

# Factors Affecting the R Side of the A-R Metric Equation in Ag Order 4.0

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# Agricultural Order 4.0

- Ag Order 4.0 relies upon the A-R metric to regulate N loading in production fields
- $A-R = \text{Nitrogen Application Targets/Limits lbs N/A/year}$

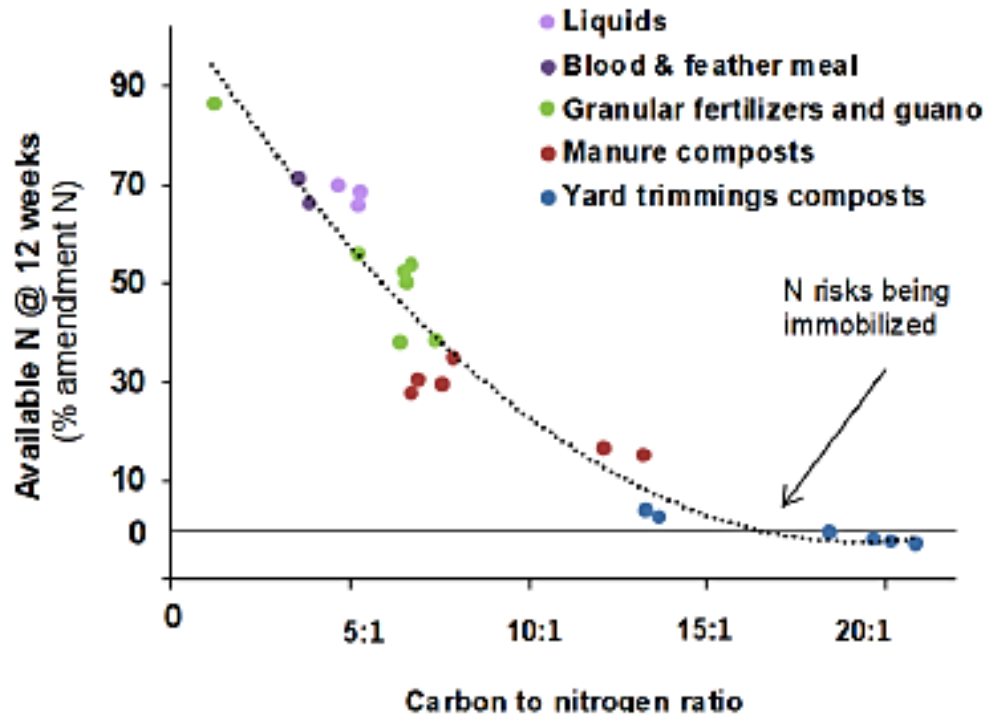
Compliance Dates*		
Target	500	2023
Target	400	2025
Limit	300	2027
Limit	200	2031
Limit	150	2036
Limit	100	2041
Limit	50	2051

# Applied Side of the Equation

$$A_{\text{FER}} + (C \times A_{\text{COMP}}) + (O \times A_{\text{ORG}}) + A_{\text{IRR}}$$

- **A in fertilizer**
- **A in compost x mineralization factor**
  - **C:N<11 = 0.10; C:N>11 = 0.05**
- **A in organic fert x mineralization factor**
  - **Uses a regression from Lazicki's paper**
- **A in Irrigation water (accounting only for the water applied to supply crop Et)**

# Nitrogen Release from Organic Fertilizers & Amendments



**Relationship between N release and C:N ratio**

Lazicki et al 2020

C to N Ratio of Organic Product	Discount Factor Based on Predicted Mineralization Rate (O)
< 1.5	1.00
1.5	0.904
2.0	0.852
2.5	0.802
3.0	0.754
3.5	0.707
4.0	0.661
4.5	0.617
5.0	0.574
5.5	0.533
6.0	0.493
6.5	0.455
7.0	0.418
7.5	0.383
8.0	0.349
8.5	0.317
9.0	0.285
9.5	0.256
10.0	0.228
10.5	0.202
11.0	0.177
11.5	0.153
12.0	0.131
12.5	0.111
13.0	0.091
13.5	0.074
14.0	0.058
14.5	0.043
15.0	0.030

