Project Title:
Nitrogen Use Efficiency in Two Ontario Legume Crops

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WAMQI project

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Promotion Summary: This research should provide growers with the confidence to reduce nitrogen fertilizer applications in snap bean and edamame crops without yield or quality penalties while saving input costs and minimizing risks of environmental nitrogen loss.

Executive Summary.
There is a need to better understand nitrogen fertilizer requirements for 1) edamame, also known as fresh vegetable soybean, a relatively new crop in Ontario for which there are no fertility recommendations and 2) snap beans, where nitrogen recommendations were determined in 1962. At Ridgetown, Simcoe, and Rodney, a nitrogen response trial with 4 replicates was established with snap beans and edamame crops. Preplant incorporated nitrogen fertilizer (34-0-0) was applied at five different rates (0, 20, 40, 60, 80, 120 lb/ac) and crop response evaluated. At all three locations, nitrogen fertilizer had no effect on snap bean yield, quality or economics. This suggests that growers do not need to apply N fertilizer on their snap bean crop. Edamame variety Harronomai is not tolerant to soybean cyst nematodes and the site at Rodney was not harvested due to soybean sudden death syndrome. At Simcoe there was no yield, quality or economical response of edamame to applied N fertilizer. In contrast, at Ridgetown, N fertilizer impacted yield response but not quality. The most economical N rate at Ridgetown was 40 to 60 lb N/ac. Given the differences between sites, edamame growers should consider evaluating if their soil is responsive to N fertilizer applications.

Purpose.

By determining the most economical rate of nitrogen fertilizer, growers will be able to optimize inputs while minimizing the impacts on the environment, such as nitrogen loss. There are significant environmental and economic benefits to gaining a better understanding of nitrogen use efficiency in both of these crops. In either crop, unnecessarily high applications of nitrogen fertilizer could potentially compromise the quality of the harvested product, as well as increase the risk of residual nitrogen at the end of the season which can be lost during the fall, winter and spring via greenhouse gas emissions or leaching to groundwater and surface water (through tiles). Both crops are commonly grown on coarse-sandy loam textured soils which have a high risk of nutrient leaching and contamination of water. Determining the most economic rate of nitrogen fertilizer and estimating the nitrogen budget (inputs at planting and outputs at harvest) for the crops will allow for improved water quality through better nitrogen management. Considering that snap beans and edamame are legume crops, there may be opportunities to significantly reduce nitrogen fertilizer applications and protect water resources. Thus there is a need to evaluate the N fertility requirements in edamame and snap beans.

Objectives:

- Determine yield response to higher rates of nitrogen in snap beans in Ontario.
- Determine the most economic rate of nitrogen (MERN) for edamame in Ontario.
- Determine the impact supplemental nitrogen has on the quality or marketability of edamame and snap beans in Ontario.
- Estimate nitrogen losses in snap beans and edamame in Ontario.

Materials and Methods:

There were three trial locations for each crop; Ridgetown, Simcoe, and a grower location in the Rodney area, which represent processing and fresh market growing areas. The experiment was a randomized complete block design with four replications for each crop. Nitrogen fertilizer (34-0-0) was applied at five different rates (0, 20, 40, 60, 80, 120 lb/ac) to 6 row wide by 8 m long plots of snap beans and edamame. The 0 and 120 lb/ac rates were not necessarily recommended practices but were needed to determine crop response with and without N fertilizer and to predict N losses from the field.

Soil texture and complete soil characterization were determined at 0-15 cm depth in a composite sample approximately 24 soil cores from either each replicate or the entire trial area. Harvest parameters collected included: fresh weight of plants and pods, total number of pods, total yield and marketable yield. For select N treatments (0, 60, 120 lb/ac), nitrogen dynamics were determined. Residual soil nitrogen levels were assessed pre-plant and post-harvest for N content at the 0-30 and 0-60 cm depth. Soil nitrate-N and ammonium-N were extracted with 2M KCl and concentration determined via autoanalyzer with cadium reduction method. Dry plant samples of both shoots and pods were ground and nitrogen content determined by LECO CN to calculate uptake and removal values for both crops. With soil and plant nitrogen data, nitrogen losses from the field were predicted.

