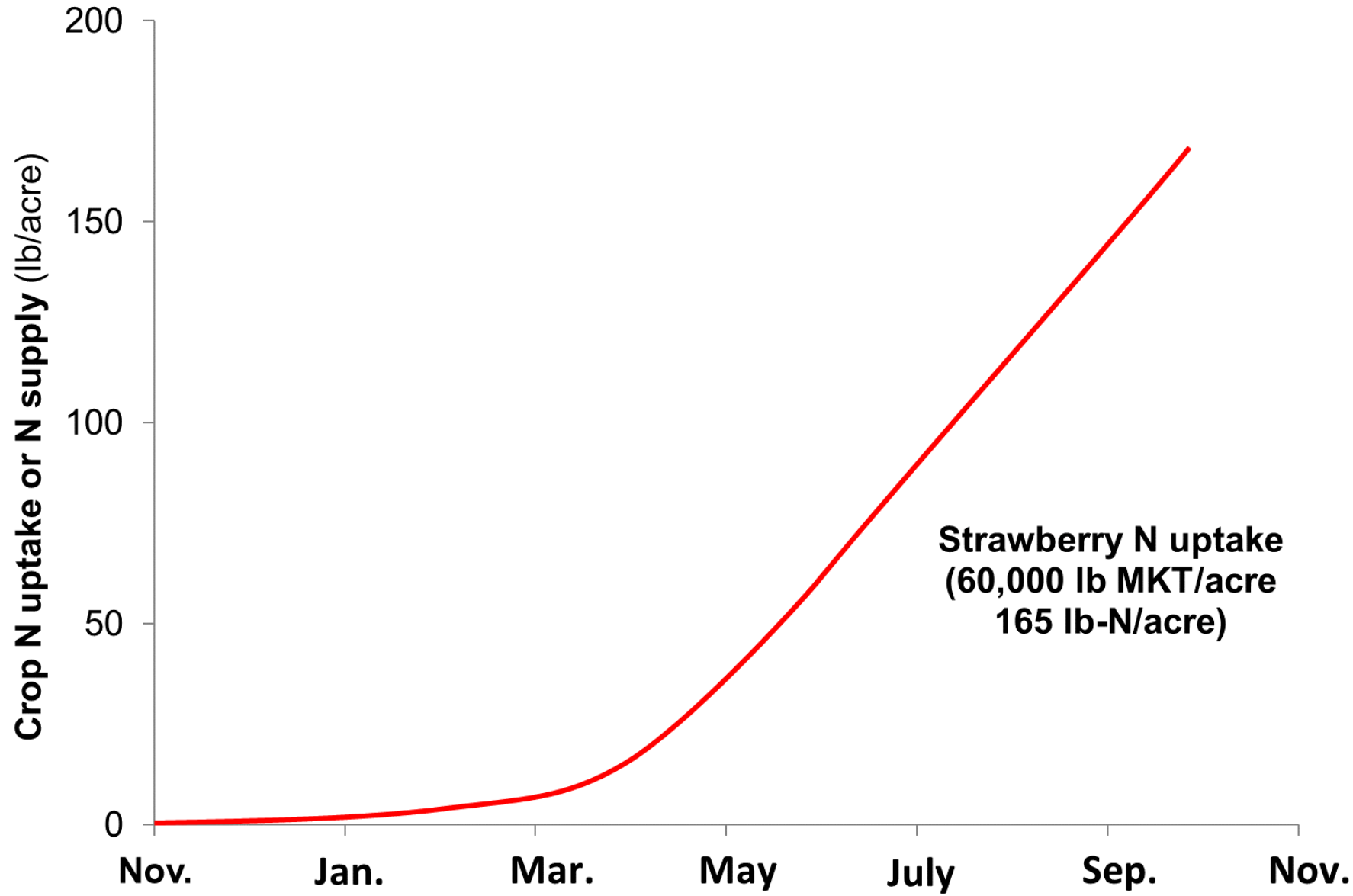
- NO_3-N lb-N/acre = 10 x 12 x 0.23 = **28 lb-N/acre**

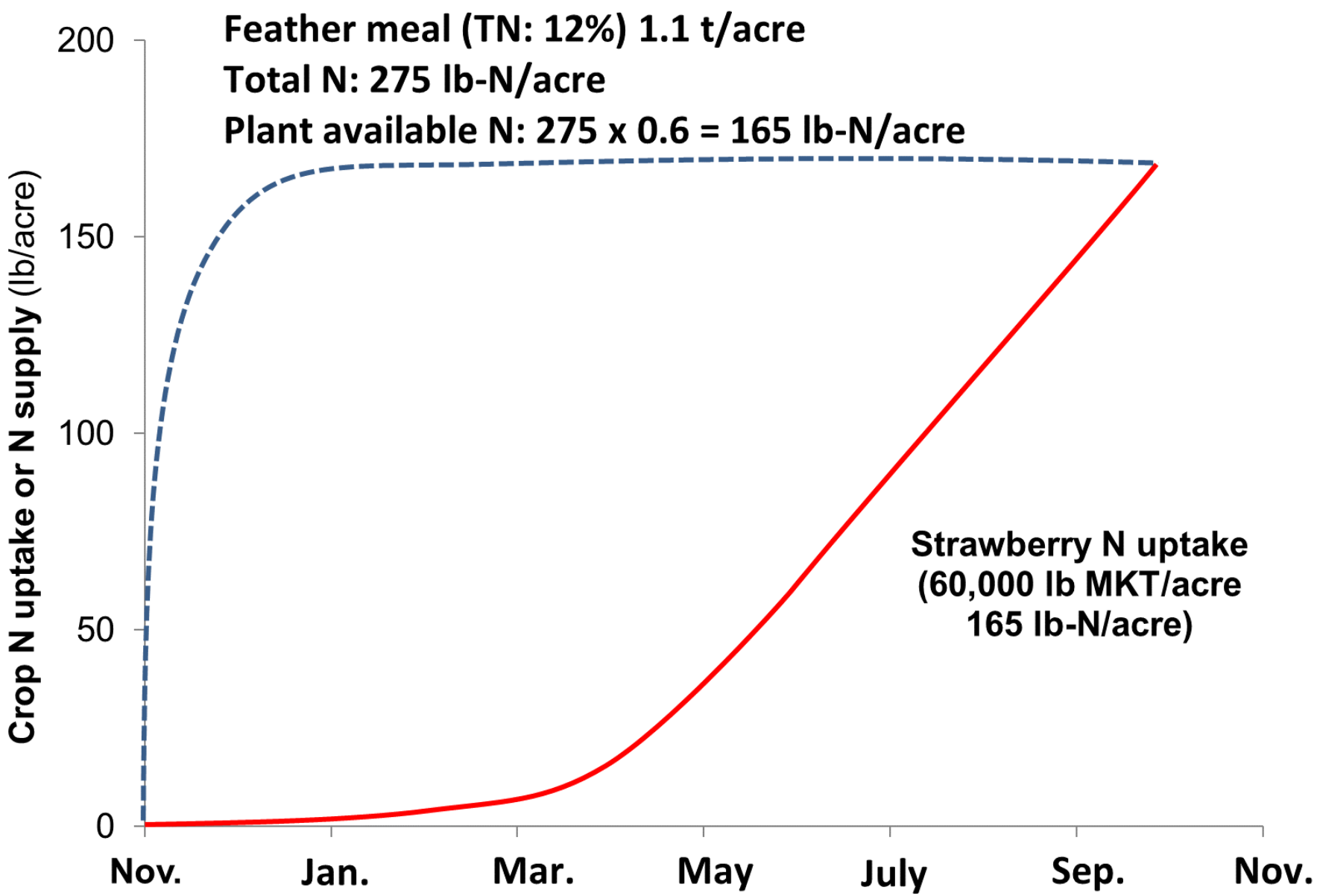
Not much pre-plant N is necessary!



