PODF
PRAIRIE ORGANIC DEVELOPMENT FUND

LESSON 1
January 5, 2023

Designing Cropping Systems with a Focus on Nutrient Management

PODF
PRAIRIE ORGANIC DEVELOPMENT FUND

The Prairie Organic Development Fund

- Investment platform established to develop organic agriculture and marketing in the Canadian Prairies
- Builds resilience in the sector by investing in
  - organic provincial associations (Capacity Fund); and
  - high impact programs (Innovation Fund) related to marketing, research, policy, education and capacity development that have broad public benefit to the organic sector.

www.organicdevelopmentfund.org

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We gratefully acknowledge funding from the Canadian Agricultural Partnership.

www.organicdevelopmentfund.org

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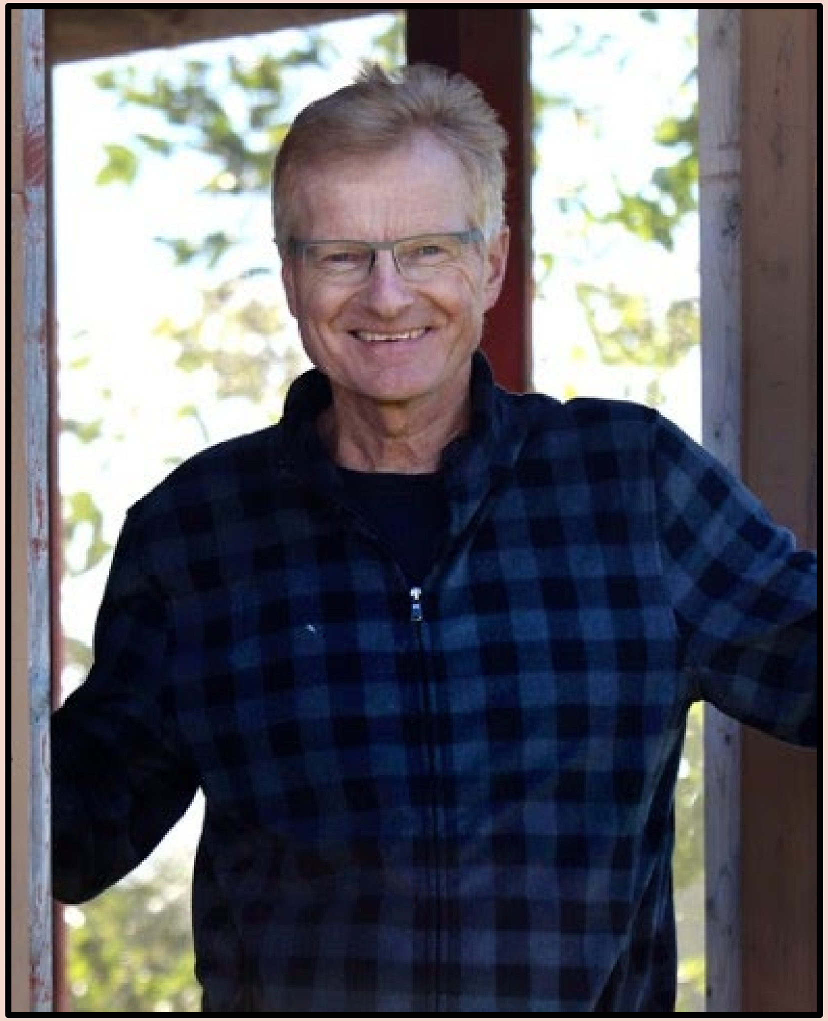
umanitoba.ca/outreach/naturalagriculture/



Agronomist Training Learning Format

Day 1: Designing cropping systems with a focus on nutrient management

Day 2: Crop establishment and seeding systems, tillage, and weed control

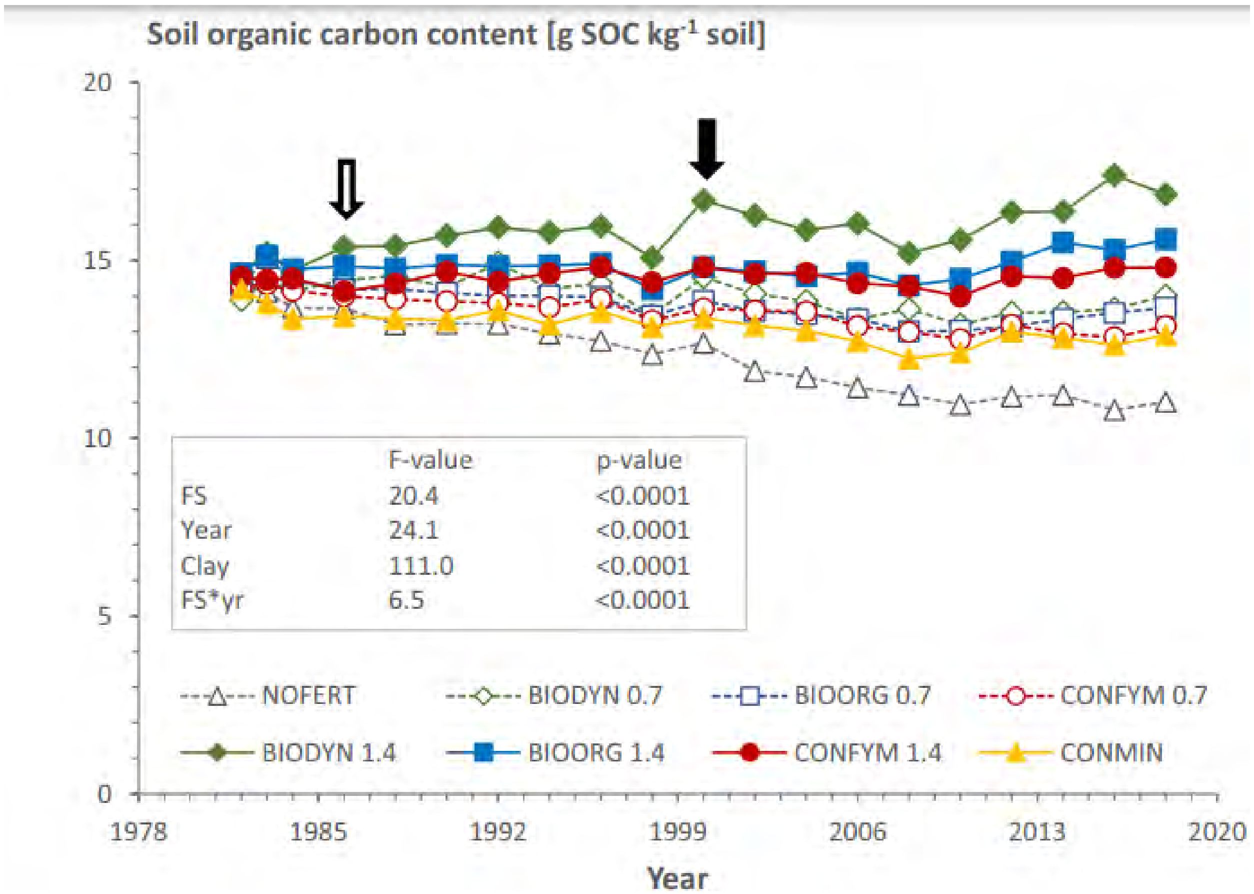
Day 3: Pest management with focus on diseases, insects (and weeds)

Day 4: Soil management for organic production: Putting theory into practice

Day 5: The questions raised on days 1-4 will all be answered. A written answer will be provided for each question. Participants can raise additional questions in the discussion period.

Question: What is better, fresh manure or composted manure?
My answer: From P perspective, no difference. From information below, composting manure resulted in more soil organic matter – after less than 10 years

Krause, H.M., Stehle, B., Mayer, J., Mayer, M., Steffens, M., Mäder, P. and Fliessbach, A., 2022. Biological soil quality and soil organic carbon change in biodynamic, organic, and conventional farming systems after 42 years. *Agronomy for Sustainable Development*, *42*(6), pp.1-14.



Compare red (fresh manure) and green (composted) lines

Let’s get started: Crop/plant options for organic production

- Legumes
  - Required to add N
- Cereals
- Oilseeds
- Other grains
  - eg., buckwheat
- Forages
  - Perennial
  - Annual
- Cover crops
- Flower/pollinator strips
- Shelterbelt trees

Spring wheat


Hemp

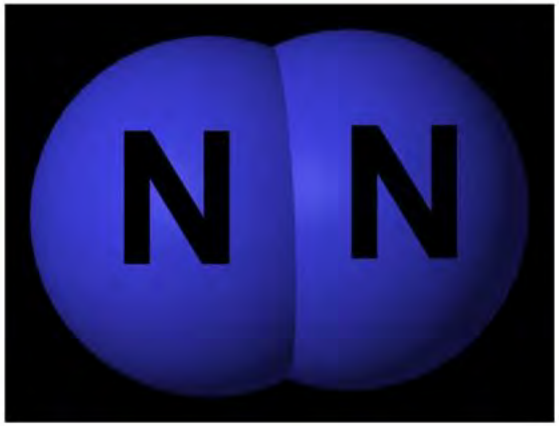
Oats

Fall rye

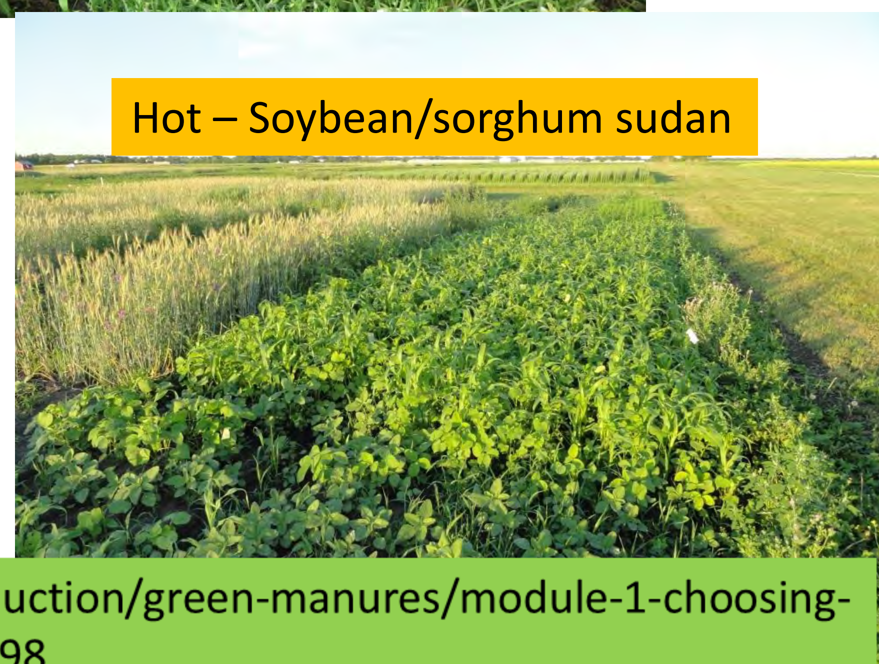
Peas


Flax

Legumes – critical to supply nitrogen



N_2



http://www.pivotandgrow.com/resources/production/green-manures/module-1-choosing-a-green-manure/#1467244573285-63e76f6c-cf98


Sweet clover green manure
Red clover green manure

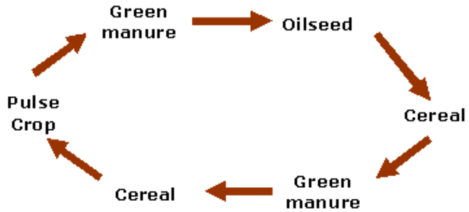
Traditional row crops in organic production in Quebec

Small grains in Ontario organic corn-soy system

Crop/plant options for organic production

- Legumes
    - Required to add N
- Cereals
- Oilseeds
- Other grains
    - eg., buckwheat
- Forages
    - Perennial
    - Annual
- Cover crops
- Flower/pollinator strips
- Shelterbelt trees

SE Saskatchewan	Alberta	Manitoba	PEI	Ontario	Quebec
Alfalfa seed 3 years	Green manure (cereal/pulse)	Green manure (grazed)	Red clover green manure	3 years legume/grass forage	Soybean
Hemp	Fall rye	Wheat or flax	Spring wheat	Winter canola	Winter wheat/pea or clover cover crop
Flax (underseeded to alfalfa)	Food grade pea/oat intercrop	Lentil or pea	Soybeans	Spelt	Corn (ryegrass cover crop interseeded)
or	Green manure (cereal/pulse)	Alfalfa hay (2 years	Pea/barley intercrop	Soybean	
Green manure (year 1)	Spring wheat	Wheat or flax	Oats underseeded to red clover	Oat/pea grain	
Spring wheat (year 2)	Pea/barley intercrop (feed)	Oats			
Two different rotations depend on soils	*Green manure every 3rd year*	*High diversity. Livestock integration*	*Diversity of legume species*	*Winter and spring seeded grains*	*Manure used to supply some N*



Organic Crop Yields

Table 1. Yields of green manure and grain crops in the Organic Crops Field Laboratory, Carman, MB. Each parcel of land, or rotation block, can be followed through the table by following a specific colour. Where two crops are listed for a particular year, those crops were grown on two different parts of that rotation block.