Results and Discussion:

We went to sites where we might expect a N fertilizer response. These were sandier soils with lower organic matter. Although 2014 was a wet, cool season, the later planting dates for edamame and snap beans avoided a lot of the rain.

Table 1. Soil characteristics for three experimental sites in 2014.

Soil characteristics:*	Ridgetown	Rodney	Simcoe	
			Snaps	Edamame
Soil texture	Sandy Loam	Loamy Sand	Sandy Loam	Sandy Loam
% sand:silt:clay	73:20:7	84:10:6	54:40:6	65:31:4
pH	6.5	6.9	6.7	6.8
% Organic Matter	1.4	3.3	2.3	1.5
CEC (MEQ/100g)	6.8	7.3	8.4	6.6
Nutrients (ppm):				
P	59	40	50	39
K	146	112	158	104
Ca	777	932	1044	744
Mg	165	136	190	166
Zn	0.8	3.1	0.8	0.5
Mn	21.2	6.6	14.1	11.3
Cu	1.7	0.4	1.4	0.9
Fe	34.4	18.5	19.6	15.7
B	0.24	0.25	0.29	0.24

*All soil parameters were taken from a composite of over ten cores to 15 cm depth.

Root Nodules.

During the growing season 3 plant roots were dug up and the number of nodules counted

- There were more nodules on edamame than on snaps. This is likely due to differences between plant species (*Glycine max* vs. *Phaseolus vulgaris*) and perhaps variety.
- At Rodney, there were significantly more nodules in the zero N fertilizer treatment than the fertilized treatments. This trend was similar at the other two sites.
- The trend of lower nodulation with N fertilizer was expected as association with rhizobium bacteria decreases with increasing N fertility.
- In general, across the province, nodulation was poor due to poor growing conditions (low temperatures) OMAFRA specialist H. Bohner (Ontario Farmer –2 Sept. 2014).

Table 2. Average number of nodules on crop roots*.

Effect	Treatment	Ridgetown	Rodney	Simcoe
		Number per plant		
Crop	Edamame	**33.1 a****	40.4 a	**34.7 a**
	Snap beans	**18.4 b**	2.14 b	**5.28 b**
	p value	**0.0456**	0.0019	**<.0001**
N rate	0	34.3	40.0 a	20.1
	60	24.1	14.2 b	23.4
	120	18.9	9.54 b	16.5
	p value	ns	<.0001	ns
Crop x N rate	Edamame 0	36.8	**74.1 a**	38.6
	Edamame 60	37.6	**27.9 b**	37.2
	Edamame 120	25.1	**19.1 bc**	28.6
	Snap bean 0	31.8	**5.91 bc**	1.67
	Snap bean 60	10.6	**0.5 c**	9.75
	Snap bean 120	12.7	**<<0 c**	4.42
	p value	ns	**0.013**	ns

*Three plants were sampled on 13 July in Rodney and Simcoe and 14 Aug. at Ridgetown.

**In each column and each effect, different letters indicates a statistical difference (P<0.05).

Snap bean:

- Variety: Caprice
- At all three locations, N fertilizer rate did not have an effect on snap bean yield (P=0.877) or plant shoot growth.
- There was no significant correlation between N applied and yield (Fig. 1)
- Yield at both Ridgetown and Rodney was 8.5±0.65 t/ac and 3.4±0.43 t/ac at Simcoe