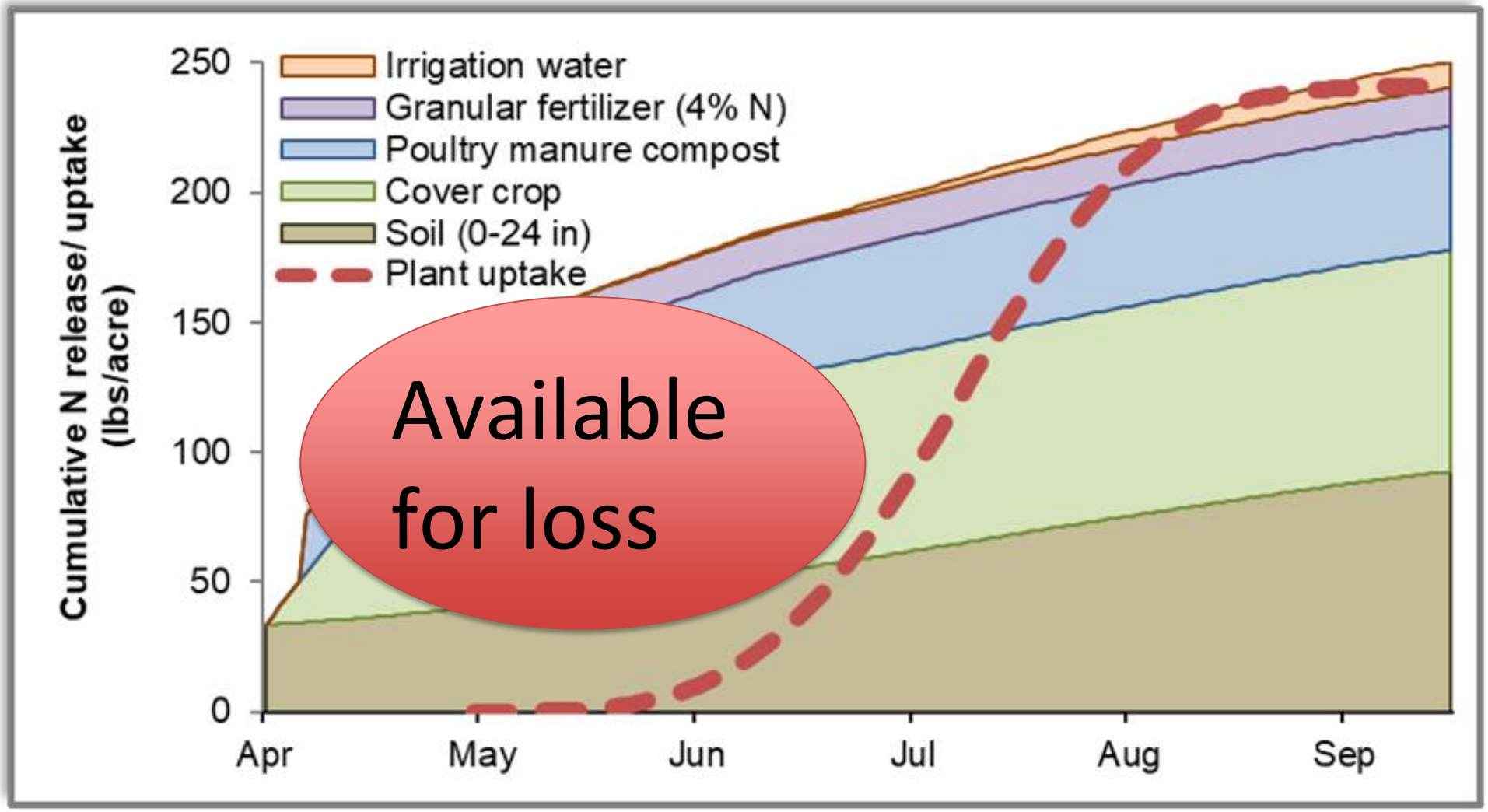
(N: 12%, PAN: 60%)

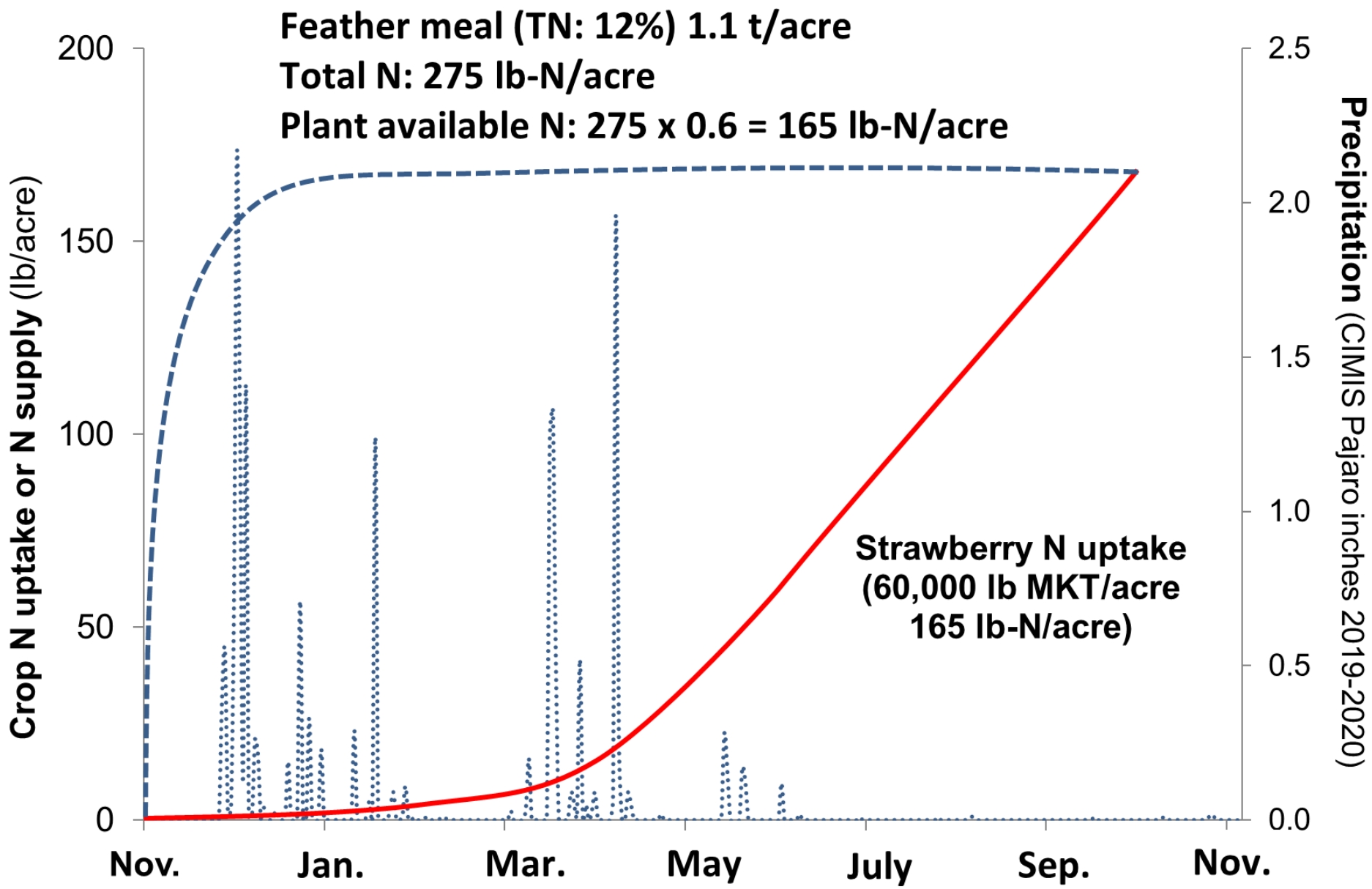
(Lazicki et al., 2020)


200
150
100
50
0
Crop N uptake or N supply (lb/acre)
Nov.
Jan.
Mar.
May
July
Sep.
Nov.
Strawberry N uptake
(60,000 lb MKT/acre
165 lb-N/acre)


Feather meal (TN: 12%) 1.1 t/acre
Total N: 275 lb-N/acre
Plant available N: 275 x 0.6 = 165 lb-N/acre
Crop N uptake or N supply (lb/acre)
200
150
100
50
0
Nov.
Jan.
Mar.
May
July
Sep.
Nov.
Strawberry N uptake
(60,000 lb MKT/acre
165 lb-N/acre)