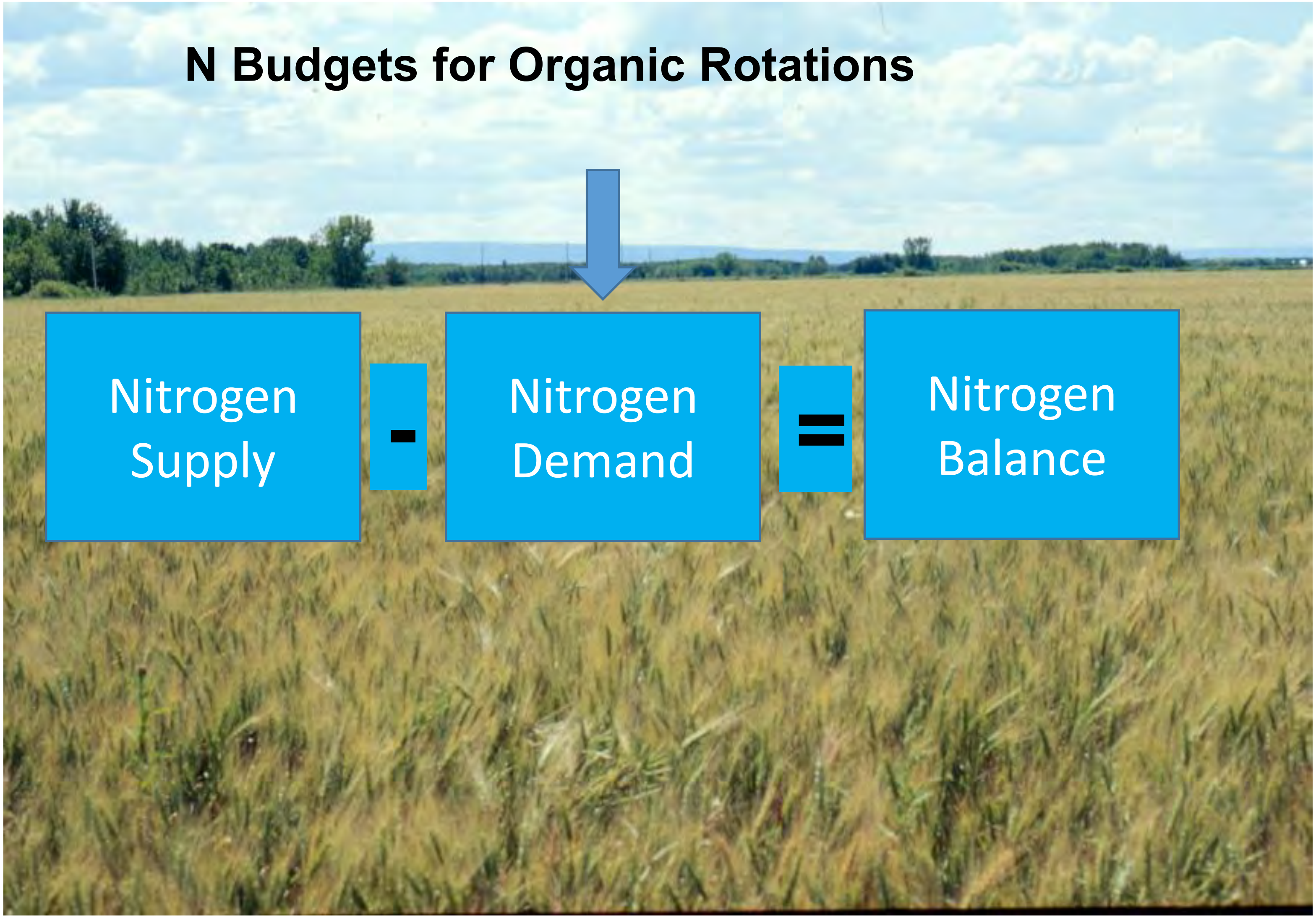
	Year 1		Year 2	Year 3	Year 4		Year 5		Year 6	
	Green Manure		Cereal	Pulse	Hay / green manure		Oilseed		Cereal	
	Pea / oat	Chickling vetch	Wheat	Soybean	Berseem clover / alfalfa	Barley or oat / hairy vetch	Flax	Buckwheat	Fall rye	Oats
	lb/ac	lb/ac	bu/ac	bu/ac	lb/ac	lb/ac	bu/ac	bu/ac	bu/ac	bu/ac
2004*	4804	-	-	-	-	-	-	-	-	-
2005	-	3721 (29% weeds)	34	32.5	2435 (65% weeds)	-	18	-	-	18
2006	-	3101 (42% weeds)	50	23	4375 (70% weeds)	-	24	-	-	73
2007	7566	-	43	32	-	7050	16	9	60	-
2008	5164	-	54	26.5	-	6227	18	-	53	51
2009	5489	-	60	28	-	7038	33	-	26	107
2010	3499		49	32		8064	24		-	106
Average	**5304**	**3411**	**48**	**29**	**3405**	**7095**	**22**	**9**	**46**	**71**

*In 2004, a pea/oat green manure was grown on all six rotation blocks.

Rotations must consider nutrient budgeting

Entz, M.H., Guilford, R. and Gulden, R., 2001. Crop yield and soil nutrient status on 14 organic farms in the eastern portion of the northern Great Plains. *Canadian Journal of Plant Science*, *81*(2), pp.351-354.

	Manitoba (kg/ha)		Australia (mg/kg)	
	Organic	Conv'l	Organic	Conv'l
Nitrogen	92.5	70		
Phosphorous	15.5	30	14.2	27.2
Potassium (Australia - meq/kg)	654	700	1.58	1.69
Sulfur	101	60	16.4	26.9
Copper			0.70	0.57
Zinc			0.85	0.56
Iron			14	15


N Budgets for Organic Rotations
Nitrogen Supply
-
Nitrogen Demand
=
Nitrogen Balance

Rough N contributions from legumes

Cropping system		Amount of N contributed
Annual green manures and legume cover crops		2.5% of above ground dry matter is fixed N
Perennial alfalfa		130 lb/acre if hay stand 2 years or longer
Grain legume		see table below

Grain Legume	N addition to following crop
Pea, lentil, fababean	10-15 kg N/1000 kg of seed harvested
Chickpea	3 kg N/1000 kg of seed harvested
Dry bean	1 kg N/1000 kg of seed harvested
Soybean	1 kg N/1000 kg of seed harvested

Rule of thumb

4000 lb/acre @ 2.5% N = 100 lb/ac

60% available in first year = 60 lb/acre

40% available in second year = 40 lb/ac

Anglade, J.A., Billen, G., and Garnier, J. 2015. Relationships for estimating N2 fixation in legumes: incidence for N balance of legume-based cropping systems in Europe. Ecosphere, 6: 37. doi:10.1890/ES14-00353.1.

Full season legume green manure

Crop demand

Crop	N	$P_2 0_5$	$K_2 0$	S
Crop nutrient removal (lb/bushel)				
Wheat 10% protein	1.2	0.5	0.35	0.1
12%	1.5	0.5	0.35	0.1
14%	1.9	0.5	0.35	0.1
Barley	1.1	0.36	0.35	0.07
Oat	.96	0.25	0.18	0.06
Corn	0.75	0.37	0.27	
Pea	2.3	0.7	0.7	0.14
Flax	2.12	0.6	0.6	0.2
Sunflower (lb/lb)	0.026	0.008	0.006	0.002
Alfalfa (lb/ton)	56	15	60	5
Bromegrass (lb/t)	36	13	59	3

A **bushel of corn removes** about 0.75 **lb nitrogen**, 0.37 **lb** P2O5, and 0.27 **lb** K2O from the soil. A **bushel** of soybeans will **remove** 4 **lbs nitrogen**, 0.8 **lb** P2O5, 1.4 **lbs** K2O (Figure 1).

Crop nutrient removal: Wheat grain example

30 bushels per acre x *1.9 lb N/bu = 57 lb N removed

48 bushels per acre x **1.5 lbN/bu = 72 lb N removed

*14% protein
**12% protein


Grain crops with green manures
Green manure – wheat - flax

Crop	N	P	K	S
Nutrient balance (lb/ac)				
Green manure pea, lentil or c. vetch 4000 lb/ac @2.5% N	+100			
Wheat (30 bu/ac)	-57			
Flax (14 bu/ac)	-30			
Long-term balance	**+13**			

Green manure-wheat-flax-oat

Crop	N	P	K	S
Nutrient balance (lb/ac)				
Green manure pea, lentil or c. vetch 4000 lb/ac @2.5% N	+100			
Wheat (30 bu/ac)	-57			
Flax (14 bu/ac)	-30			
Oat (50 bu/ac)	-48			
Long-term balance	**-35**			

SE Saskatchewan	Alberta	Manitoba	PEI	Ontario	Quebec
Alfalfa seed 3 years	Green manure (cereal/pulse)	Green manure (grazed)	Red clover green [illegible]	3 years [illegible]	Soybean
Hemp	[illegible]	[illegible]	[illegible]	[illegible]nter canola	Winter wheat/pea or clover cover crop
Flax (underseeded to alfalfa)	Food grade pea/oat intercrop	Lentil or pea	Soybeans	Spelt	Corn (ryegrass cover crop interseeded)
or	Green manure (cereal/pulse)	Alfalfa hay (2 years	Pea/barley intercrop	Soybean	
Green manure (year 1)	Spring wheat	Wheat or flax	Oats underseeded to red clover	Oat/pea grain	
Spring wheat (year 2)	Pea/barley intercrop (feed)	Oats			
Two different rotations depend on soils	*Green manure every 3rd year*	*High diversity. Livestock integration*	*Diversity of legume species*	*Winter and spring seeded grains*	*Manure used to supply some N*

No farmer rotations had 3 “extractive” crops after a legume phase

Crop	N	P	K	S
Nutrient balance (lb/ac)				
Green manure pea, lentil or c. vetch 4000 lb/ac @2.5% N	+100			
Wheat (30 bu/ac)	-57			
Flax (14 bu/ac)	-30			
Oat (50 bu/ac)	-48			
Long-term balance	**-35**			

N deficit filled from soil organic matter


Green manure – wheat – pulse - cereal

Rough N contributions from legumes

Cropping system		Amount of N contributed
Annual green manures and legume cover crops		2.5% of above ground dry matter is fixed N
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Crop	N	P	K	S
Nutrient balance (lb/ac)				
Green manure pea, lentil or c. vetch 4000 lb/ac @2.5% N	+100			
Wheat (30 bu/ac)	-57			
Soybean (30 bu/ac)	* +3			
Oat (50 bu/ac)	-48			
Long-term balance	**-2**			

*Manitoba. N contribution in Eastern Canada likely higher

Crop	N	P	K	S
Nutrient balance (lb/ac)				
Green manure pea, lentil or c. vetch 4000 lb/ac @2.5% N	+100			
Wheat (30 bu/ac)	-57			
Peas (30 bu/ac)	+20			
Oat (50 bu/ac)	-48			
Long-term balance	**+20**			

Surplus N added to soil organic matter

Because soil has a C:N ratio of about 10, increases in soil N allow for increases in soil C.

Example of N benefit of a pea grain crop…

Pulse crop researcher, Kristen McMillan, (presenter) has demonstrated that certain edible dry bean varieties do not require any supplemental N fertilizer. This is a “Game changer” for organic dry bean production.

Reality check: What are farmers experiencing?

Plant biomass production was highly variable, ranging from 1736 to 11 744 kg/ha, with a mean of 4572 kg/ha.

Weed proportion in total biomass averaged 18%

Estimates of N fixation ranged from near zero to over 300 kg N/ha, with a mean and median of 71 and 47 kg N/ ha, respectively

Table 1. Biomass and nutrient concentration properties of 41 green manures in the eastern prairie region of Canad

Legume species[a]	Other species[a]	Site	Province	Year	Soil properties: pH	Soil properties: Organic matter (%)	Soil properties: Olsen P (mg kg^{-1})	Aboveground biomass: Total (kg ha^{-1})	Aboveground biomass: Legume (kg ha^{-1})	Aboveground biomass: Weeds (kg ha^{-1})	Biomass proportion: Legume (%)	Biomass proportion: Weeds (%)
Alfalfa	—	Kamsack	SK	2015	7.5	7.0	4	4148	4065	83	98	2
Alfalfa	—	Kamsack	SK	2015	7.8	3.3	4	2574	1776	798	69	31
Alfalfa	Forage grasses	Melville	SK	2015	8.0	4.0	3	4221	1899	17	45	0.4
Alfalfa	Forage grasses	Melville	SK	2016	8.2	4.1	6	3504	1577[b]	0[b]	45[b]	0[b]
Alfalfa	Forage grasses	Melville	SK	2016	8.0	3.7	7	3184	1433[b]	0[b]	45[b]	0[b]
Alfalfa	Forage grasses	Carman	MB	2016	5.6	4.0	17	5740	3214	287	56	5
Red clover	—	Brandon 1	MB	2015	7.6	6.7	3	3826	1798	383	47	10
Red clover	—	Notre Dame	MB	2016	7.5	3.0	3	7321	7175	146	98	2
Red clover	—	St. Claude	MB	2016	7.6	1.4	5	2580	1445	206	56	8
Red clover	—	St. Claude	MB	2016	7.7	1.7	4	4090	2290	123	56	3
Red clover, hairy vetch	Fall rye	Kenton	MB	2015	8.3	4.6	3	2160	1080	432	50	20
Red clover, hairy vetch	Fall rye	Kenton	MB	2016	8.0	5.4	3	4520	2983	1175	66	26
Red clover, sweet clover	—	Nesbitt	MB	2015	8.0	4.8	4	3652	2739	913	25	75
Sweet clover	—	Austin	MB	2015	8.1	1.4	9	5583	5136	447	92	8
Sweet clover	—	Brandon 1	MB	2016	7.0	6.6	3	4040	2101	1939	52	48
Sweet clover	—	Brandon 1	MB	2016	7.6	6.2	3	3704	3074	630	83	17
Sweet clover	—	Miami	MB	2016	7.0	4.3	3	6176	5188	988	84	16
Sweet clover	—	Somerset	MB	2015	6.4	4.5	18	1988	954	1034	48	52
Fababean	Barley	Brandon 2	MB	2015	7.4	7.0	3	2335	327	1401	14	60
Fababean	Oat	Winkler	MB	2015	8.3	2.7	61	6038	1449	604	24	10
Fababean	Oat, barley	Carman	MB	2016	5.5	3.5	24	5100	1071	714	21	14
Pea	Barley	Brandon 2	MB	2015	8.2	3.8	4	3114	1090	1152	35	37
Pea	Oat	Brandon 2	MB	2016	7.8	6.2	3	5003	2852	1201	57	24
Pea	Oat	Nesbitt	MB	2015	7.8	5.7	4	3763	903	1242	24	33
Pea	Oat	Nesbitt	MB	2016	6.9	6.2	5	3648	876	292	24	8
Pea	Oat	Notre Dame	MB	2015	8.0	4.0	7	1736	1163	278	67	16
Pea	Oat	Notre Dame	MB	2015	7.5	5.2	5	3362	807	1345	24	40
Pea	Oat	Winkler	MB	2015	8.3	3.2	44	6898	1311	414	19	6
Pea	Oat	Winkler	MB	2016	8.1	2.4	36	3995	2637	120	66	3
Pea	Oat	Marquette	MB	2016	7.8	6.8	13	3701	3183	0	86	0
Pea	Oat	Marquette	MB	2016	7.9	5.0	6	5589	2627	168	47	3
Pea	Oat	Carman	MB	2016	5.5	3.5	24	4175	1336	459	32	11
Pea, hairy vetch	Oat, buckwheat	St. Claude	MB	2015	8.4	3.4	3	5202	1196	1769	23	34
Pea, hairy vetch	Oat, millet	Brandon 2	MB	2016	8.1	7.2	4	4600	506	3266	11	71
Pea, hairy vetch	Oat, radish, sunflower	Brandon 1	MB	2016	7.7	7.0	6	3561	285	1709	8	48
Hairy vetch	Barley	Carman	MB	2015	5.5	3.3	10	9581	8144[b]	479[b]	85[b]	5[b]
Hairy vetch	Barley	Carman	MB	2016	5.5	3.5	24	4300	1290	473	30	11
Hairy vetch	Barley	Glenlea	MB	2015	7.8	6.5	18	11 744	10 570[b]	587[b]	90[b]	5[b]
Hairy vetch	Barley	Glenlea	MB	2016	7.5	6.5	29	9038	8134[b]	452[b]	90[b]	5[b]