Note: Refer to Attachment A, Section C.1 for a discussion of

**Table developed from the graph included in Ag Order 4.0**

# Removed Side of the Equation

$$R_{\text{harv}} + R_{\text{seq}} + R_{\text{scav}} + R_{\text{treat}} + R_{\text{other}}$$

- R in the harvested crop
- R sequestered (perennial crops - wood)
- R scavenged in cover crop and high carbon compost
- R that is treated to remove N (e.g. denitrification beds)
- R other demonstratable forms of removal (e.g. denitrification from field?)

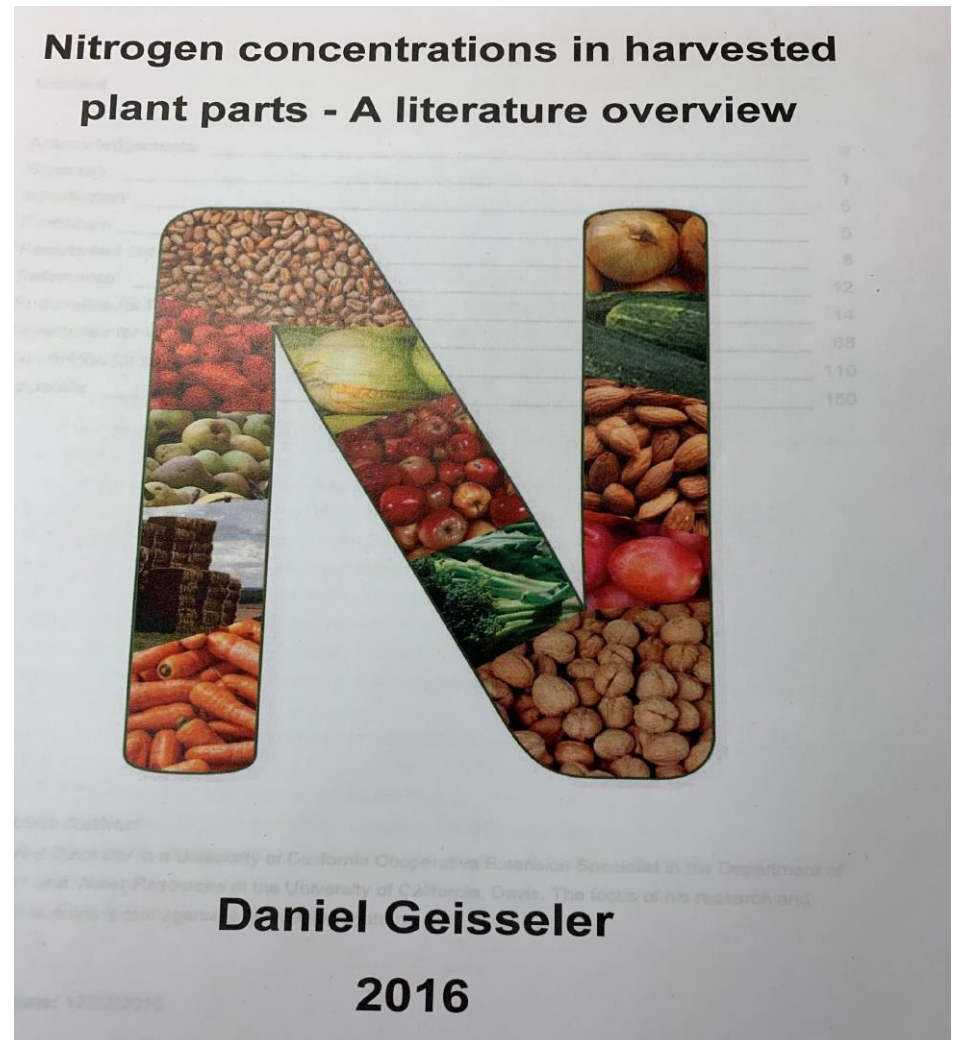
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# Crop N Removal Coefficients