N Uptake and N Supply in Organic Tomatoes

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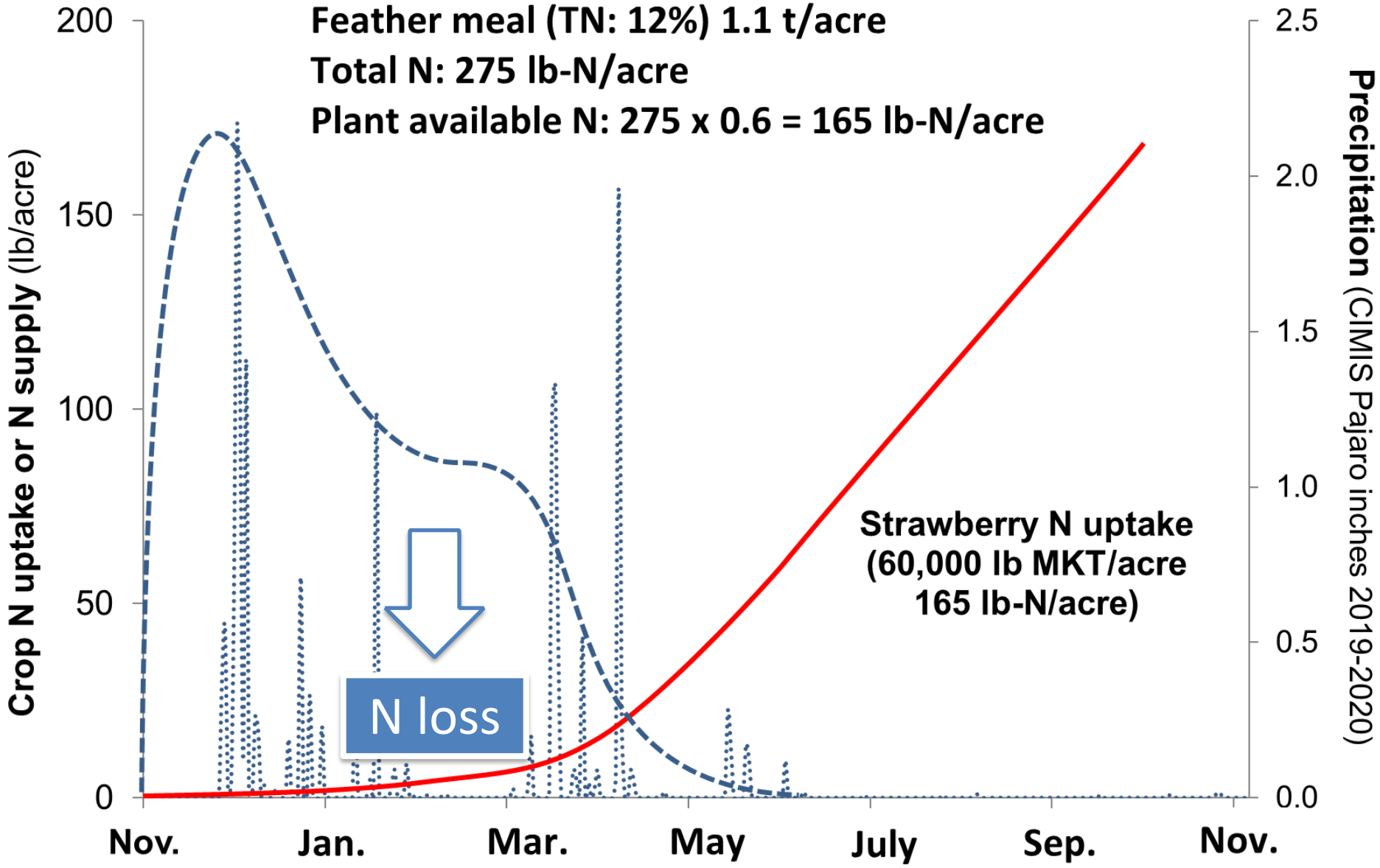
Strawberry N uptake
(60,000 lb MKT/acre
165 lb-N/acre)
Crop N uptake or N supply (lb/acre)
Precipitation (CIMIS Pajaro inches 2019-2020)
200
150
100
50
0
2.5
2.0
1.5
1.0
0.5
0.0
Nov.
Jan.
Mar.
May
July
Sep.
Nov.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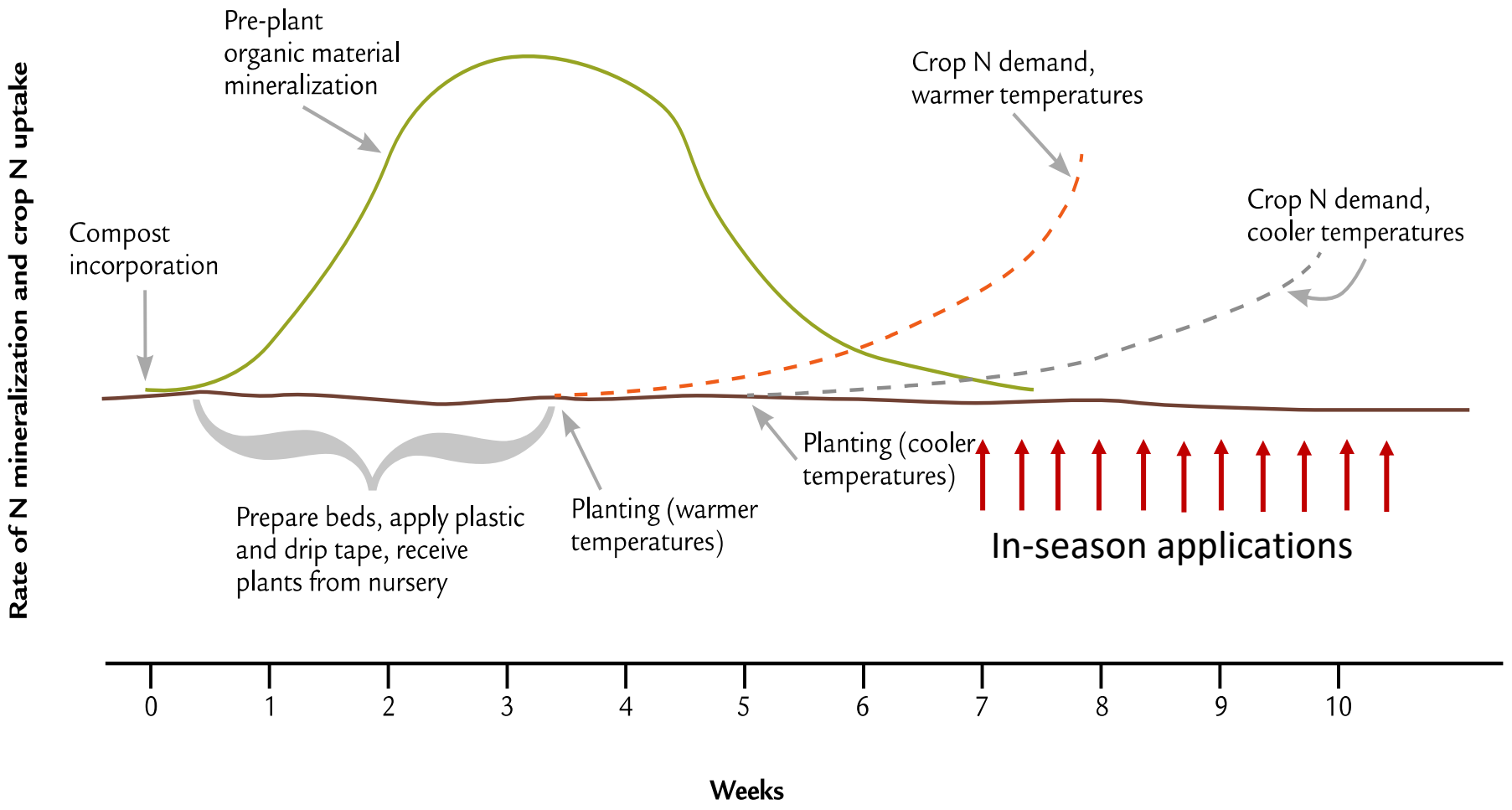
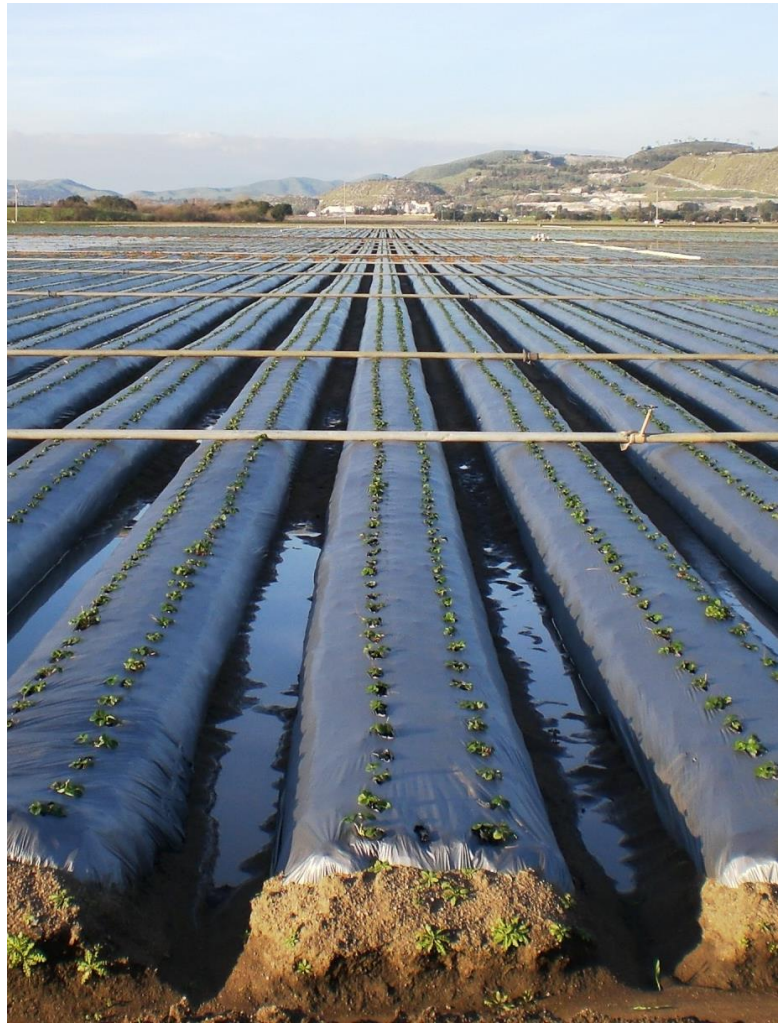
Crop N uptake or N supply (lb/acre)
Precipitation (CIMIS Pajaro inches 2019-2020)
200
150
100
50
0
2.5
2.0
1.5
1.0
0.5
0.0
N loss
Strawberry N uptake
(60,000 lb MKT/acre
165 lb-N/acre)
Nov.
Jan.
Mar.
May
July
Sep.
Nov.