Can. J. Plant Sci. 99: 772–776 (2019)

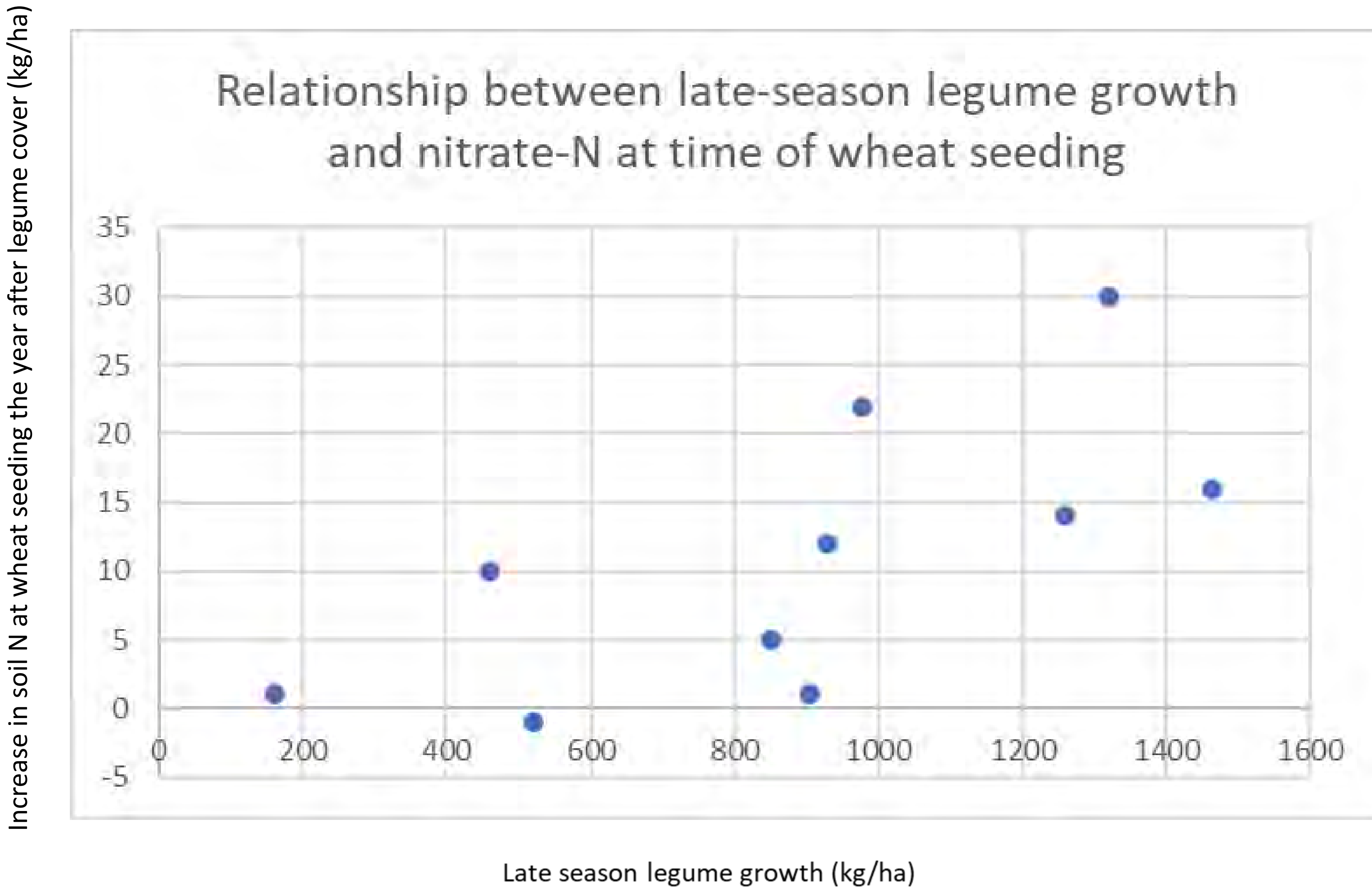
What about late season cover crops?

Drilling cover crops immediately after cereals cut (Germany, 1930's)

Abb. 198: Drillen zwischen den Stiegen

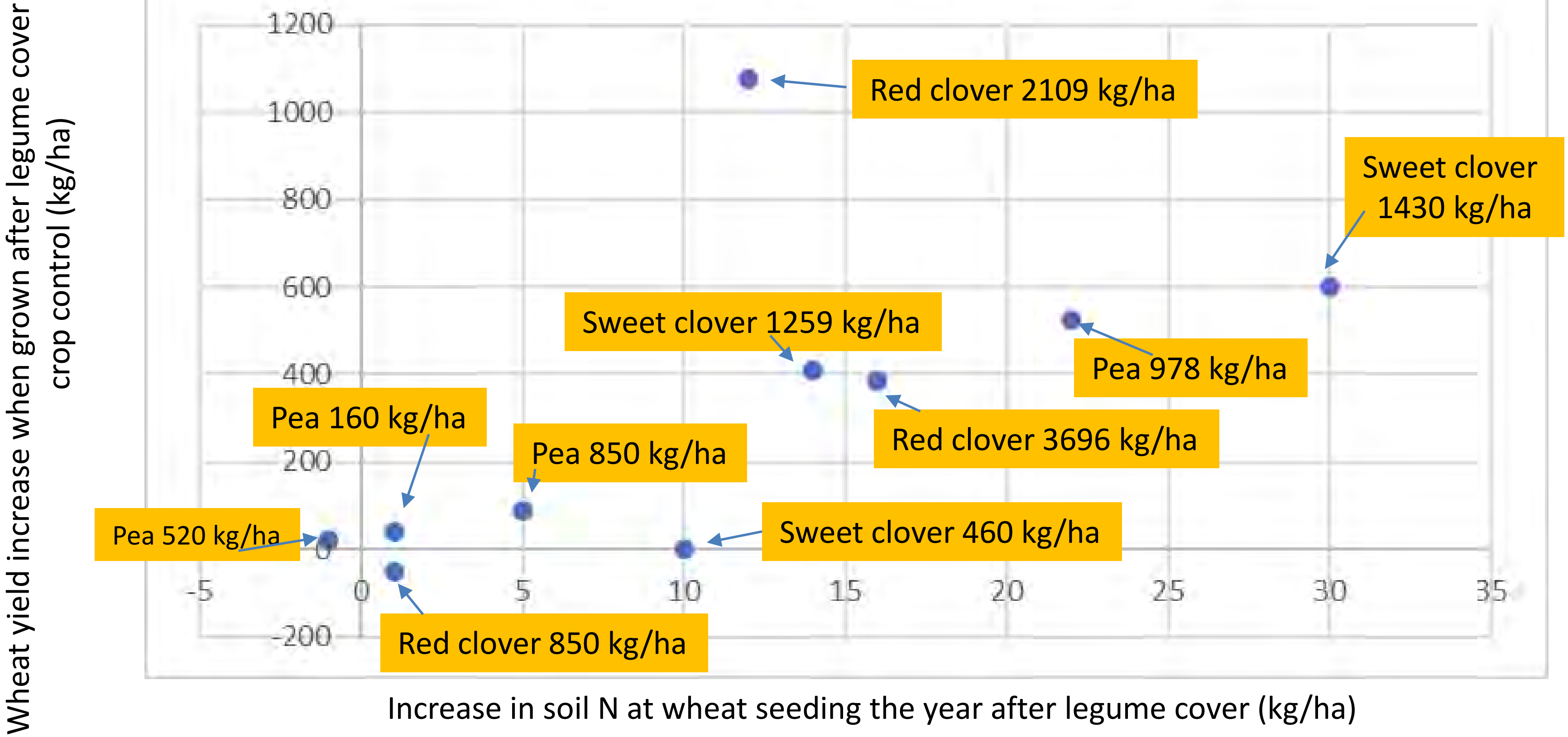
Bild: DLG, Frankfurt/Main

Cicek, H., et al 2014. Productivity and nitrogen benefits of late-season legume cover crops in organic wheat production. *Canadian Journal of Plant Science*, *94*(4), pp.771-783.



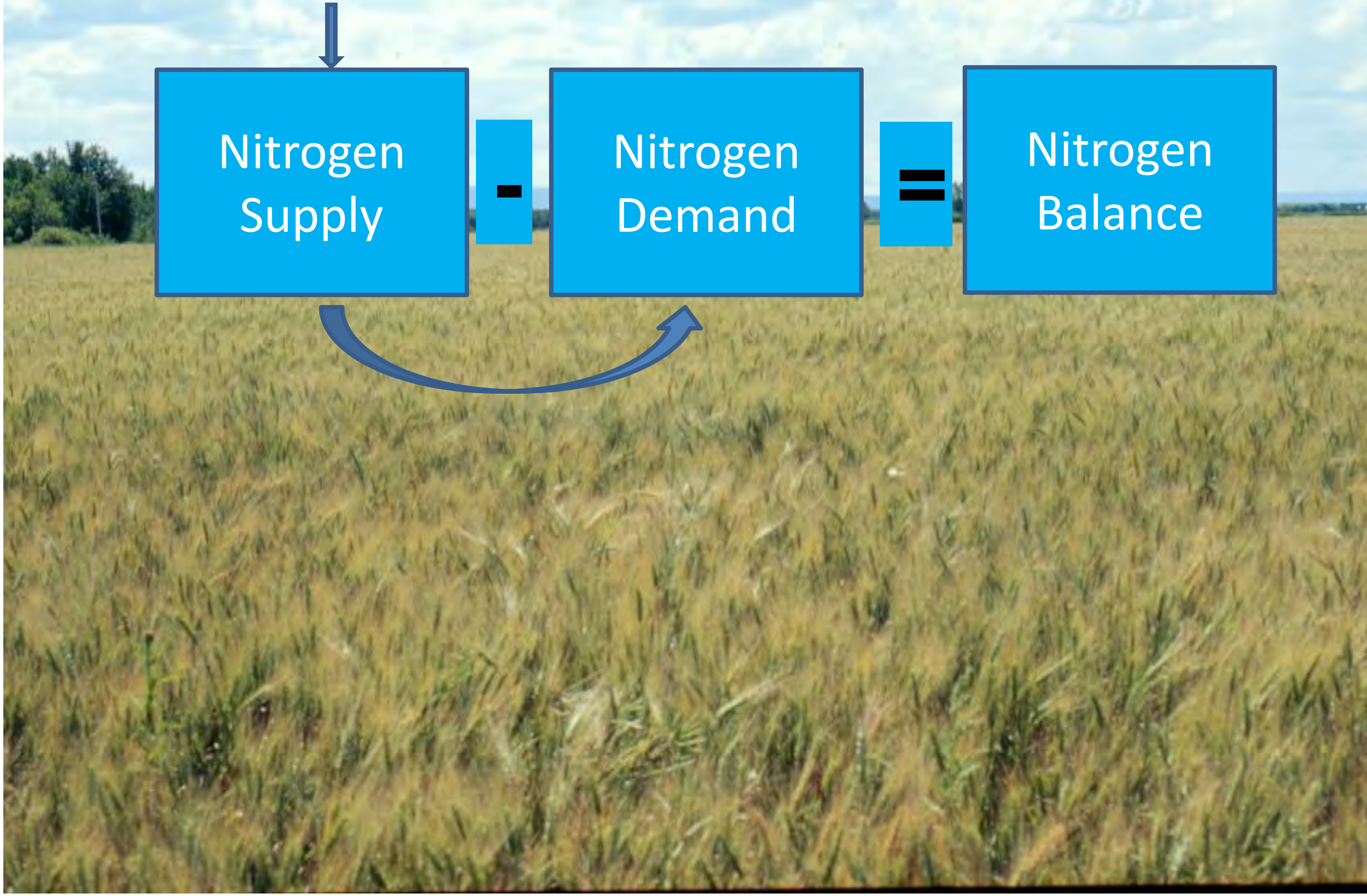
How much N do late-season legume cover crops contribute?

1000 lb/acre dry matter growth =
7 bu/ace wheat yield increase



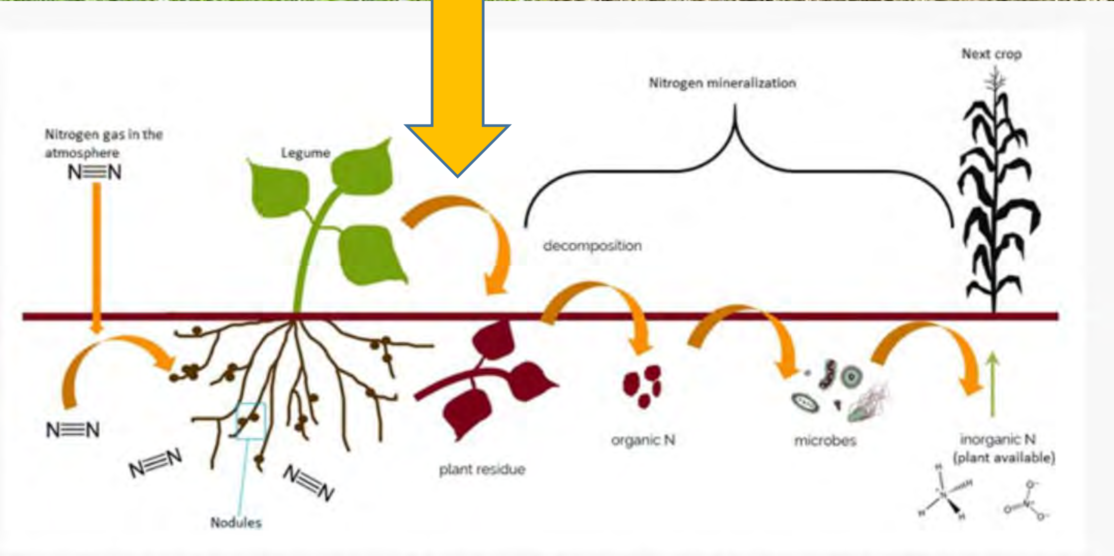
Cicek, H., et al 2014. Productivity and nitrogen benefits of late-season legume cover crops in organic wheat production. *Canadian Journal of Plant Science*, *94*(4), pp.771-783.