- **N removal coefficient is calculated by multiplying the N and water content of the harvested product**
- **Current coefficients in Order 4.0 are based on this literature search**



# Crop N Removal Coefficients

- **Over the past two years we have been filling in the data gaps in removal coefficients**
- **Collected samples from commercial harvest crews and measure moisture and nitrogen content**



**Funding from FREP and CLGRB**

**Artichoke, annual**  
**Arugula**  
**Beet**  
**Blueberry**  
**Bok Choy**  
**Broccolini**  
**Cabbage, Green**  
**Cabbage, Red**  
**Cauliflower**  
**Celery**  
**Chinese celery**  
**Endive**  
**Fennel**  
**Frissee**  
**Gai Choy (Mustard Greens)**  
**Kale, curled leaf multi pick**  
**Leek**

**Lettuce, Butter leaf**  
**Lettuce, Green leaf**  
**Lettuce, Iceberg**  
**Lettuce, Red leaf**  
**Lettuce, Romaine**  
**Napa Cabbage**  
**Onion, dry bulb (yellow and red)**  
**Parsley**  
**Pepper**  
**Radicchio**  
**Radish**  
**Rapini**  
**Shallot**  
**Snap Peas**  
**Tung Ho (Edible Chrysanthemum)**  
**Yam (leaves)**

# Lettuces Broken Out By Pack Types

<b>Commodity</b>	<b>Product</b>	<b>Pack type</b>
<b>Butter</b>	<b>Fresh Market</b>	<b>Carton</b>
<b>Green Leaf</b>	<b>Fresh Market</b>	<b>Carton</b>
<b>Red Leaf</b>	<b>Fresh Market</b>	<b>Carton</b>
<b>Head Lettuce</b>	<b>Bulk</b>	<b>Field Cored</b>
<b>Head Lettuce</b>	<b>Fresh Market</b>	<b>Film Wrap</b>
<b>Head Lettuce</b>	<b>Fresh Market</b>	<b>Liner</b>
<b>Romaine</b>	<b>Bulk</b>	<b>Bulk</b>
<b>Romaine</b>	<b>Fresh Market</b>	<b>Liner</b>
<b>Romaine</b>	<b>Hearts</b>	<b>Carton</b>
<b>Endive</b>	<b>Fresh Market</b>	<b>Carton</b>
<b>Escarole</b>	<b>Fresh Market</b>	<b>Carton</b>

# Coefficients Varied by Plant Part Harvested

<b>Veg type</b>	<b>Percent N</b>	<b>Coefficient</b>
<b>Bulb</b> (onion)	<b>1.6</b>	<b>0.00186</b>
<b>Petioles</b> (celery)	<b>2.1</b>	<b>0.00104</b>
<b>Whole plant</b> (beets)	<b>2.9</b>	<b>0.00244</b>
<b>Fruit</b> (peas)	<b>2.9</b>	<b>0.00333</b>
<b>Whole Head</b> (lettuce)	<b>3.2</b>	<b>0.00205</b>
<b>Flower</b> (broccoli)	<b>4.6</b>	<b>0.00434</b>
<b>Leaves</b> (cilantro)	<b>4.7</b>	<b>0.00465</b>

# Example of R Calculation for N Removed by Romaine

Commodity	Percent Solids	Percent N	Coefficient Mean*	Coefficient Minimum	Coefficient Maximum
Romaine (Liner)	5.91	3.09	0.00182	0.00147	0.00243

\*  $0.0591 \times 0.0309 = 0.00182$

**N removal in a typical romaine harvest**

Yield	Mean Lbs N/A	Minimum Lbs N/A	Max Lbs N/A
30,000	55	44	73

# Removed Side of the Equation

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- R that is treated to remove N (e.g. denitrification beds)
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# Scavenging Nitrogen from Crop Residues Over Winter