Asynchrony of pre-plant nitrogen release and strawberry N uptake



N Supply: In-season N applications

- *In-season band application and cultivation with organic pelleted or milled fertilizer…impractical under plasticulture CA strawberry systems*
- *Fertigation: liquid organic fertilizer applications via drip tapes.*
- *Clogging of drip tapes by fertigation of liquid organic fertilizers is a common issue*
- ***<u>Set up double drip lines or use water soluble organic fertilizers (hydrolyzed soy protein)</u>***



Costs of Liquid Organic Fertilizers

Material	Type	Cost/lb of Nitrogen
5-1-2	Liquid – Fish, corn	$12.10
4-1-3	Liquid – Fish	$13.30
14-0-0	Dry (soluble) – hydrolyzed soy protein	$18.50 – 35.70
4-4-2	Dry – Poultry manure, feather and meat & bone	$4.20

(Smith, Per. Comm.)

Approximate N Uptake by Strawberry during Harvest Season

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July	7	14
August	7	15
September	7	13
October	6	11
November	4	8
December	3	6

(Geisseler, 2021)

SOM 1.5%

N = 5+6+6+7+7+7 = **38 lb-N/acre/foot**

Av. Per week

38 / 26 = **1.5 lb-N/acre/week**

SOM 3.0%

N = 9+11+12+14+15+13 = **74 lb-N/acre/foot**

Av. Per week

74 / 26 = **2.8 lb-N/acre/week**

It is worth building SOM!

Nitrate-N from Irrigation Water during the Harvest Season (April –Sep. 26 weeks)

- Typical Irrigation rate: ~18 inches (Cahn, Per. Comm.)

5 ppm NO_3-N

- NO_3-N lb-N/acre = 5 x 18 x 0.23 = 21 lb-N/acre
- For per week, 21 / 26 = **0.8 lb-N/acre/week**

10 ppm NO_3-N

- NO_3-N lb-N/acre = 10 x 18 x 0.23 = 41 lb-N/acre
- For per week, 41 / 26 = **1.6 lb-N/acre/week**

N Management Tools for Organic Strawberry

- Tissue test: TN of leaf blades (young matured leaves)

Stage	Early flowering	Early harvest	Main harvest
TN in blade	3.1-3.8%	2.7-3.2%	2.4-3.0%

(Bottoms et al., 2013)

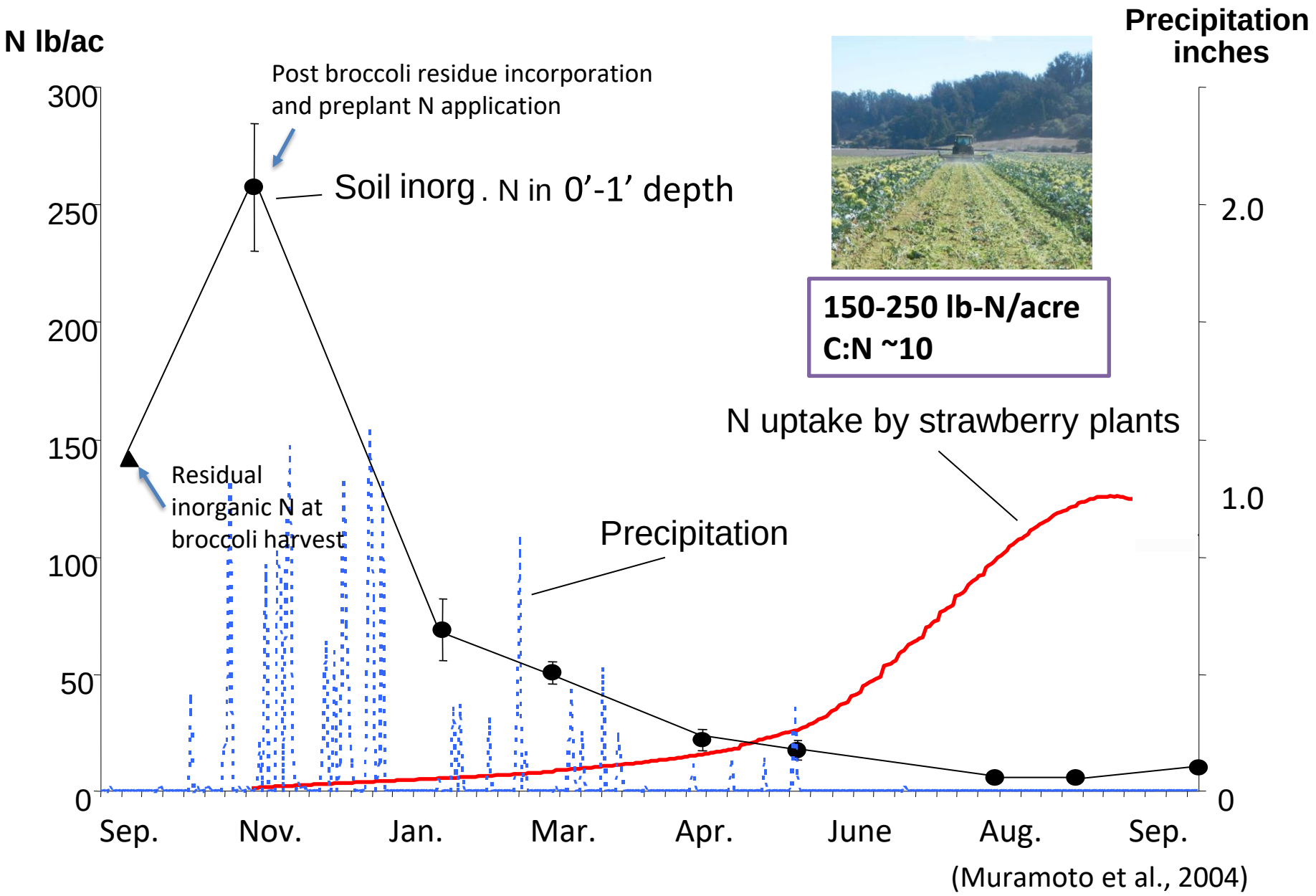
  - NO_3 in petioles: highly variable and may be less reliable for organic systems

- Soil nitrate test (combined with tissue TN test)
  - NO_3-N 10 - 25 ppm (=mg-N/kg dry soil) in 0'-1' depth
  - Optimum tissue TN and low soil nitrate pool may indicate a tightly-coupled plant-soil N cycling (Bowles et al., 2015)