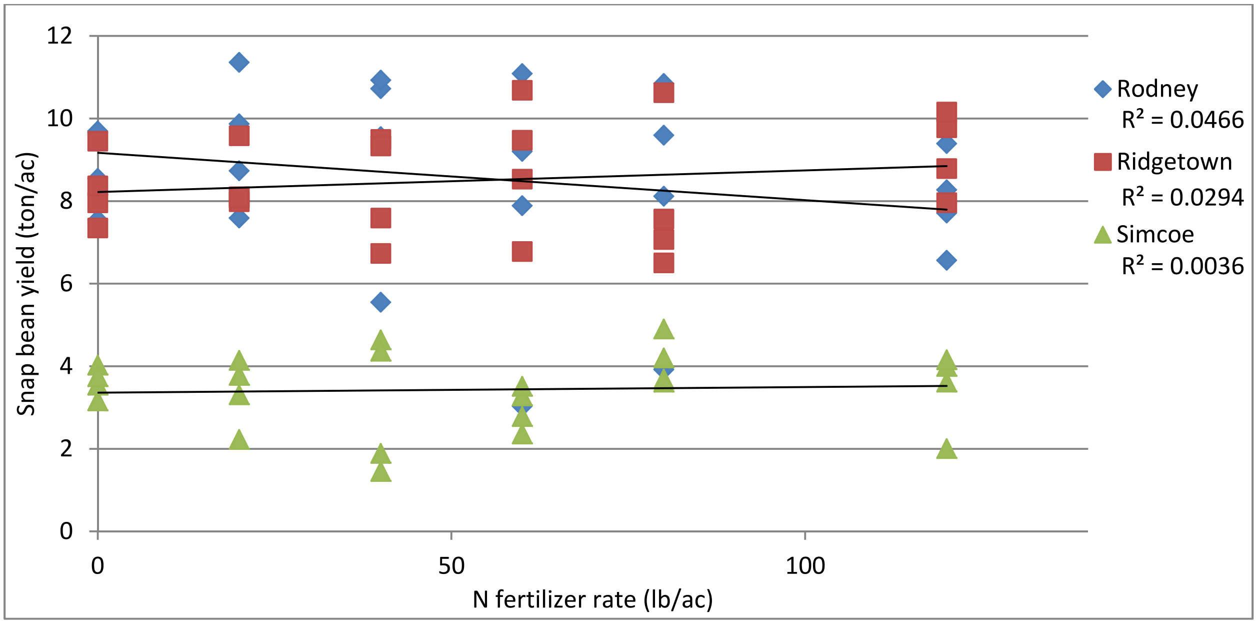

Fig. 1. Marketable yield response of snap bean to pre-plant nitrogen fertilizer at three locations in 2014.

<u>Quality</u>:

Although growers are not paid by sieve size, one indicator of snap bean quality is sieve size. A random subsample of 100 pods was put through 5 sieves. All sizes are marketable; sieve 1 is the smallest and 5 the largest.

- The lower yield at Simcoe was due to smaller size beans rather than less pods harvested. Simcoe harvest was more representative of fresh market size. At Simcoe 75% by weight was sieve #3 or smaller (Table 3). At Ridgetown and Rodney, 55% was sieve #3 or smaller (Table 3), which was ideal for processing market.
- There was no impact of N rate on average bean weight (P=0.26) on all 5 sieves at all three locations.
- At Ridgetown and Rodney: N rate did not affect distribution of beans on sieves #1, #3, #4, and #5 (P=0.15), whether expressed as a percent in terms of the number or weight of beans.
- At Ridgetown and Rodney: Based on the total number of beans sieved, the zero N control had lower number of beans on the #2 sieve, than 60 or 120 lb N/ac treatments. The 60 and

120 treatments were not different from each other. The percent number beans on sieve #2 was 11%, 14.9% and 15.4% for 0, 60, 120 N treatments, respectively.