- The amount of N/A in crop residues:
- 40-60 lbs for lettuce and spinach
- 100-150 for celery
- >200 for broccoli and cauliflower



# **Ag Order Cover Crop Definition**

- Cover crop grown on a ranch to prevent leaching of nitrate during the wet/rainy season (Oct-April). Must not contain nitrogen fixing plants. Must be grown for three months during the wet/rainy season. Must have a minimum estimated biomass of 4,500 lbs/A of oven dry shoot weight. Must have a C:N ratio of equal to or greater than 20:1.**
- N credit is the difference of N contained in the cover crop and the amount mineralized based on the organic fertilizer discount factor (97%).**

# **Ag Order Cover Crop Credits**

- **Cover crops grown during the winter months stipulated in Ag Order 4.0 (Oct-April) can accumulate 100 - 200 lbs N/A**
- **These cover crops represent a significant credit on the R side of the equation, even if only grown on a percentage of a grower's acreage**

# **Ag Order Cover Crop Credits**

- **Given scheduling and economic barriers, can growers realistically increase the use of over wintered cover crops?**
- **Fall-grown cover crops (incorporated by end of November) do not technically fit the Ag Order definition for a cover crop, but may be more realistic option for including cover crops**

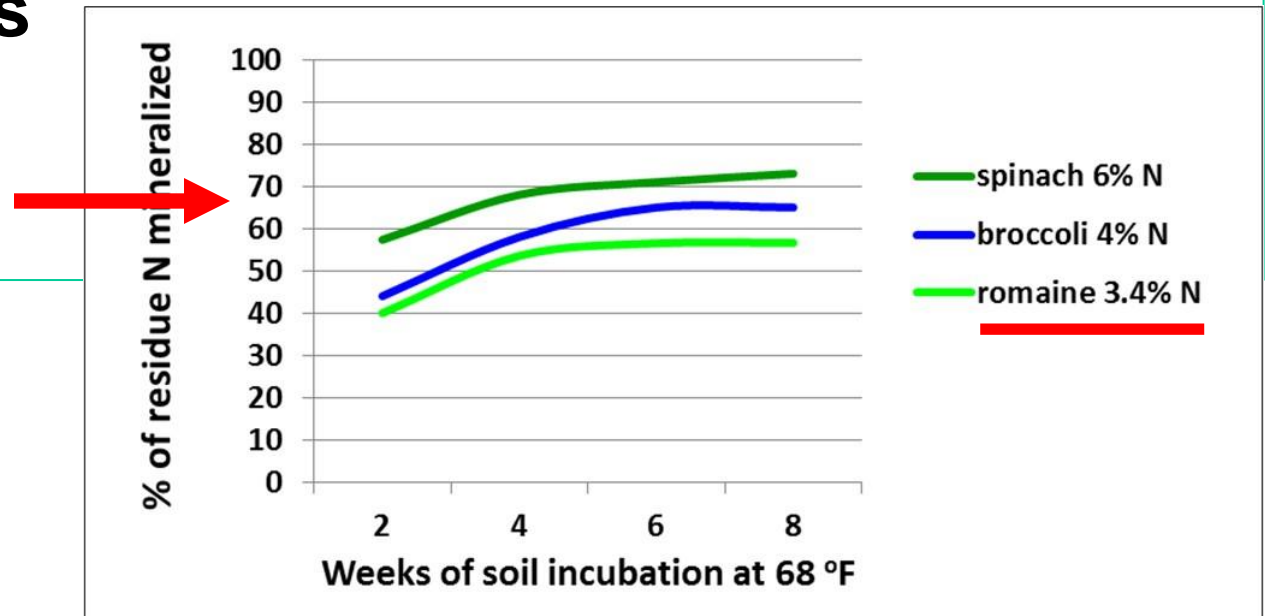
# Fall Cover Crop Evaluation

Average of Four Fields (Aug-Oct 2021)