N Management in Organic Strawberries: Summary

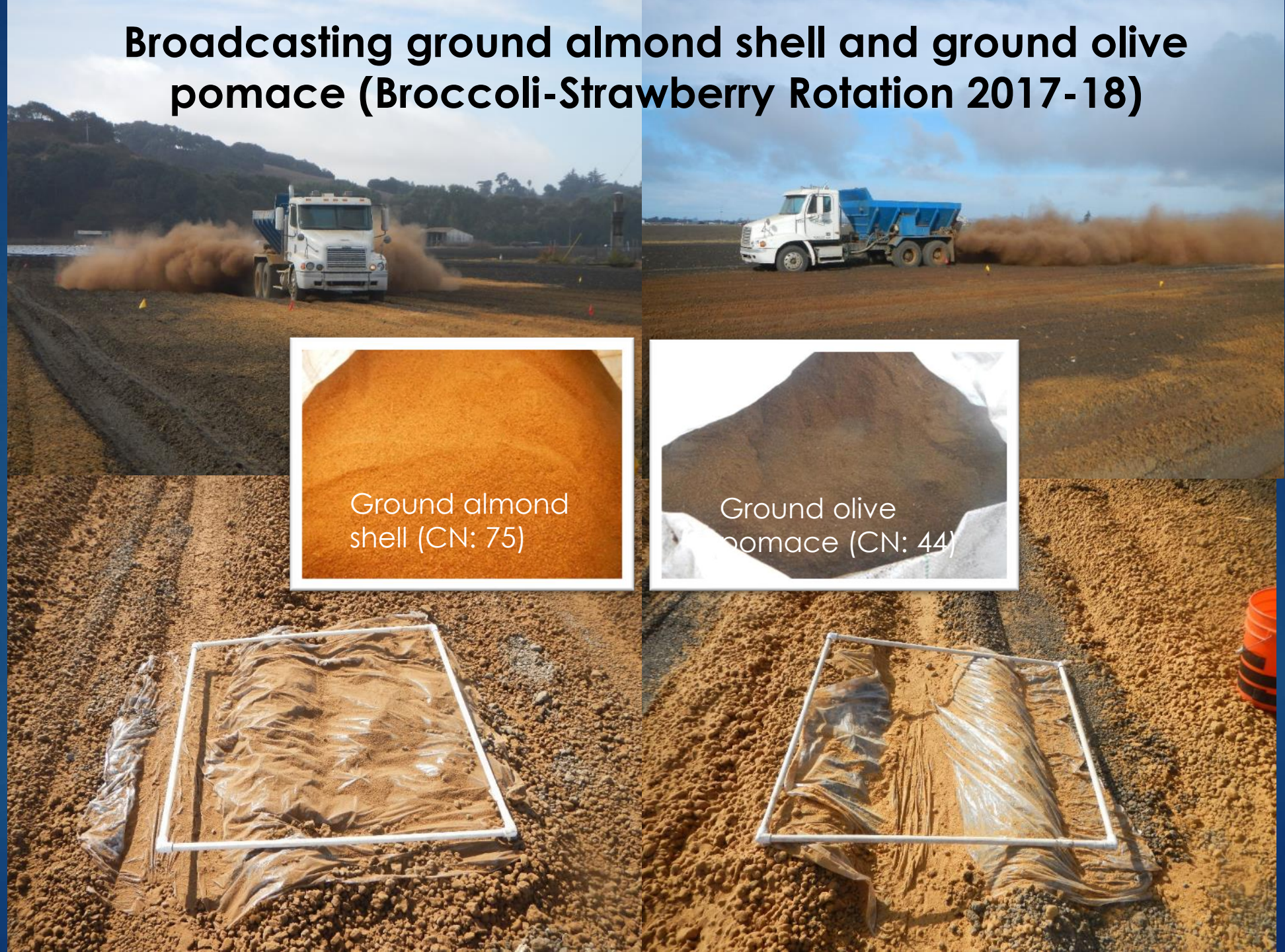
- *N uptake of strawberries in the first 4 months is low (20-40 lb-N/acre) followed by a steady uptake (4-8 lb-N/week) throughout the harvest period*
  - Pre-plant N: Moderate rate (50-75 lb-N/acre) recommended to avoid N loss to the environment during rainy winters
  - For a warm/dry winter, start fertigation early (e.g., Jan or Feb.)
- *In-season N applications necessary during the harvest period*
  - 4-8 lb-N/acre/week during the harvest season…..adjust according to the target yield, SOM content, Nitrate-N in irrigation water, and tissue TN tests
- *Fertigation of liquid organic fertilizer*
  - Common organic liquid organic fertilizer + double drip lines, or
  - Hydrolyzed soy protein N fertilizer (water soluble but expensive)
- *SOM and irrigation water can be significant N sources for organic strawberry*

Asynchrony of N supply and N demand in an organic strawberry field in the Northern region, CA



(Muramoto et al., 2004)

Broadcasting ground almond shell and ground olive pomace (Broccoli-Strawberry Rotation 2017-18)