- At Ridgetown and Rodney: Based on the total weight of beans sieved, the zero N control had lower weight on the #2 sieve, than the 60N treatment. The 120 lb N/ac treatment was not different than 0 or 60 N treatment. The percent weight beans on sieve #2 was 7.0%, 9.8% and 9.0% for 0, 60, 120 N treatments, respectively.
- At Simcoe: N rate did not affect distribution of beans on sieves #1, #2, #3, and #5 (P=0.117), whether expressed as a percent in terms of the number or weight of beans.
- At Simcoe: Based on all beans sieved, the zero N control had lower number and weight on the #4 sieve, than the 120N treatment. The 60 lb N/ac treatment was not different than 0 or 120 N treatment. The percent number of beans on sieve #4 was 8.9, 11.0%, 12.7% and 9.0% for 0, 60, 120 N treatments, respectively. The percent weight beans on sieve #4 was 16.2, 19.7%, 23.9% and 9.0% for 0, 60, 120 N treatments, respectively
- Quality conclusion: given that other than one out of five sieves, there was no difference among N treatments in snap bean size, count or weight, it is reasonable to conclude that N rate had very little impact on snap bean quality.

Table 3. Differences among sites in the percent weight of each sieve size.

Sieve #	Simcoe	Ridgetown	Rodney
		% weight	
1	15.8	3.3	2.3
2	26.8	9.3	8.0
3	33.3	40.5	46.3
4	19.9	43.5	42.3
5	4.2	3.4	1.2

Economics:

- Based on a dual –purpose (whole and cut beans) price for processing snap bean of $189.11/ton and cost of 50¢/lb of fertilizer, the most economical rate of N for snaps was zero at all locations.
- This was because there was no snapbean yield response to N fertilizer applied, so it did not pay to apply N fertilizer.
- Therefore the recommended rate of preplant N fertilizer was 0 lb N/ac.

Nitrogen cycling:

- N concentration (lb N/ac) and content (%N) was determined on plants from the 0, 60, 120 N rates at each location (Table 4).
- There were differences among locations but no location by N treatment interaction. The lower N content in pods at Simcoe compared to the other two sites was due to the lower overall yield at Simcoe and higher %N. Differences in plant N content and concentration among sites is not unexpected.
- Increasing N fertilizer caused an increase in N concentration in the shoots and pods.

- But increasing N fertilizer did not increase N content in the bean pods but did increase N in the shoots.
- There was no increase in crop yield with N fertilizer, thus N increase in the shoots did not benefit overall crop yield. This suggests luxurious N consumption.
- Soil N data still needs to be run in the lab and data analyzed. From this data we will know the amount of N left in the field and can predict potential N losses through leaching or greenhouse gas emissions.

Table 4. Nitrogen in the snap bean crop at three locations.

Treatment	N concentration (%)		N content (lb/ac)		
N rate	Shoot	Pod	Total	Shoot	Pod
0	2.39 b	2.61 b	98.6 b	71.5 b	27.1 a
60	2.77 ab	2.99 ab	112 a	84.0 ab	28.5 a
120	3.16 a	3.18 a	127 a	95.9 a	31.7 a
se	0.164	0.114	7.51	6.38	3.58
Rodney	2.43 b	2.54 c	101 b	67.2 b	33.4 a
Ridgetown	2.68 b	3.00 b	130 a	91.3 a	38.7 a
Simcoe	3.22 a	3.24 a	108 b	93.0 a	15.1 b
se	0.14	0.072	6.95	5.58	2.11

*For each column and each effect, different letters indicates a statistical difference (P<0.05).
se = standard error of the mean.

Edamame:

- At each site, the following yield measurements were taken:
  - Marketable yield per hectare and per plant
  - Total yield per hectare and per plant
  - Leaf and stem weight per hectare and per plant
  - Harvest index (ratio of pods to vegetative tissue)
  - number of plants per 4 m row
- The site at Rodney was not harvested due to soybean sudden death syndrome, associated with soybean cyst nematode pressure at that location.
  - Harronomai variety is not tolerant to soybean cyst nematodes. The trial at Rodney was located in a commercial soybean field. The commercial soybean variety was not affected by sudden death syndrome.
- At Simcoe, there was no marketable yield response to N fertilizer (Fig. 1). There was no difference in any of the measured parameters to N fertilizer.
- At Ridgetown, unmarketable yield was not influenced by N fertilizer.
- At Ridgetown, marketable and total yield had a positive linear response to N fertilizer applied (P<0.05). Thus the higher the amount of fertilizer applied the higher the yield.