Managing the N Supply



Terminating green manures

-starts the N mineralization process in soil



Nitrogen cycling with a legume green manure. Figure modified slightly from that kindly provided by Dr. Julie Grossman and Sharon Perrone, University of Minnesota.

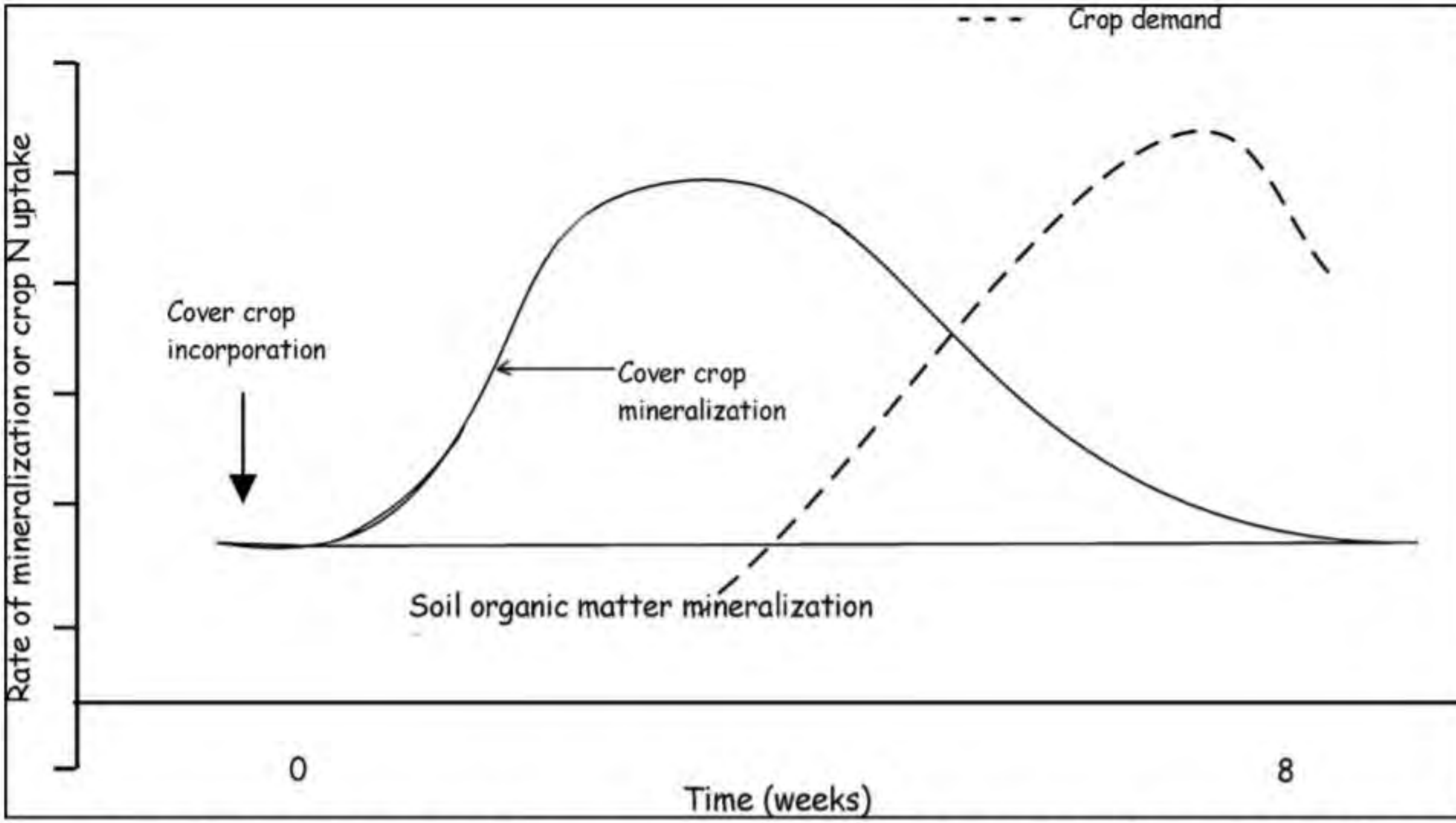
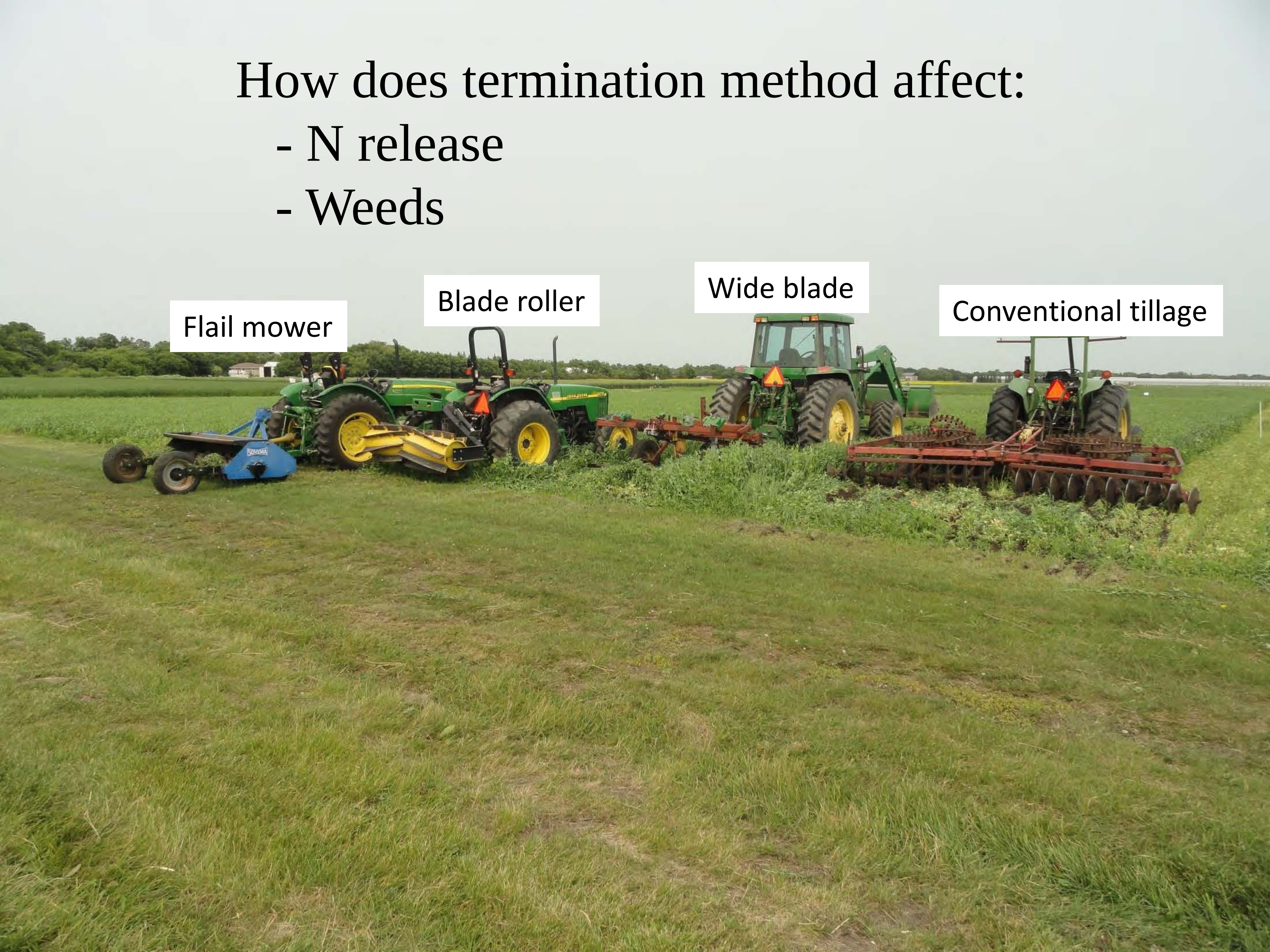


Figure 6. Timing of nitrogen (N) mineralization from cover crop residue in relation to crop N uptake (adapted from Gaskell et al., 2006). From Gaskell, M., and R. Smith. 2007. "Nitrogen Sources for Organic Vegetable Crops." HortTechnology October-December 2007 vol. 17 no. 4, 431-441) Note: Soil temperature plays an important role in the rate of N mineralization from soil organic matter.

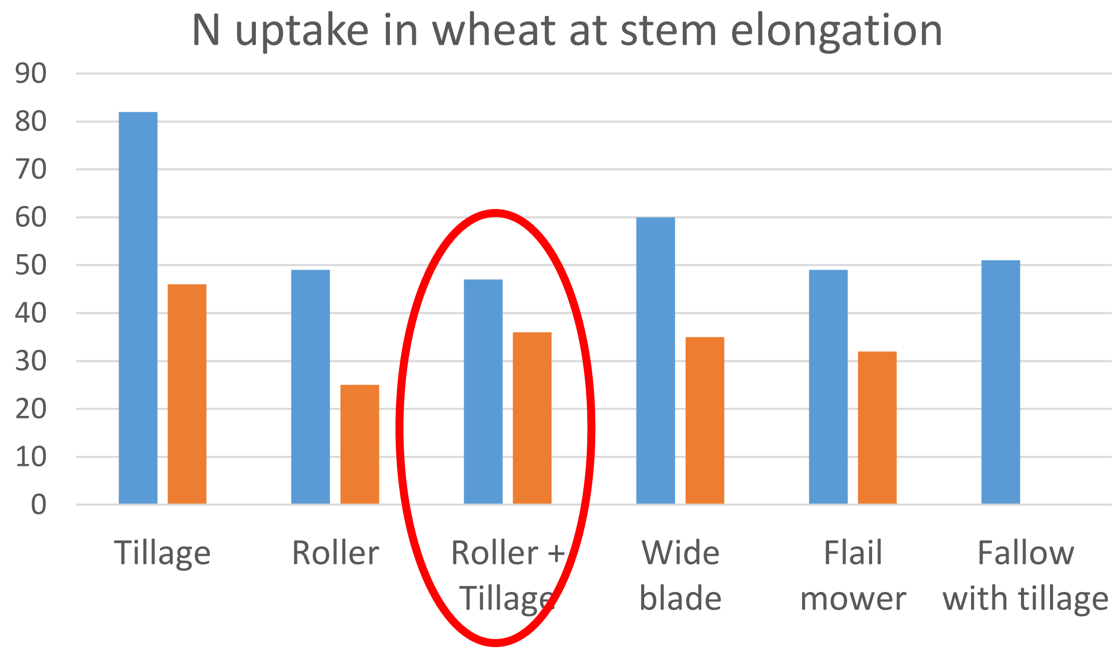
file:///C:/Users/mentz/Downloads/Nutrient-Management-in-Organic-Systems-Western-States-Implementation-Guide.pdf

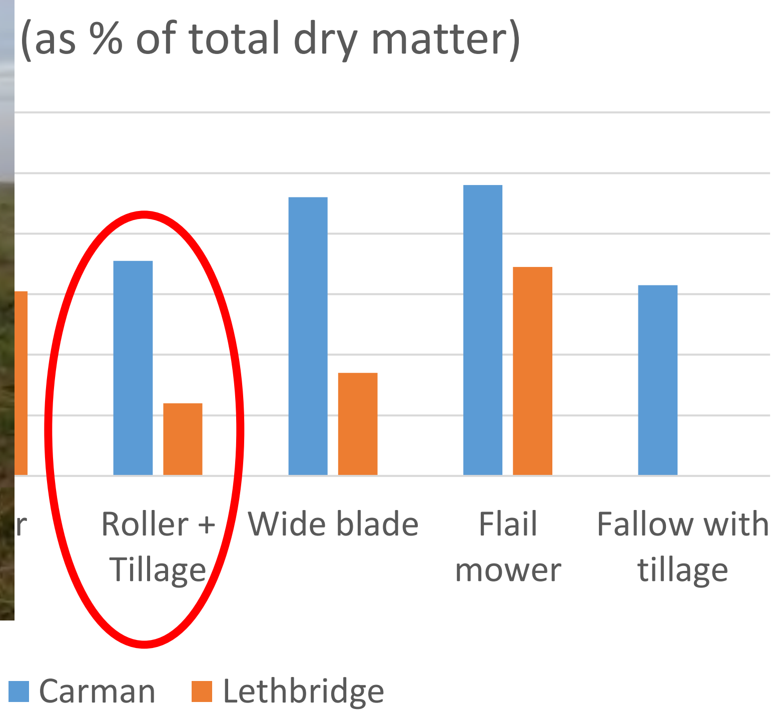

How does termination method affect:
- N release
- Weeds
Flail mower
Blade roller
Wide blade
Conventional tillage

Vaisman, I., Entz, M.H., Bamford, K.C. and Cushon, I., 2014. Green manure species respond differently to blade rolling. *Can J Plant Sci*, *94:*1507-1511.

Vaisman, I., Entz, M.H., Flaten, D.N. and Gulden, R.H., 2011. Blade roller–green manure interactions on nitrogen dynamics, weeds, and organic wheat. *Agronomy Journal*, *103*:879-889.