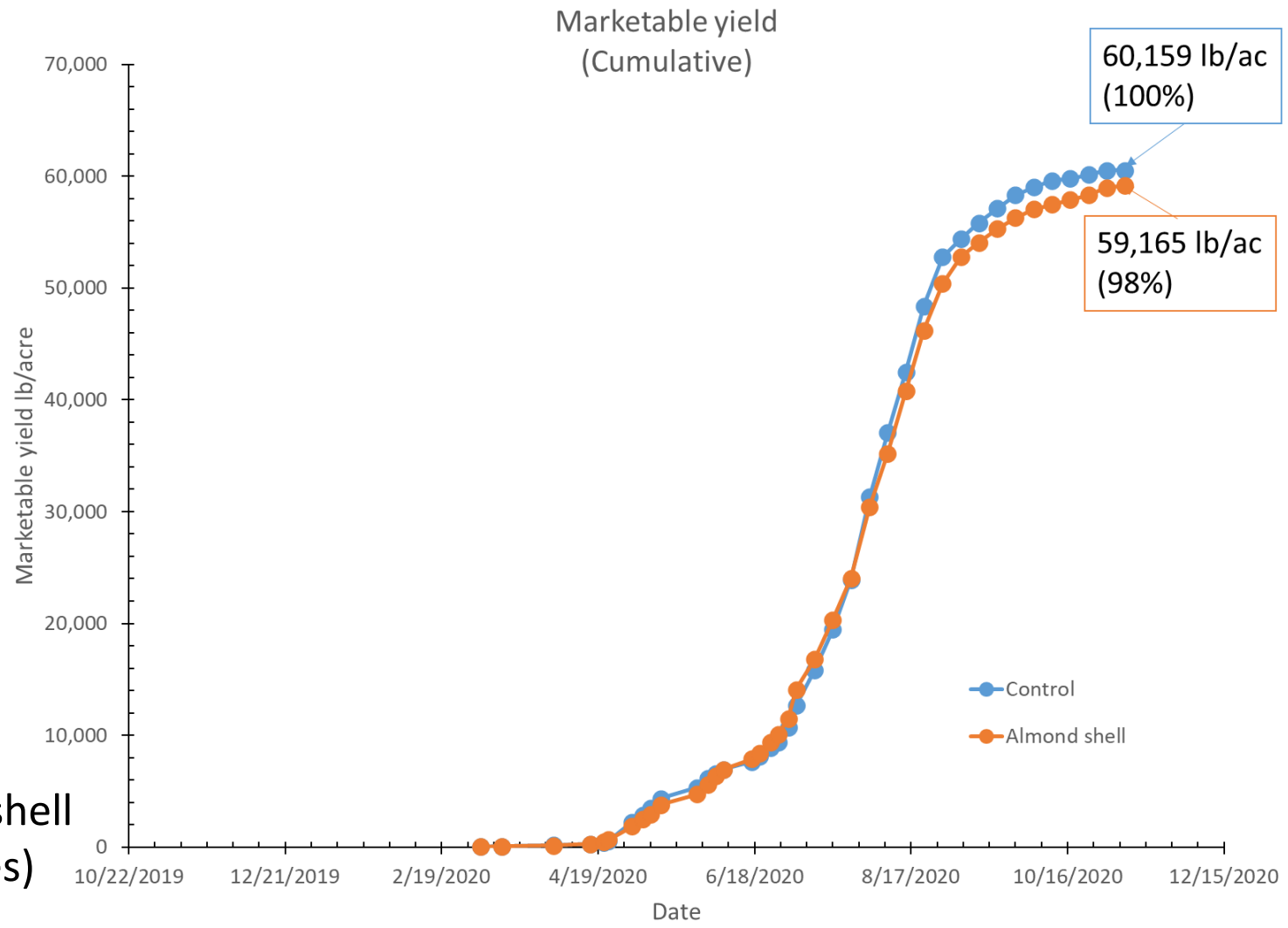


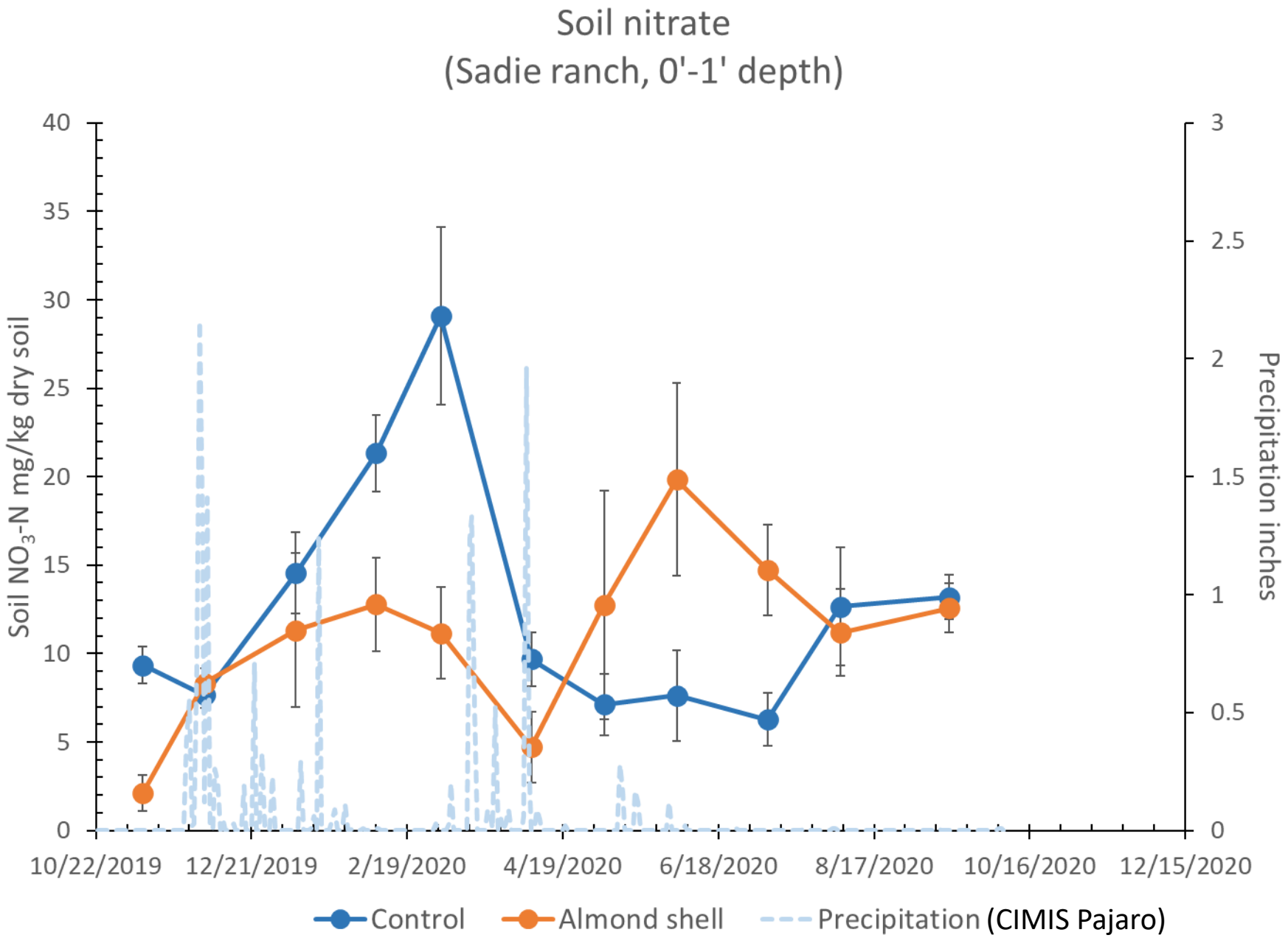
Large-scale non-replicated demonstration trial (Watsonville, CA 2019-20)

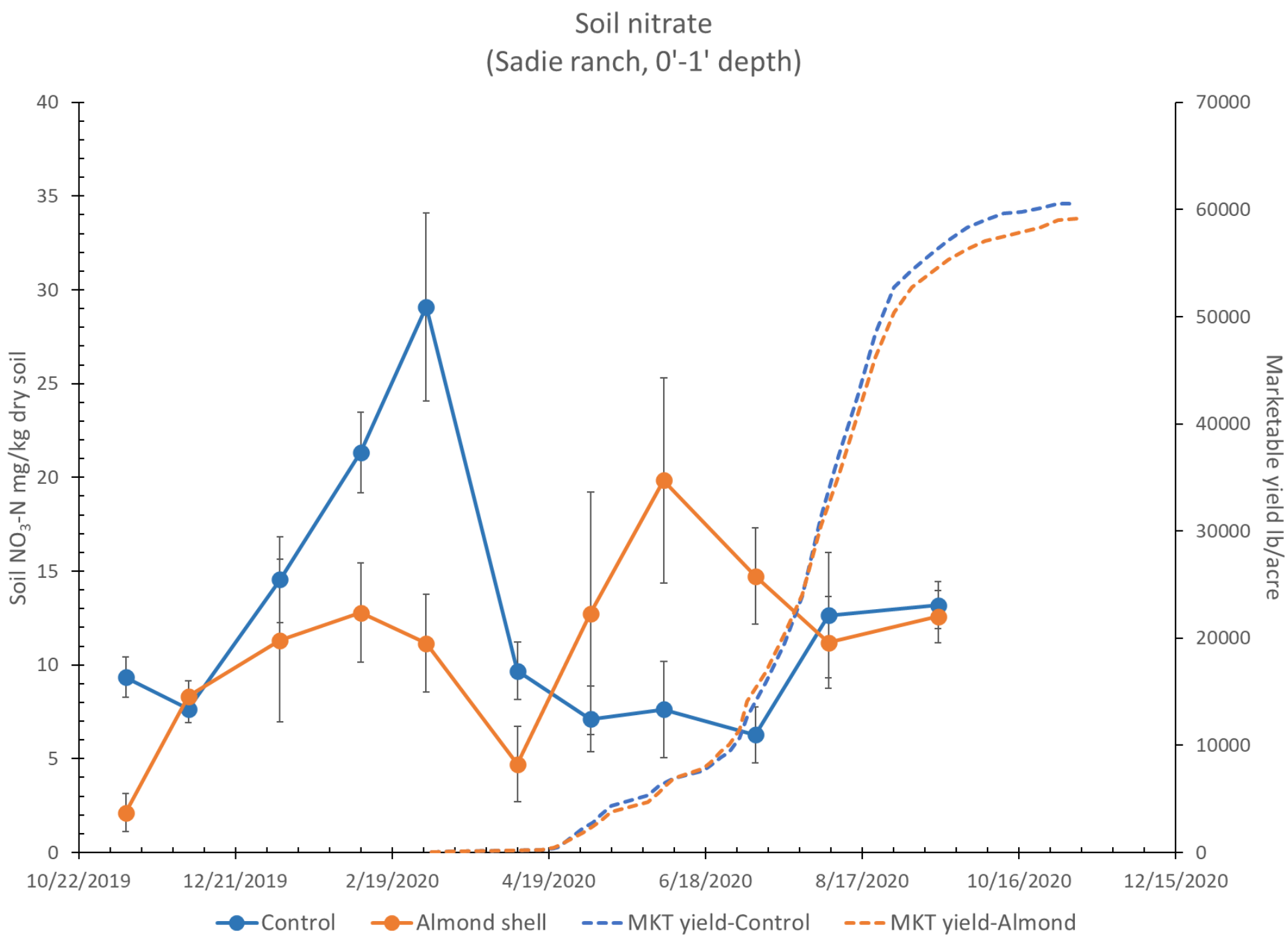
Sandy loam – loam.
Organic broccoli-strawberries.