- Although there was a yield response to N fertilizer at Ridgetown, there was no statistical difference in yield among higher N rates. For instance, yields at the 60, 80, and 120 N rate were 6.4, 6.3 and 6.8 ±0.56 tonne/ha. Therefore, it may be hard to justify higher N rates.
- At Ridgetown, plant shoot (leaves +stems) weight was highest with the 60 lb N/ac treatment and lowest with 0 N treatment.
- At Ridgetown, there was no influence of N treatment on the following: individual plant weight, marketable yield per plant (g/plant), unmarketable yield per plant (g/plant), total yield per plant (g/plant), or harvest index (P>0.694)

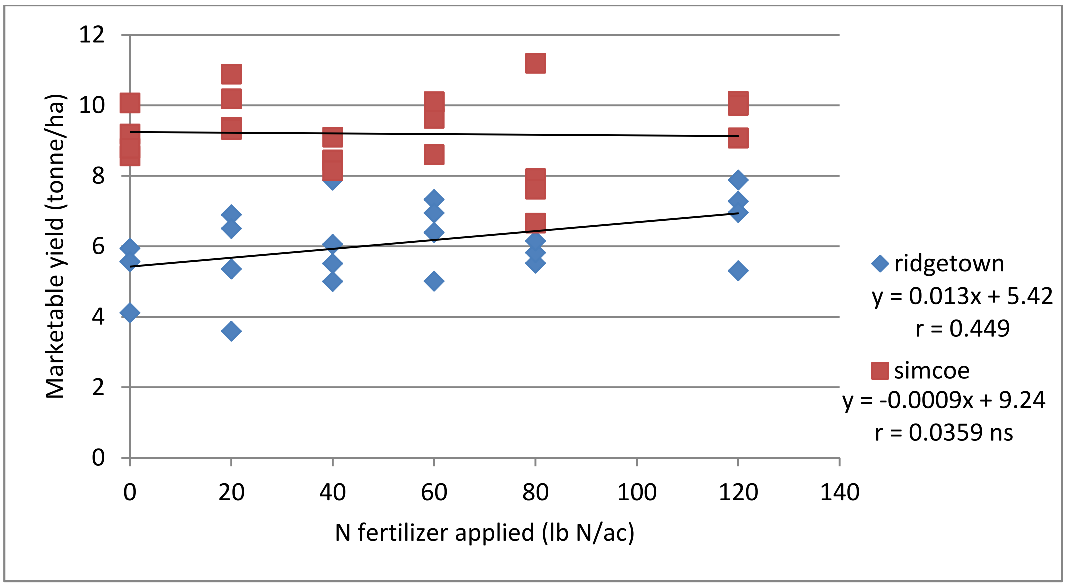

Fig. 3. Marketable yield response of edamame to pre-plant nitrogen fertilizer at two locations in 2014.

<u>Quality:</u>

- At each site, the following quality indicators were measured:
    - unmarketable yield per ha and per plant
    - 100 pod weight of marketable pods
    - number, percent or weight of pods with 3 or more beans (100 pod count)
- At Ridgetown, N fertilizer did not impact any of the quality parameters measured.
- At Simcoe, N rate impacted the number, percent, and weight of pods with 3 or more beans in a 100 pod sample. It was highest at 55 lb N/ac. Although significant, the strength of the relationship between N rate and this quality indicator was quite weak (r=0.45). Further research would be needed to confirm if this relationship holds true.
- At Simcoe, no other quality parameters were impacted by N fertility or the variability in the data was too high to detect a difference.
- Based on these two sites in 2014, there is little evidence to suggest that N fertilizer greatly influences edamame quality in the parameters measured.

Economics:

- With no N fertilizer yield response at Simcoe the most economical rate of N was 0 lb N/ac.
- At Ridgetown, the most economical rate of N was the N rate that optimized marketable yield, which was the highest rate tested.