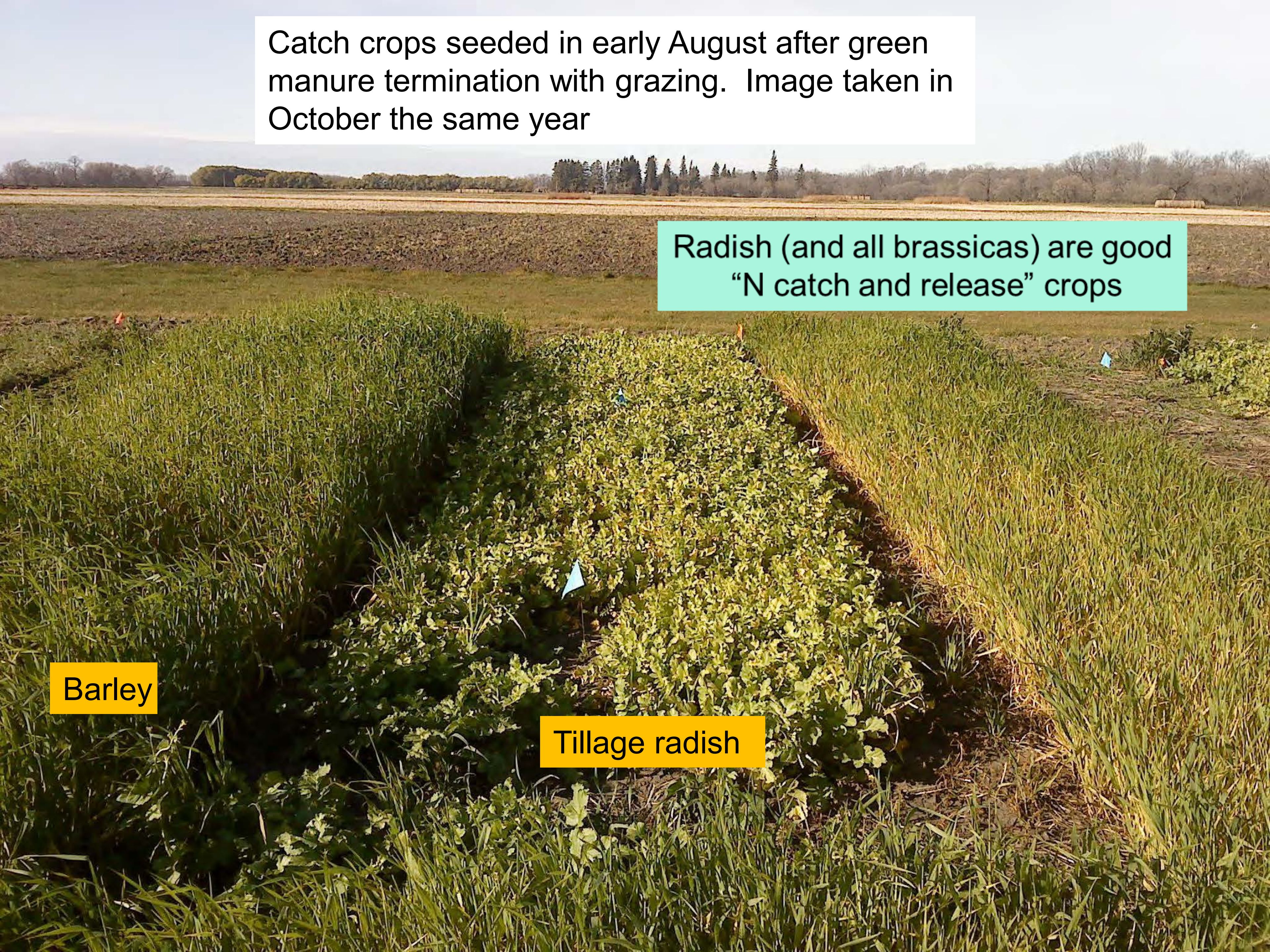
Podolsky, K., Blackshaw, R.E. and Entz, M.H., 2016. A comparison of reduced tillage implements for organic wheat production in western Canada. *Agronomy Journal*, *108*:2003-2014.

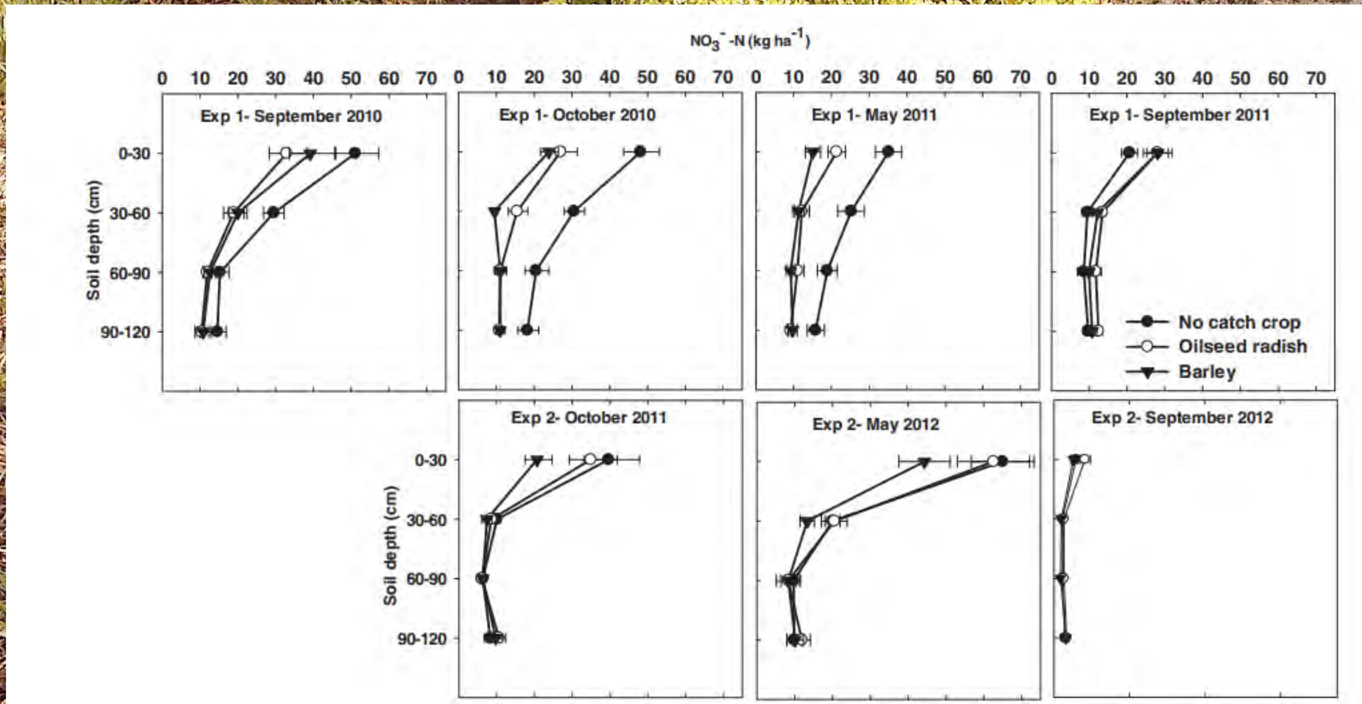

N uptake in wheat at stem elongation
90
80
70
60
50
40
30
20
10
0
Tillage
Roller
Roller + Tillage
Wide blade
Flail mower
Fallow with tillage


(as % of total dry matter)
r
Roller + Tillage
Wide blade
Flail mower
Fallow with tillage
Carman
Lethbridge

Cover crop: Grown for multiple purposes including adding N after a cereal crop, reducing soil erosion and increasing soil biological activity.

Catch crop: Grown specifically to stop N losses


Catch crops seeded in early August after green manure termination with grazing. Image taken in October the same year
Radish (and all brassicas) are good "N catch and release" crops
Barley
Tillage radish



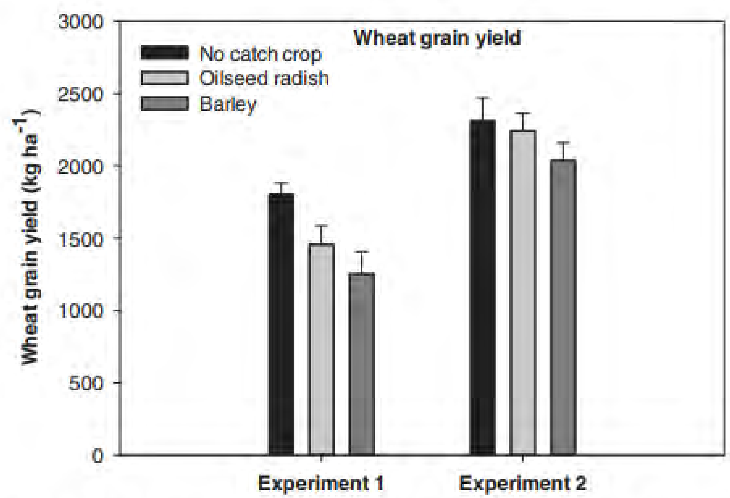


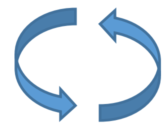
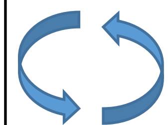
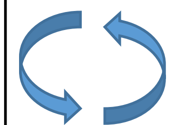
Fig. 4. Effect of catch crop species (no catch crop, barley and oilseed radish) on wheat grain yield for experiments 1 and 2. Vertical bars are standard errors.

Cicek, H., Martens, J.R.T., Bamford, K.C. and Entz, M.H., 2015. Late-season catch crops reduce nitrate leaching risk after grazed green manures but release N slower than wheat demand. *Agriculture, ecosystems & environment*, *202*, pp.31-41.

Nutrients other the Nitrogen

Crop demand

Crop	N	P_2O_5	K_2O	S
Crop nutrient removal (lb/bushel)				
Wheat 10% protein	1.2	0.5	0.35	0.1
12%	1.5	0.5	0.35	0.1
14%	1.9	0.5	0.35	0.1
Barley	1.1	0.36	0.35	0.07
Oat	.96	0.25	0.18	0.06
Rye	1.22	0.33	0.33	0.22
Pea	2.3	0.7	0.7	0.14
Flax	2.12	0.6	0.6	0.2
Sunflower (lb/lb)	0.026	0.008	0.006	0.002
Alfalfa (lb/ton)	56	15	60	5
Bromegrass (lb/t)	36	13	59	3

Crop	N	P	K	S
Nutrient balance (lb/ac)				
Green manure pea, lentil or c. vetch 4000 lb/ac @2.5% N	+100			
Wheat (30 bu/ac)	-57	-15	-12.6	-3
Flax (14 bu/ac)	-30	-16.5	-9	-3
Long-term balance	**+13**	**-31.5**	**-19.6**	**-6**

After 12 years of organic, grain organic only system had lots of P; green manure-grain system had more available P in organic than conventional; and forage-grain system had low P in organic. Carkner et al. 2020.

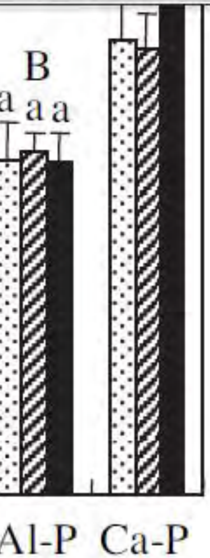
Table 1. Soil nutrient status (kg ha^{-1}) for the Glenlea long-term cropping systems study flax test crop in 2003.

Rotation	Inputs	N[1]	P[2]
Annual	Conventional	32	46
	Organic	22	33
Green Manure	Conventional	29	24
	Organic	31	37
Forage	Conventional	81	24
	Organic	37	11
Rotation (R)		0.0024	0.0020
Inputs (I)		0.0093	0.1899
R x I		0.0158	0.0153

[1]sampling depth 0 to 60 cm
[2]sampling depth 0 to 15 cm

Green manure increased P

200% Tools Sign Comment



aba bean (*b*),
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phosphorus

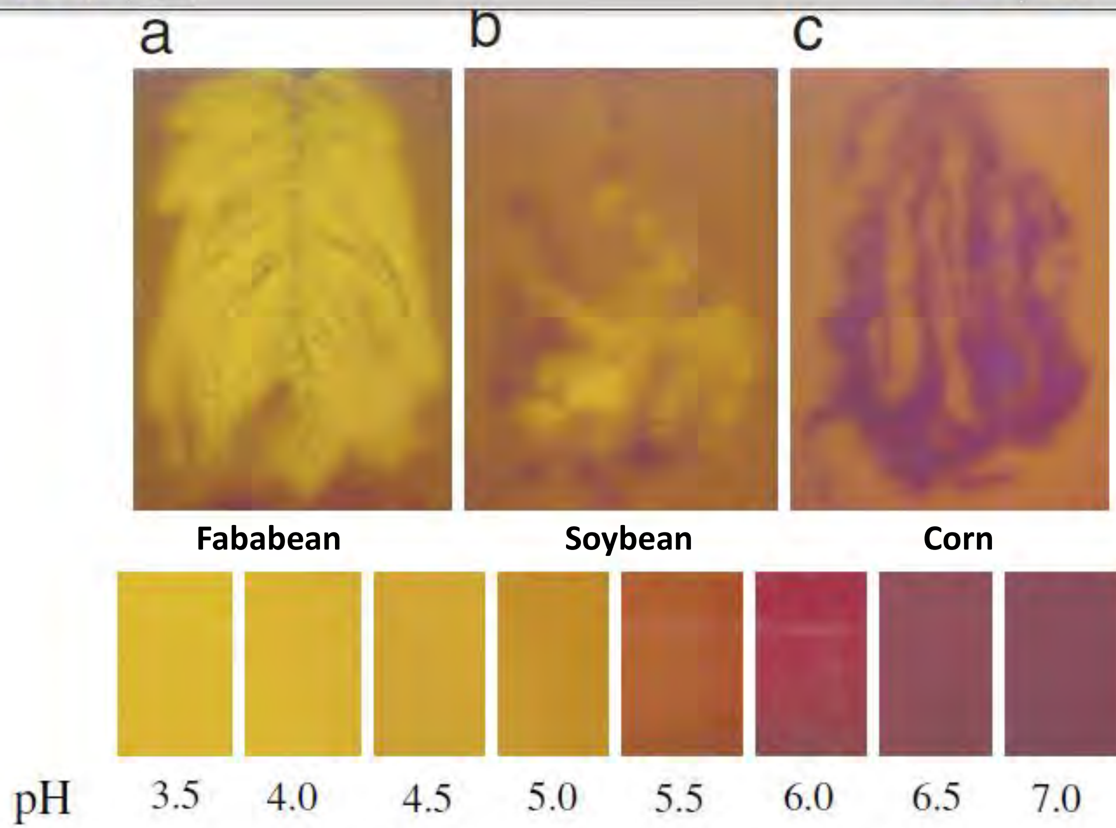

Fig. 2. Visualization of rhizosphere acidification of faba bean (*a*), soybean (*b*), and maize (*c*). The roots were imbedded for 6 h in agar gel containing a pH indicator (bromocresol purple) without P supply (Greenhouse Study 2). Yellow indicates acidification, and purple indicates alkalization.