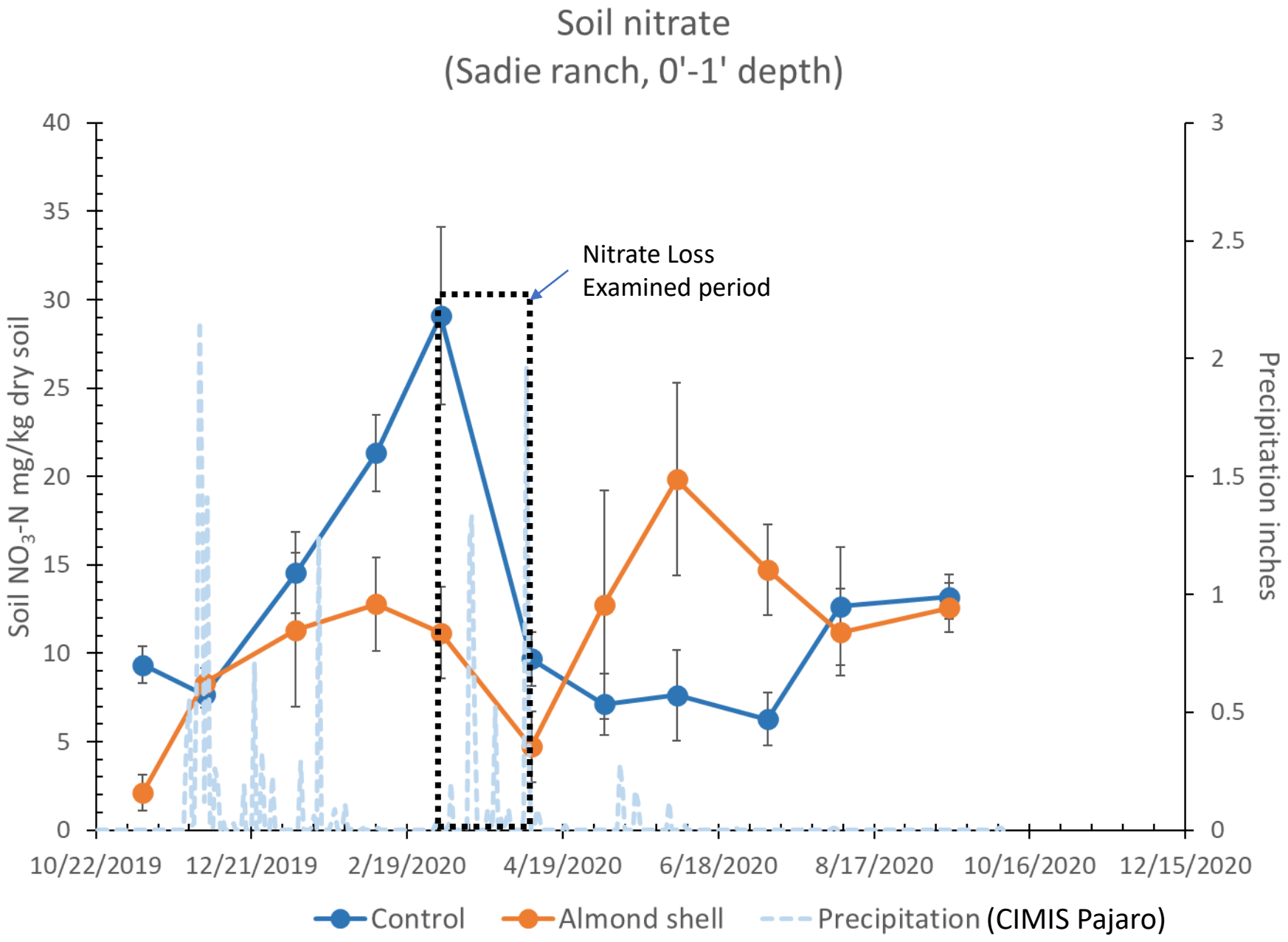
Ground almond shell
6 t/acre (3.3 acres)

Untreated control (4.2 acres)

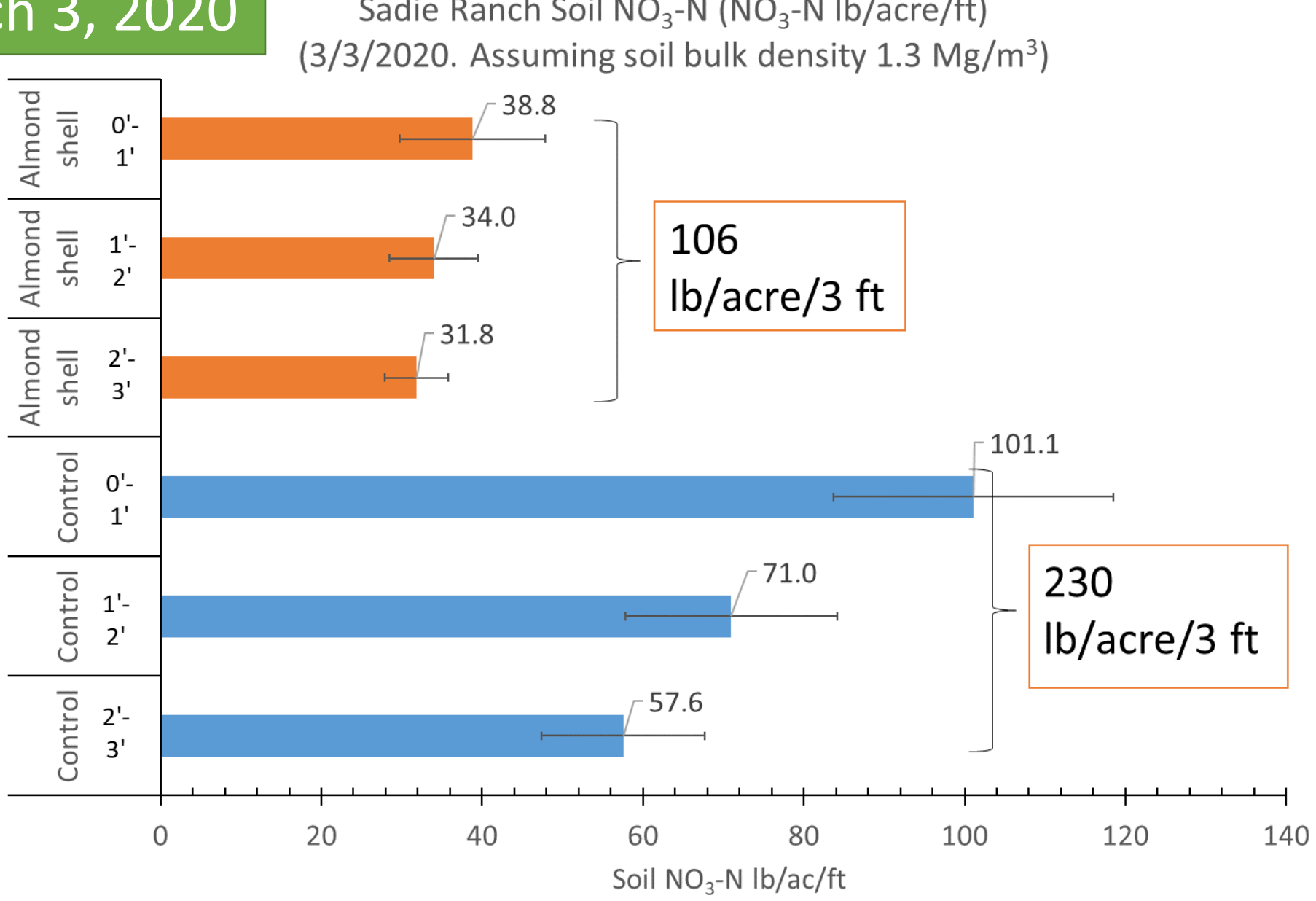



Soil nitrate
(Sadie ranch, 0'-1' depth)
Soil NO3-N mg/kg dry soil
Precipitation inches
40
35
30
25
20
15
10
5
0
3
2.5
2
1.5
1
0.5
0
10/22/2019
12/21/2019
2/19/2020
4/19/2020
6/18/2020
8/17/2020
10/16/2020
12/15/2020
Control
Almond shell
Precipitation (CIMIS Pajaro)