Variety	Growth Stage	Dry biomass	Lbs N/A Biomass	%N	C:N
Barley 696	Early Flower	5,598	192	3.5	12.1
Barley 937	Early Flower	4,618	159	3.5	12.4
Merced Rye	Full Flower	5,544	171	3.2	13.7

# Ag Order Cover Crop Credits

- Research is needed to determine if a credit can be awarded fall cover crops for the N that they take up that does not mineralize in the 12-14 week period following incorporation (e.g. November to Feb/March). Given the evaluations from other crops, the credit could range from 30-50% of N contained in the cover crops



# Removal Side of the Equation

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- R scavenged in cover crop and **high carbon amendment**
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# High Carbon Amendment

- **Must have a C:N ratio of greater than 30:1. Must be finely ground to less than ¼ inch in diameter. Must be incorporated into the top foot of soil. Must be retained for a minimum of three months during the wet/rainy season. Must have minimum application rate of 10,000 lbs/A.**
- **If these criteria are met, can get a credit of 30 lbs N/A**

# Ground Almond Shell Evaluation

Treatment	N load top 3 feet lbs N/A	Nitrate-N Reduction lbs N/A
Untreated	330	---
Almond Shells 5 T/A	215	115
Almond Shells 10 T/A	175	155



Unground



Ground

# **High Carbon Amendment**

- **Almond shells ground to 2mm sieve and glycerol in our initial studies were highly effective**
- **However, give the high cost of these materials we began looking for a local source of carbon that would also be effective**

# Cost per Ton of Material

<b>Expense</b>	<b>Forest mulch</b>	<b>Ground almond shells</b>	<b>Unground almond shells</b>
<b>Material</b>	<b>0.00</b>	<b>15.00</b>	<b>15.00</b>
<b>Trucking</b>	<b>0.00</b>	<b>37.50</b>	<b>37.50</b>
<b>Grinding</b>	<b>20.00</b>	<b>20.00</b>	<b>0.00</b>
<b>Spreading</b>	<b>8.00</b>	<b>8.00</b>	<b>8.00</b>
<b>Total Costs</b>	<b>28.00</b>	<b>80.50</b>	<b>60.50</b>

# Local Ground Amendment



- We examined a local source of ground tree trunks/limbs
- The material is ground to 3/8 inch
- That is not fine enough, but we hoped there would be sufficient fines

# Local Ground Amendment



- The material did not work well enough due to:
  - Not ground fine enough
  - Tree limb/trunk carbon may not be active enough to stimulate soil microbes

# Almond Shells



- **We are back to examining partially ground almond shells**
- **The carbon they contain is highly labile**
- **The challenge is the cost of transportation and grinding**
- **This research is on-going**

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# Treatment

- **Wood chip denitrification bioreactors**
- **Treat tile water**
- **Can draw down the nitrate-N levels by 8-10 ppm/day in summer (5 ppm/day winter)**
- **This is modest because tile water levels often range from 60-190 ppm nitrate-N**
- **Enriching with soluble carbon can increase removal but increases the cost**



**Carbon from the wood chips stimulates denitrification**  
**Nitrate → N gas**

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# **Other Demonstratable Forms of Removal**

- Not all N unaccounted for losses of N are due to leaching**
- As more research is conducted, we will improve our understanding of “other” forms of N loss**

# **One Example: Denitrification**

- Denitrification (gaseous loss of nitrogen) from the soil occurs in anaerobic conditions, for example, saturated conditions, even if temporary.**
- A study by Ryden and Lund (1980) measured 18 to 37 lbs N/A in lettuce and celery fields in Santa Barbara County on clay loam soil with furrow irrigation**
- In 2010-11 we measured 2-4 lbs N/A loss from a lettuce crop on a sandy soil with drip irrigation**
- These studies indicate that the role of denitrification from production fields may be variable, but may be significant in some situations**
- This issue needs further research to better understand the amount of nitrogen loss from denitrification**

# **The Role of Research**

- **Ag Order 4.0 is not a static document**
- **The Regional Water Quality Control Board will review the state of science in 5 years, and they are open to updating it as new understanding is developed**