Nitrogen cycling:

- N concentration and content was determined on plants from the 0, 60, 120 N rates. There was no location by N treatment interaction, so data were given for both locations together.
- N fertilizer rate had no impact on %N concentration in pods (3.4% ± 0.04%) or shoots (2.9% ± 0.13%).
- At both locations, N fertilizer rate had no impact on N content in the pods (55.9± 5.80 lb/ac) or plant (136 ± 9.1 lb/ac).
- But N content was 15 and 18 lb/ac higher in the shoots in the 60 and 120 N treatment compared to the 0 N, respectively. Thus, with more N fertilizer applied the shoots contain more N but the pods don't have more N. This phenomenon is called luxurious N consumption.
- At Ridgetown all N rates were analyzed for N content. There was a significant positive correlation between the amount of N fertilizer applied and N content in the plant. The amount of N in the total plant, shoots, and pods peaked at 100 to 120 lb N/ac. This suggests luxurious N consumption.
- Soil N data still needs to be run in the lab and data analyzed. From this data we will know the amount of N left in the field and can predict potential N losses through leaching or greenhouse gas emissions.

Conclusions:

The current OMAFRA nitrogen recommendation for snap beans is 40 kg ha^{-1}. The research conducted provides no reason to increase the provincial N recommendation. In fact, the research suggests growers could drop their N rate to zero without yield, quality or economic losses. In 2014, there was no evidence to suggest that N fertilizer greatly influences snap bean or edamame quality in the parameters measured. Growers with soybean cyst nematodes should use caution when selecting varieties and avoid Harronomai edamame. For edamame, there was too big of a difference between sites to make an N recommendation as at Simcoe there was no yield or economic response to applied N fertilizer and at Ridgetown the response was linear.

References:

McEwan, K. 2014. ONTARIO FARM INPUT MONITORING PROJECT SURVEY # 2 May 28, 2014. ECONOMICS AND BUSINESS GROUP, RIDGETOWN CAMPUS U of G.
http://www.ridgetownc.uoguelph.ca/research/documents/mcewan_ONTARIO_FARM_INPUT_MONITORING_PROJECT_SURVEY___2___May_28__2014.pdf

Communication and Reach:

Print communication:

Roddy, E.C. 2014. Edamame Bean Research in Ontario. *The Grower*. Volume 64 Number 10, p. 21.

On-line communication:

Roddy, E.C. and L.L. Van Eerd. 2014. Nitrogen Fertility of Edamame Crops.ONvegetables blog. Once the report is public, a blog post on ONvegetables blogs and posted on the *Specialty Cr*opportunity site: a resource for specialty crop growers (http://www.omafra.gov.on.ca/CropOp/en/index.html). These are the primary communication tools for the OMAFRA vegetable crop and speciality crop specialists. In 2014, the ONvegetable blog received over 46,000 hits.

Promotional Material:

Farm and Food Care Ontario -WAMQI promotional video. Roddy, E.C. and Van Eerd, L.L. 2014. Nitrogen Fertilizer Recommendations for Edamame and Snap Beans. http://youtu.be/eOxN9E5estc Produced by Farm and Food Care Ontario. Recorded 7 July 2014. Available 26 Aug. 2014.

Field Day Demonstrations/Talks:

Roddy, E.C. 2014. Nitrogen for Edamame and Snap Beans. *for*: Bonduelle North America, Tecumseh. Ridgetown. 12 Aug. 2014. Talk to approx. 12 agronomists and industry personnel.

Roddy, E.C. 2014. Nitrogen for Edamame and Snap Beans. *for*: Vegetable Open House. Ridgetown. 17 July. 2014. Talk to approx. 60 growers, agronomists and industry personnel.

Final Report:

Submitted to Farm and Food Care and posted online at on Dr. Van Eerd`s Ridgetown Campus website http://www.ridgetownc.on.ca/research/research_reports_profile.cfm?profile=vaneerd&name=Dr.%20Laura%20Van%20Eerd

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