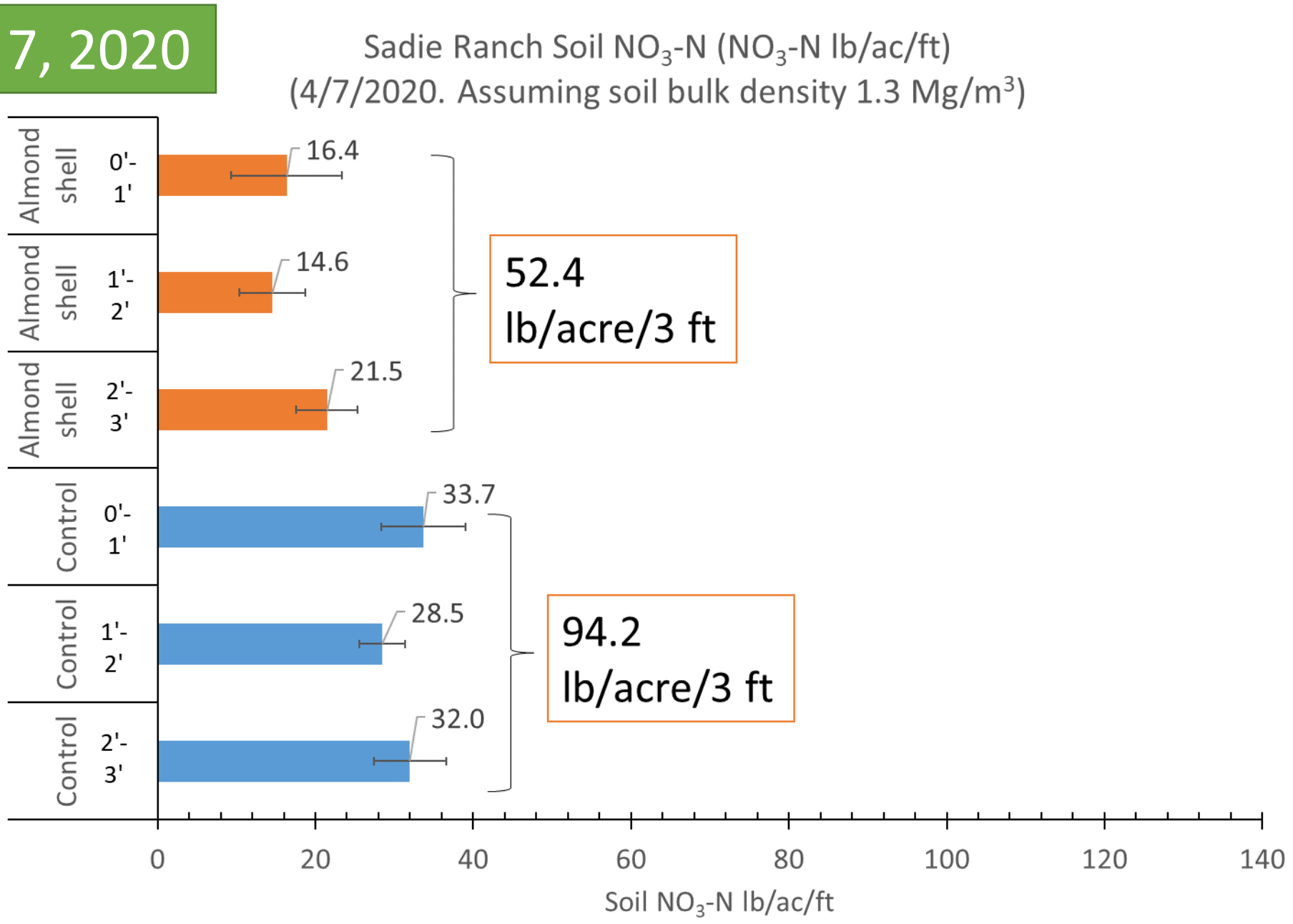

Soil nitrate
(Sadie ranch, 0'-1' depth)
Soil NO3-N mg/kg dry soil
Marketable yield lb/acre
0
5
10
15
20
25
30
35
40
0
10000
20000
30000
40000
50000
60000
70000
10/22/2019
12/21/2019
2/19/2020
4/19/2020
6/18/2020
8/17/2020
10/16/2020
12/15/2020
Control
Almond shell
MKT yield-Control
MKT yield-Almond


Soil nitrate
(Sadie ranch, 0'-1' depth)
Soil NO3-N mg/kg dry soil
Precipitation inches
Nitrate Loss
Examined period
40
35
30
25
20
15
10
5
0
3
2.5
2
1.5
1
0.5
0
10/22/2019
12/21/2019
2/19/2020
4/19/2020
6/18/2020
8/17/2020
10/16/2020
12/15/2020
Control
Almond shell
Precipitation (CIMIS Pajaro)

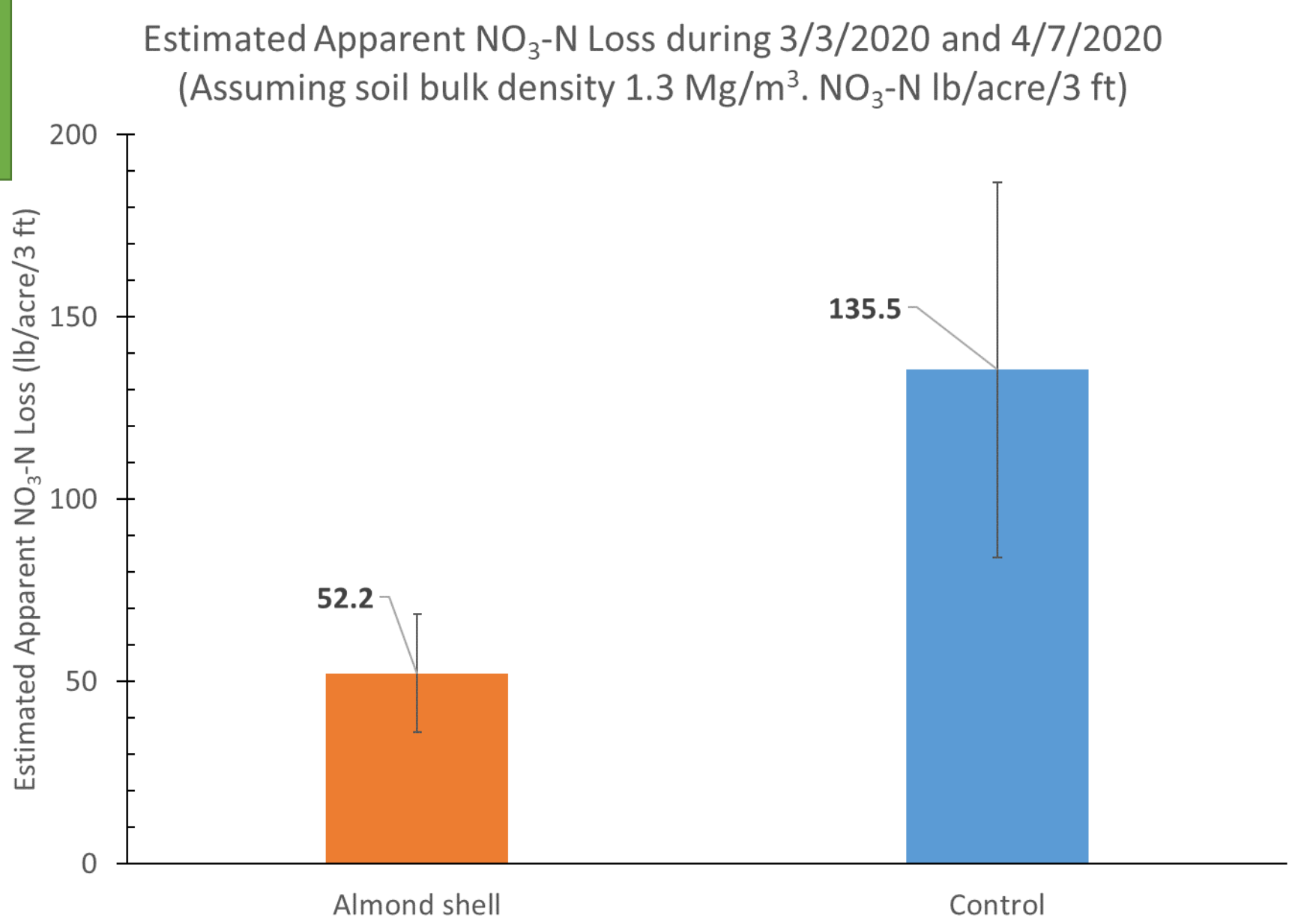
March 3, 2020


Sadie Ranch Soil NO_3-N (NO_3-N lb/acre/ft)
(3/3/2020. Assuming soil bulk density 1.3 Mg/m^3)
Almond shell 0'-1'
Almond shell 1'-2'
Almond shell 2'-3'
Control 0'-1'
Control 1'-2'
Control 2'-3'
38.8
34.0
31.8
101.1
71.0
57.6
106 lb/acre/3 ft
230 lb/acre/3 ft
0
20
40
60
80
100
120
140
Soil NO_3-N lb/ac/ft

April 7, 2020


Sadie Ranch Soil NO_3-N (NO_3-N lb/ac/ft)
(4/7/2020. Assuming soil bulk density 1.3 Mg/m^3)
Almond shell 0'-1'
16.4
Almond shell 1'-2'
14.6
Almond shell 2'-3'
21.5
52.4 lb/acre/3 ft
Control 0'-1'
33.7
Control 1'-2'
28.5
Control 2'-3'
32.0
94.2 lb/acre/3 ft
0
20
40
60
80
100
120
140
Soil NO_3-N lb/ac/ft

Nitrate Loss during March 3 and April 7



Take-home Messages

- Although the almond shell 6 tons/acre plot did not increase marketable yield, it provided a comparable yield with untreated control (98% of untreated control)
- The almond shell plot immobilized soil nitrate derived from broccoli residues during the spring storms and delayed the peak soil nitrate release in the topsoil for 3 months from March to June
- Because of this delay, the almond shell plot reduced the estimated apparent nitrate loss from 136 to 52.2 lb-N/acre/3 ft during March and April (~60% reduction compared to untreated control)
- Economic analysis to be conducted

Acknowledgements

- Peter Navarra, Jacaranda Medina, Driscoll's
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- Margherita Zavatta, Sidney Lee, Carol Shennan, UCSC

Thank you!
Question?

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