7:44 AM
22/01/2018

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[1]sampling depth 0 to 60 cm
[2]sampling depth 0 to 15 cm

Green manure increased P

Alfalfa hay reduced P

Hypothetical rotation: Grains and 3 years alfalfa

Crop	N	P_2O_5	K_2O	S
Nutrient balance (lb/ac)				
Alfalfa hay (4 ton/acre)	+130	-144	-540	-60
Wheat (34 bu/ac)	-64.5	-19	-14.2	-3
Flax (15 bu/ac)	-30	-16.5	-9	-3
Oat (50 bu/ac)	-45	-12.5	-9	-3
Balance	-9.5	-162	-572	-69

Crop demand

Crop	N	$P_2 0_5$	$K_2 0$	S
Crop nutrient removal (lb/bushel)				
Wheat 10% protein	1.2	0.5	0.35	0.1
12%	1.5	0.5	0.35	0.1
14%	1.9	0.5	0.35	0.1
Barley	1.1	0.36	0.35	0.07
Oat	.96	0.25	0.18	0.06
Rye	1.22	0.33	0.33	0.22
Pea	2.3	0.7	0.7	0.14
Flax	2.12	0.6	0.6	0.2
Sunflower (lb/lb)	0.026	0.008	0.006	0.002
Alfalfa (lb/ton)	56	15	60	5
Bromegrass (lb/t)	36	13	59	3

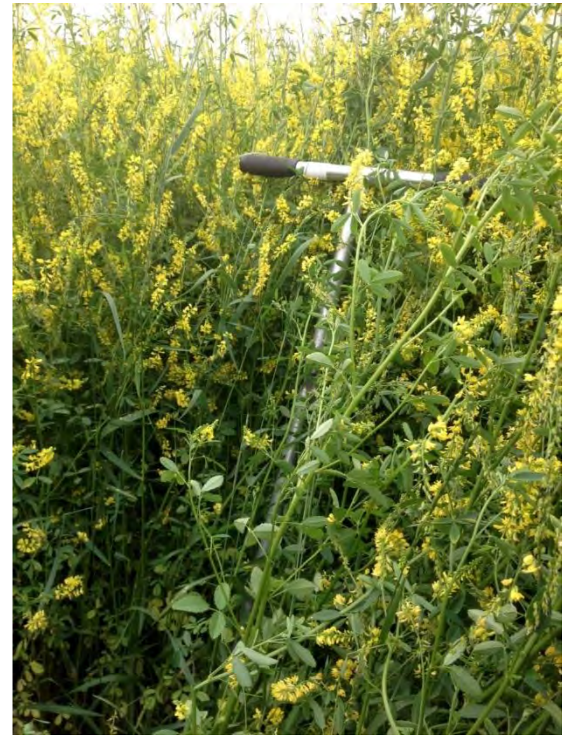
Crop	N	P_2O_5	K_2O	S
Nutrient balance (lb/ac)				
Alfalfa grazed or seed production	+160	-25	-108	-12
Wheat (34 bu/ac)	-64.5	-19	-14.2	-3
Flax (15 bu/ac)	-30	-16.5	-9	-3
Oat (50 bu/ac)	-45	-12.5	-9	-3
Long-term balance	**+20.5**	**-73**	**-140.2**	**-21**

How do I know if I have enough soil P?

- When soil test P below 5 PPM, you know crops will be deficient
- When soil test P above 10 PPM, you know crops will be OK

- Problem is when soil test P is between 5 and 10 PPM.

When soil test between 5 and 10, use plant tissue analysis to assess P

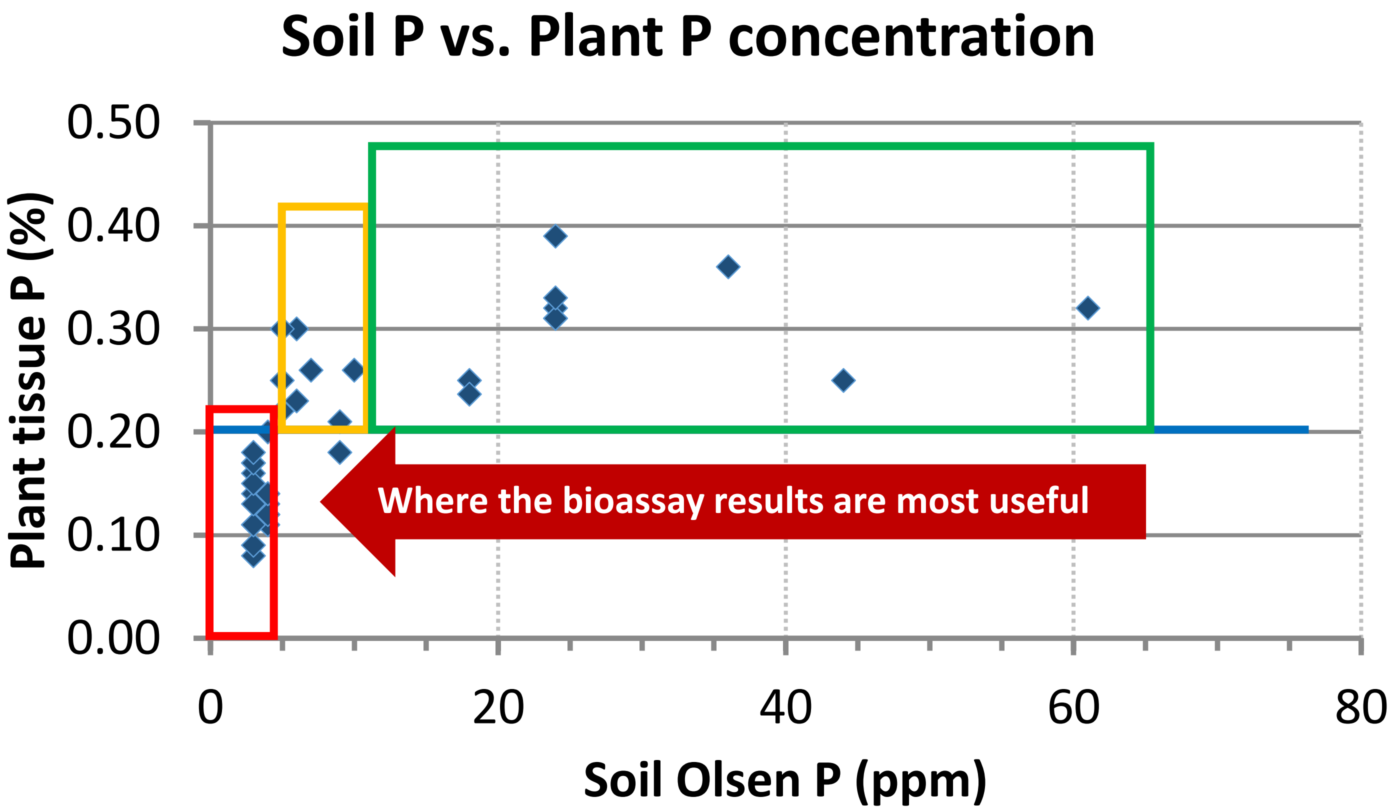


Dr. Joanne Thiessen Martens, Dept Soil Science, University of Manitoba

Why the green manure crop?

Legume is not limited by N – more sensitive to other nutrient deficiencies

Green Manure Bioassay: Phosphorus



Thiessen Martens et al. Can J Plant Sci 2019

7 of 28 fields between 5-10 ppm P

P value should be above 2.0 ppm

Table 1. Biomass and nutrient concentration properties of 41 green manures in the eastern prairie region of Canada.

					Soil properties			Aboveground biomass			Biomass proportion		Plant tissue nutrient concentration				
Legume species[a]	Other species[a]	Site	Province	Year	pH	Organic matter (%)	Olsen P (mg kg^{-1})	Total (kg ha^{-1})	Legume (kg ha^{-1})	Weeds (kg ha^{-1})	Legume (%)	Weeds (%)	N (g kg^{-1} dry matter)	P (g kg^{-1} dry matter)	K (g kg^{-1} dry matter)	S (g kg^{-1} dry matter)	N fixation estimate (kg ha^{-1})
Alfalfa	—	Kamsack	SK	2015	7.5	7.0	4	4148	4065	83	98	2	24	1.1	17	1.9	130
Alfalfa	—	Kamsack	SK	2015	7.8	3.3	4	2574	1776	798	69	31	20	1.3	13	1.2	47
Alfalfa	Forage grasses	Melville	SK	2015	8.0	4.0	3	4221	1899	17	45	0.4	14	0.8	10	1.3	35
Alfalfa	Forage grasses	Melville	SK	2016	8.2	4.1	6	3504	1577[b]	0[b]	45[b]	0[b]	20	1.3	19	1.3	41
Alfalfa	Forage grasses	Melville	SK	2016	8.0	3.7	7	3184	1433[b]	0[b]	45[b]	0[b]	22	1.0	12	1.1	41
Alfalfa	Forage grasses	Carman	MB	2016	5.6	4.0	17	5740	3214	287	56	5	18	2.2	22	1.2	77
Red clover	—	Brandon 1	MB	2015	7.6	6.7	3	3826	1798	383	47	10	17	0.9	17	1.4	40
Red clover	—	Notre Dame	MB	2016	7.5	3.0	3	7321	7175	146	98	2	20	1.7	19	1.0	192
Red clover	—	St. Claude	MB	2016	7.6	1.4	5	2580	1445	206	56	8	33	3.0	23	2.0	63
Red clover	—	St. Claude	MB	2016	7.7	1.7	4	4090	2290	123	56	3	22	2.0	16	1.0	67
Red clover, hairy vetch	Fall rye	Kenton	MB	2015	8.3	4.6	3	2160	1080	432	50	20	23	1.1	16	1.8	24
Red clover, hairy vetch	Fall rye	Kenton	MB	2016	8.0	5.4	3	4520	2983	1175	66	26	18	1.7	19	1.0	50
Red clover, sweet clover	—	Nesbitt	MB	2015	8.0	4.8	4	3652	2739	913	25	75	21	1.2	20	1.9	76
Sweet clover	—	Austin	MB	2015	8.1	1.4	9	5583	5136	447	92	8	21	1.8	10	1.8	144
Sweet clover	—	Brandon 1	MB	2016	7.0	6.6	3	4040	2101	1939	52	48	21	1.3	18	1.6	58
Sweet clover	—	Brandon 1	MB	2016	7.6	6.2	3	3704	3074	630	83	17	22	1.5	22	2.4	90
Sweet clover	—	Miami	MB	2016	7.0	4.3	3	6176	5188	988	84	16	24	1.6	19	1.8	166
Sweet clover	—	Somerset	MB	2015	6.4	4.5	18	1988	954	1034	48	52	15	2.5	19	0.8	18
Fababean	Barley	Brandon 2	MB	2015	7.4	7.0	3	2335	327	1401	14	60	16	1.4	15	1.9	6
Fababean	Oat	Winkler	MB	2015	8.3	2.7	61	6038	1449	604	24	10	22	3.2	22	1.6	30
Fababean	Oat, barley	Carman	MB	2016	5.5	3.5	24	5100	1071	714	21	14	21	3.3	26	1.5	22
Pea	Barley	Brandon 2	MB	2015	8.2	3.8	4	3114	1090	1152	35	37	20	1.2	15	1.4	21
Pea	Oat	Brandon 2	MB	2016	7.8	6.2	3	5003	2852	1201	57	24	22	1.8	23	2.1	58
Pea	Oat	Nesbitt	MB	2015	7.8	5.7	4	3763	903	1242	24	33	15	1.4	18	1.9	14
Pea	Oat	Nesbitt	MB	2016	6.9	6.2	5	3648	876	292	24	8	20	2.2	22	1.1	17
Pea	Oat	Notre Dame	MB	2015	8.0	4.0	7	1736	1163	278	67	16	35	2.6	24	2.3	38
Pea	Oat	Notre Dame	MB	2015	7.5	5.2	5	3362	807	1345	24	40	26	2.5	30	3.1	20
Pea	Oat	Winkler	MB	2015	8.3	3.2	44	6898	1311	414	19	6	27	2.5	22	1.6	34

Thiessen Martens, et al. Canadian *Journal of Plant Science*, *99*(5), pp.772-776.

P fertilization in organic farming

- Manure / compost – readily available to crop
- Feed and hay (mixed farm) – eg bale grazing
- Mineral sources – rock P (does not work in neutral to alkaline pH soils
- Organic fertilizers – bone meal, other biological sources
- Nutrients from the circular economy

Arcand and Schneider, 2005

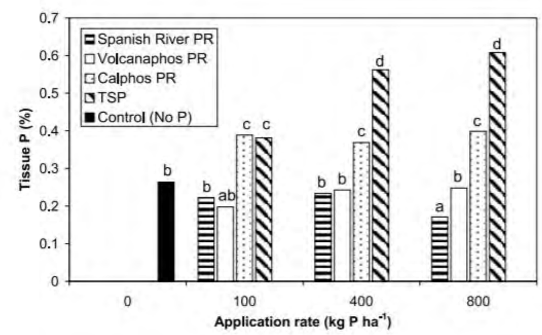
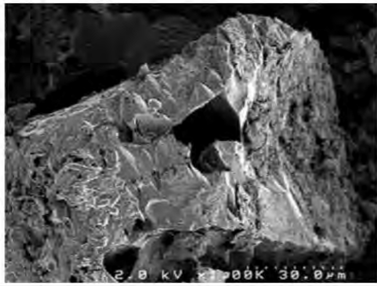
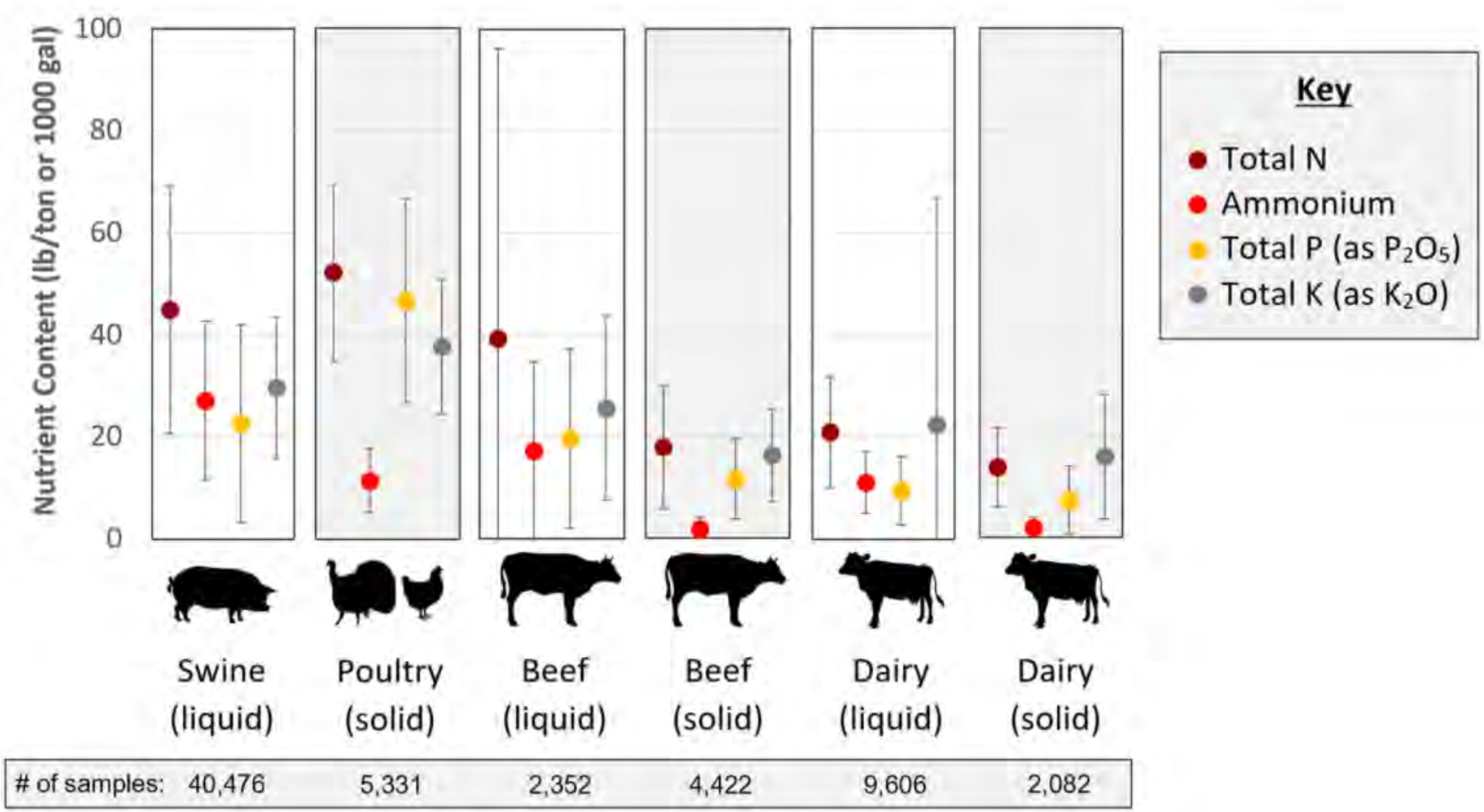


Fig. 1





Nutrient Content (lb/ton or 1000 gal)
100
80
60
40
20
0
Key
Total N
Ammonium
Total P (as P2O5)
Total K (as K2O)
Swine (liquid)
Poultry (solid)
Beef (liquid)
Beef (solid)
Dairy (liquid)
Dairy (solid)
# of samples: 40,476 5,331 2,352 4,422 9,606 2,082

Table 5. Nutrient Content of Common Animal Manures and Manure Composts

This table includes general estimates of nutrient availability for manures and composts. These can vary widely depending on animal feed, management of grazing, the age of the manure, amount and type of bedding, and many other factors. Manure applications must be done in accordance with NOP 205.203 C.1-3. See page 4.

Production Guide for Organic Snap Beans for Processing. 2012. (A. Seaman, ed.) Cornell University Coop¬erative Extension. 50 p. http://nysipm.cornell.edu/organic_guide/bean.pdf

	Total N	P_2O_5	K_2O		N1 [1]	N2 [2]	P_2O_5	K_2O
	Nutrient content lbs/ton				Available nutrients lbs/ton in first season			
Dairy (with bedding)	9	4	10		6	2	3	9
Horse (with bedding)	14	4	14		6	3	3	13
Poultry (with litter)	56	45	34		45	16	36	31
Composted dairy manure	12	12	26		3	2	10	23
Composted poultry manure	17	39	23		6	5	31	21
Pelleted poultry manure [3]	80	104	48		40	40	83	43
Swine (no bedding)	10	9	8		8	3	7	7
	Nutrient content per 1000 gal				Available nutrients per 1000 gal in first season			
Swine finishing (liquid)	50	55	25		25 *	20 +	44	23
Dairy (liquid)	28	13	25		14 *	11 +	10	23

1. N1 is an estimate of the total available for plant uptake when manure is incorporated within 12 hours of applications.
2. N2 is an estimate of the total N available for plant uptake when manure is incorporated after 7 days.
3. Pelletized poultry manure compost.

* injected

\+ incorporated

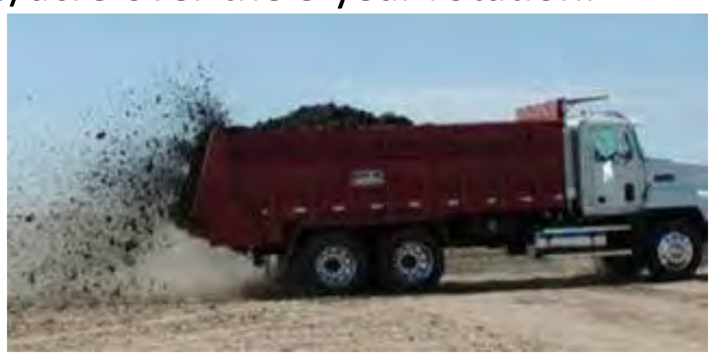
USDA Nutrient-Management-in-Organic-Systems-Western-States-Implementation-Guide.pdf

- 1000 lb Beef animal produces 9.9 tonne raw manure per year

Crop	N	P	K	S
Nutrient balance (lb/ac)				
Green manure pea, lentil or c. vetch 4000 lb/ac @2.5% N	+100			
Wheat (30 bu/ac)	-57	-15	-12.6	-3
Flax (14 bu/ac)	-30	-16.5	-9	-3
Long-term balance	**+13**	**-31.5**	**-19.6**	**-6**

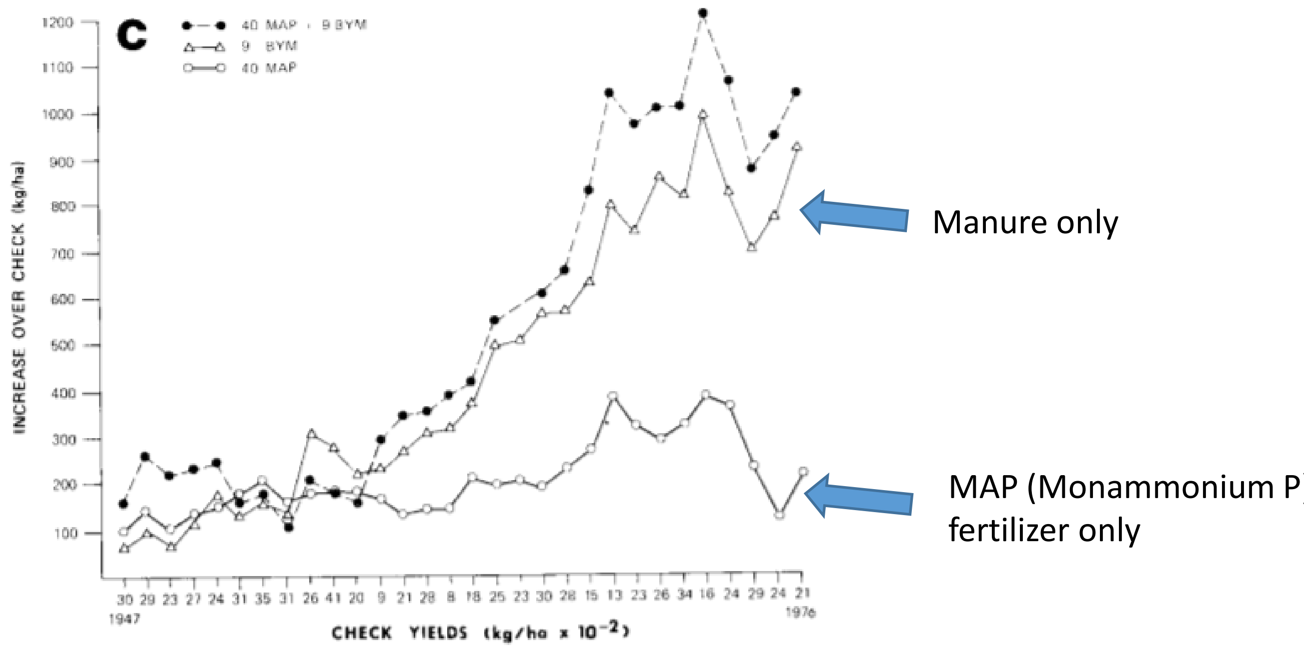
- 9.9 tonne/year x 4.2 $P_2 0_5$ /tonne = 41.5 kg $P_2 0_5$ per 1000 lb beef animal per year

- If you have a P deficiency of 31.5 kg (see above), how much beef manure needed?
  - 31.5 kg per ha/41.5 kg per tonne = 0.75 beef cattle/ha over the rotation
  - That's 0.30 beef cattle/acre over the 3 year rotation.




No manure added
Manure added

Manure vs fertilizer – long term study at Indian Head, SK



1. Yield of grain from wheat after fallow when fertilized with MAP and BYM (5-yr averages) at Indian Head

Spratt, E.D. and McIver, R.N., 1979. The effect of continual use of phosphate fertilizer and barnyard manure on yield of wheat and the fertility status of a clay chernozem soil. *Canadian Journal of Soil Science*, *59*(4), pp.451-454.

Soil nutrients after 30 years of manure vs fertilizer as P source

Table 2. Soil tests from agronomy experiments started in 1947; extractable P in 1964 and extractable P, SO_4-S and Zn in 1977

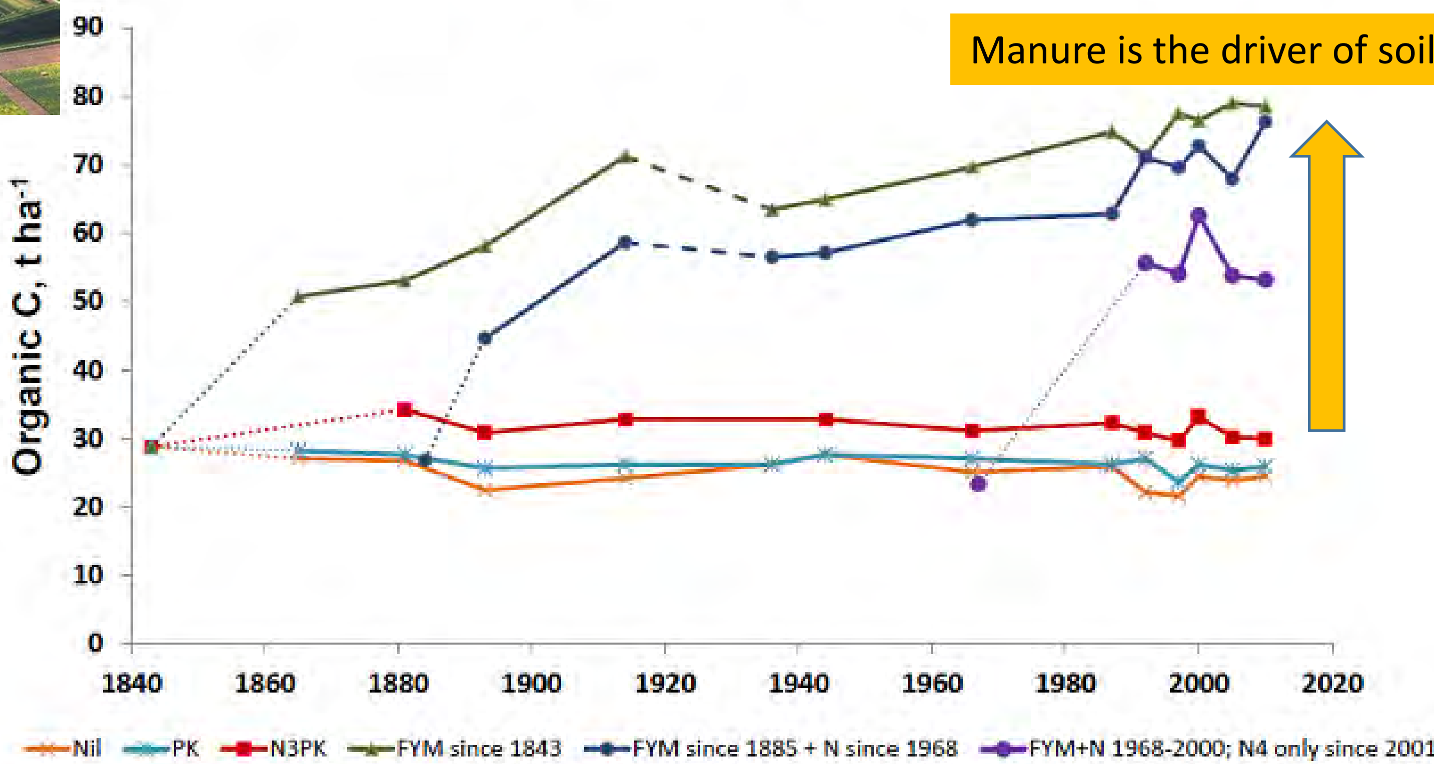
	Soil tests (ppm)†			
	1964‡	1977		
Treatments	P	P	SO_4-S	Zn
Check (0 kg/ha)	11.4	7.3	2.6	0.48
40 MAP (9.4 kg P/ha)	13.6	10.0	5.3	0.49
80 MAP (18.9 kg P/ha)	15.7	13.3	4.3	0.53
9 BYM (19 kg P/ha)	25.8	37.0	10.0	1.20

Manure only

†Extractions done with 0.5 M $NaHCO_3$ for P, 0.01 N $CaCl_2$ for SO_4-S and DTPA for Zn (according to Spratt and Smid 977).
Taken from Spratt and McCurdy 1966.

Broadbalk. Changes in soil organic carbon t ha^{-1} (0-23cm)

Manure is the driver of soil C



Data includes adjustment for changes in bulk density on FYM treatments. All data is from continuous wheat sections. Starting values for all treatments in 1843 and the later FYM treatments were estimated (.......). Decreases between 1914 and 1936 are due to the introduction of regular fallowing in 1926; FYM was not applied in fallow years (- - - -). Updated from Powlson et al, 2012.

Table 1 | **Effect of stockpiling on the concentrations of total C, total N, inorganic N and total P and C:N ratios (*wet weight basis*) of beef cattle manure (adapted from Larney et al. 2006).**

Location	Age of Manure	Water %	Total C %	Total N lb/ton	Inorganic N lb/ton	Total P lb/ton	C:N Ratio
Lethbridge	Fresh	57.1	12.6	14.2	2.4	3.8	17.6
	Stockpiled	45.9	13.2	16.0	4.2	5.0	16.3
Brandon	Fresh	73.1	8.9	8.4	2.6	2.6	21.8
	Stockpiled	68.4	8.0	10.4	3.4	4.0	15.4

Table 11 | **Effect of composting on the concentrations of total C, total N, inorganic N and total P and C:N ratios (*wet weight basis*) of beef cattle manure (adapted from Larney et al. 2006).**

Location	Age of manure	Water %	Total C %	Total N lb/ton	Inorganic N lb/ton	Total P lb/ton	C:N Ratio
Lethbridge	Fresh	57.1	12.6	14.2	2.4	3.8	17.6
	Compost	33.6	12.6	21.0	1.2	7.4	11.7
Brandon	Fresh	73.1	8.9	8.4	2.6	2.6	21.8
	Compost	38.4	8.2	15.2	0.6	6.0	10.9

https://www.gov.mb.ca/agriculture/environment/nutrient-management/pubs/properties-of-manure.pdf

Stockpiling or composting concentrates nutrients in the manure

Bales contain high amounts of P, K, S and micronutrients!

Crop demand

Crop	N	P_2O_5	K_2O	S
Crop nutrient removal (lb/bushel)				
Wheat 10% protein	1.2	0.5	0.35	0.1
12%	1.5	0.5	0.35	0.1
14%	1.9	0.5	0.35	0.1
Barley	1.1	0.36	0.35	0.07
Oat	.96	0.25	0.18	0.06
Rye	1.22	0.33	0.33	0.22
Pea	2.3	0.7	0.7	0.14
Flax	2.12	0.6	0.6	0.2
Sunflower (lb/lb)	0.026	0.008	0.006	0.002
Alfalfa (lb/ton)	56	15	60	5
Bromegrass (lb/t)	36	13	59	3

Figure 1

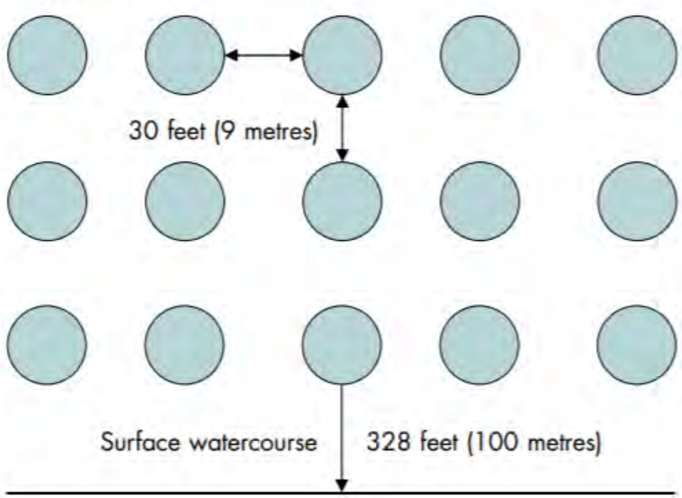
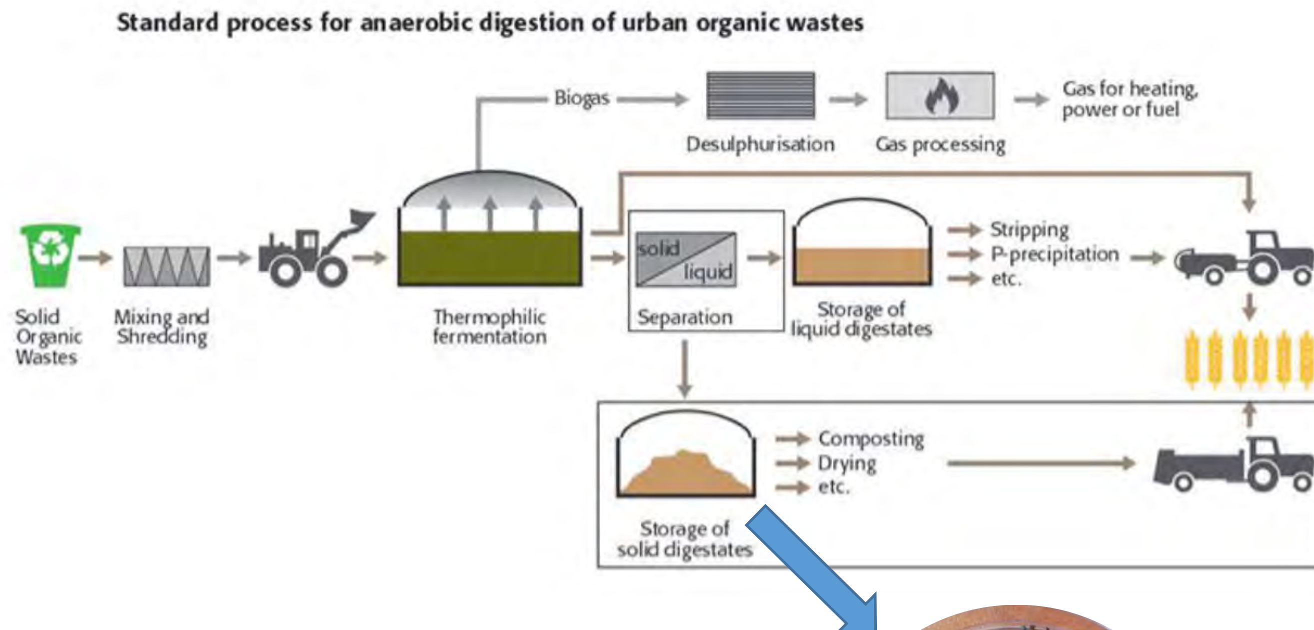


Table 1. Common organic nitrogen (N) fertilizer materials and their nutrient analysis.[z]

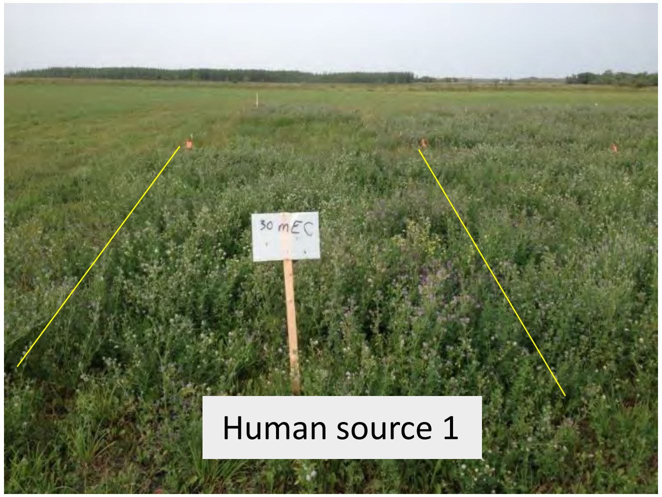
Material	Nitrogen (% N)	Phosphorus (% P)	Potassium (% K)
Fish meal or powder	10–11	1.3	<1
Pelleted chicken manure	2–4	<1	<1
Processed liquid fish residues	4	<1	<1
Feather meal	12	0	0
Seabird and bat guano	9–12	<1–1.75	<1
Alfalfa meal (*Medicago sativa*)	4	<1	<1
Soybean meal (*Glycine max*)	7	<1	<1
Bone meal	2	<1	0
Kelp (order Laminariales)	<1	0	1.7
Chilean nitrate	16	0	0
Blood meal	12	0	0
Meat and bone meal	8	2.2	<1

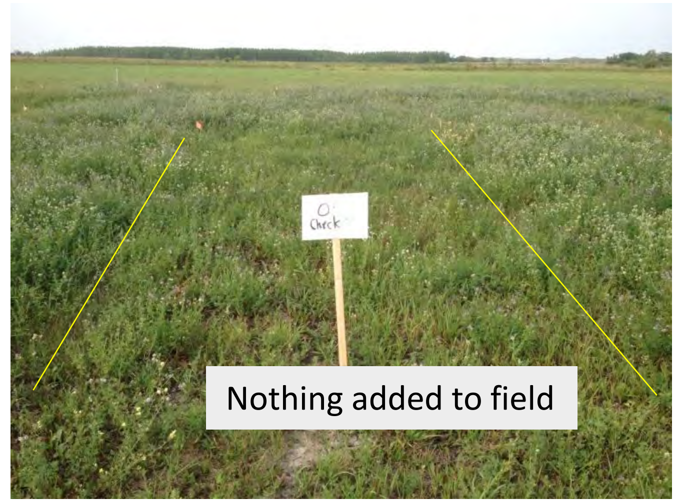
Gaskell, M. and Smith, R., 2007. Nitrogen sources for organic vegetable crops. HortTechnology, 17(4), pp.431-441.

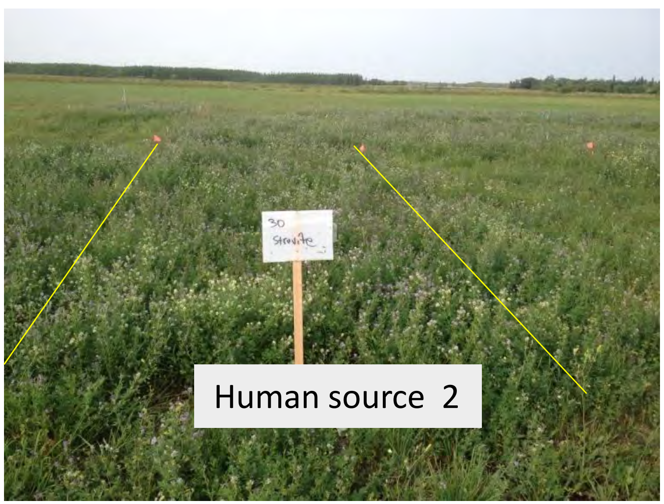
http://www.fertilizer-machines.com/solution/fertilizer-technology/biogas-digestate-compost-fertilizer-produ.html

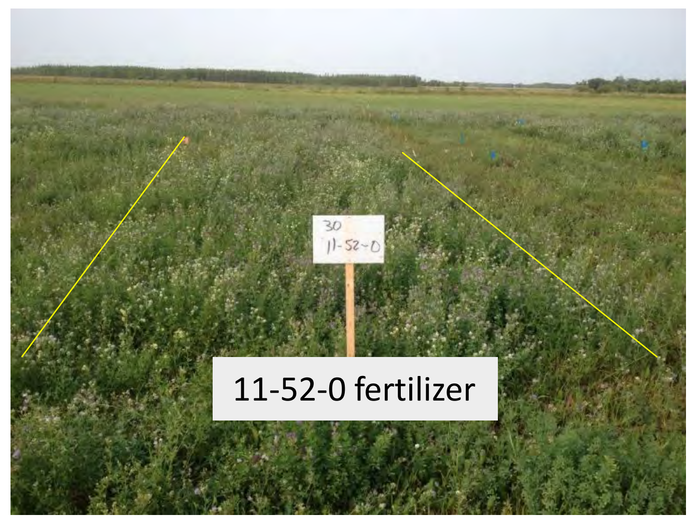


Research on alternative P sources in organic agriculture

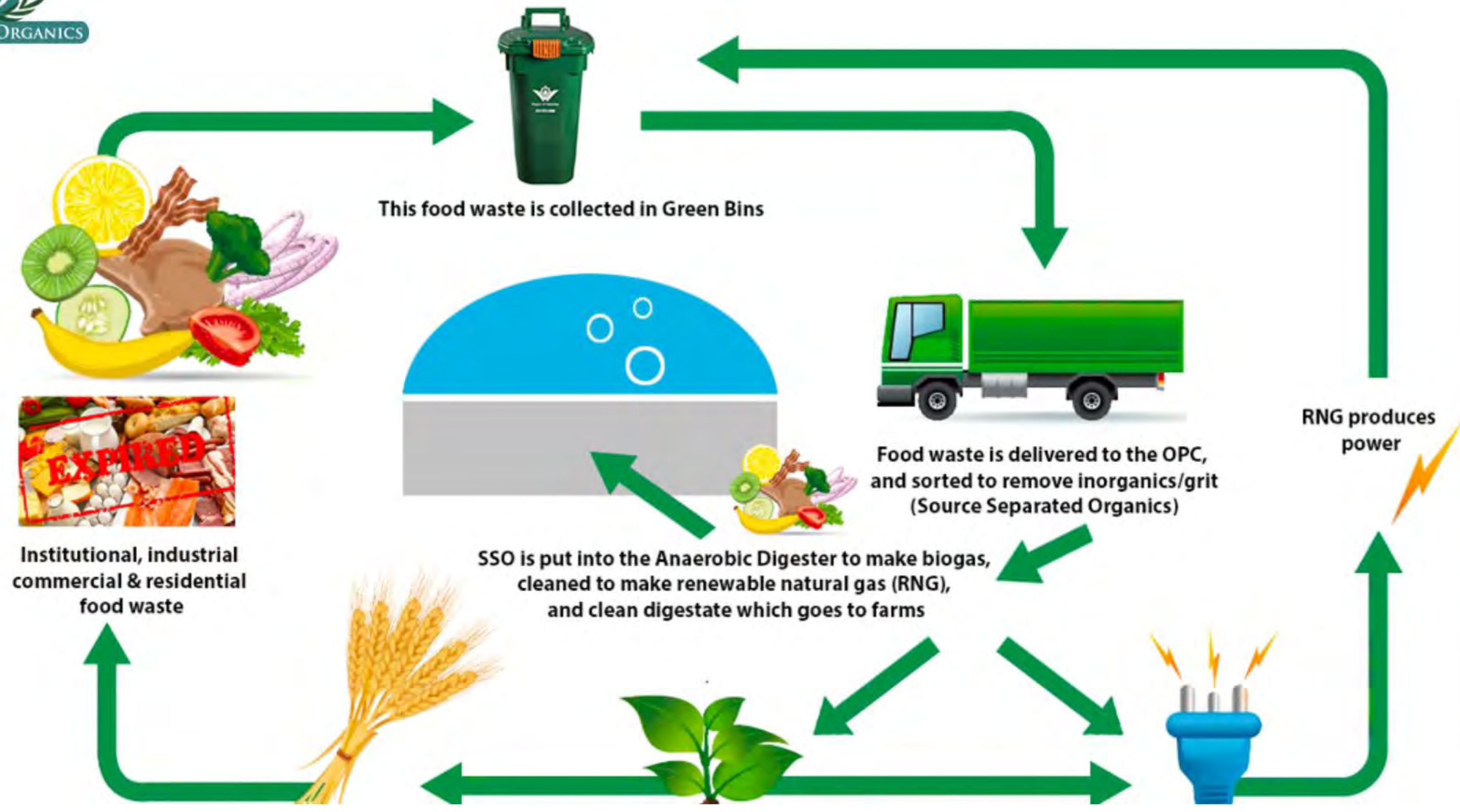








https://www.coronationorganics.com/operations.html



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