Determining Nitrogen Fertility Requirements of Lavender

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Sean Westerveld, Ginseng and Herbs Specialist

Background:
Lavender is a relatively new crop for Ontario and acreage continues to increase. Initial research efforts focussed on identification of cultivars suitable for Ontario growing conditions and for various end purposes. Research has also been conducted on row covers for winter protection and mulches for weed control as well as surveys for pest issues. There is a misconception in the lavender industry that it does not need fertilizer. While this is likely not the case, there has been no fertility research in Ontario to determine the fertility requirements.

Issue:
There have been no studies under Ontario growing conditions on the fertility requirements of lavender. While phosphorus and potassium research is needed, most soils in Ontario are at least moderate in these nutrients due to fertilization of previous crops. There is a need to determine the nitrogen (N) requirements of lavender for Ontario growing conditions. Where lavender grows without competition from weeds or grass between the rows, plants can be up to twice as large after 2 or 3 years. This suggests that grass between the rows of lavender, a typical practice for most lavender farms open to the public, could be using up much of the N in the soil. As a result, supplemental N fertilization may substantially improve lavender yield. Since plants fertilized with N will likely be more vegetative, there is also a need to determine what effect N has on essential oil yield, overwintering success and foliar diseases.

Goal:
The goal of this project is to determine the N requirements of lavender in Ontario for the eventual creation of N recommendations. This will allow lavender growers to make informed decisions about N application and could significantly improve lavender yields across Ontario.

Methods:

An N fertigation trial was established at Apple Hill Lavender near Simcoe, Ontario in 2015. The field had been established with ‘Folgate’ lavender in 2013 and all plants received only minimal fertilization for the first two years. The lavender was established on solid black plastic tree mulch with grass between the rows and 1.8 m between-row spacing and 0.6 m in-row spacing. Nitrogen treatments were applied each year for four years beginning in 2015. There were 5 treatments including a 0 N control and 4 rates of N: 40, 80, 120 and 160 kg/ha applied as a band assuming the lavender occupied 60 cm of the 1.8 m row spacing in 2015, 2016 and 2017. As the plants grew, the fertilized area was expanded to 90 cm in 2018. Lavender is often planted at a wide row spacing to allow for agri-tourism activities, but not all this space is necessary for lavender production. The main rooting zone was assumed to occupy the area under the canopy when plants were at full bloom. The rates were split among three applications per year in early June, early July and early August. Each treatment consisted of a single row approximately 30 m in length. The trial was arranged as a randomized complete block design with four replications. Severe winter kill over the winter of 2018/2019 killed or severely harmed most of the plants in the trial resulting in no harvest potential. The trial was suspended at that time and no further assessments or treatments were conducted.

To track N uptake, removal and losses over a growing season, soil and tissue samples were collected in 2017. Soil samples were collected May 15, 2017 and Oct. 20, 2017 and submitted for nitrate-N (NO_3-N), ammonium-N (NH_4-N) and organic matter analysis. Samples were collected from each experimental unit from both 0-30 cm and 30-60 cm depth for N budgeting purposes. Flower/stem samples and trimming samples were collected at harvest July 12, 16 and 18, 2017, fresh weighed, dry weighed and submitted for total N analysis.

A winter damage rating was planned for the trial in May 2016 and 2017, but due to the mild winters in those years, no damage occurred. A winter damage rating was conducted on May 24, 2018 after moderate damage occurred over the winter of 2017/2018. Ten plants in each experimental unit were assessed for winter kill by rating the plants according to the following scale: 0 = dead, 1 = 1-10% undamaged and from thereon each point on the scale increased in 10 percentage point increments up to 10 = 91-100% undamaged. Septoria leaf spot ratings were also planned for each plot, but no significant symptoms were identified in the trial.

Each plot was commercially harvested for bundles from 25 of the plants in each treatment when the first flowers began to open on June 30, 2016, June 28-30, 2017, and July 3-4, 2018. Bundles were approximately 1.5 to 2 cm in diameter with an average weight of 30 g. The total number and weight of bundles in each plot was determined. A separate bundle of 30 flowers was collected during the same period in 2016 and 2018 for stem length measurements. The stems were cut below the highest pair of leaves to simulate a harvest for dried bundles and the full length of the flower and stem was measured to the tip of the tallest flower bud. The weight of buds compared to stems was also assessed in 2018.

Each plot was commercially harvested for oil production when plots were past 50% bloom on July 14 and 18, 2016, July 12, 16 and 18, 2017 and July 16 and 18, 2018 and the weight of flowers per plant was determined. A sub-sample of each of these of approximately 8 kg of flowers was collected for oil distillation to determine the oil yield per kg of flowers for each treatment. Oil was distilled with a 40 L stainless steel Heart Magic steam distiller the day of harvest or the day after to ensure there was little degradation in oil quality. Samples not distilled immediately were placed in a cooler at 1^{o}C until distillation. Total oil yield from each sample was measured after 30 min. of flow and the amount of oil extracted per kg of flowers was determined.

Data were analyzed using the Linear Regression and Polynomial Regression functions of Statistix version 9.0.

Regression Analysis
Regression analysis is used to determine if there is a statistically significant trend in the data and it is generally considered significant if the P (probability) value is below 0.05. It is used for experiments in which the treatments are a range of different rates. If the analysis is significant, regression analysis provides an R^2 value, which is the proportion (values between 0 and 1) of the variation in all of the data that is described by the treatments. For example, if you are analyzing the change in the weight of flowers at increasing N rates and the R^2 value is 0.90, then 90% of the variability in flower weight among the plots in the trial can be attributed to changes in N rate. If the R^2 value was 0 then N rate had no influence on the crop and any differences among the plots in the trial would be due to other factors and/or random chance.

The regression analysis also provides an equation that can be used to predict the value of a variable at a specific treatment, and for a linear response is described by the equation Y=a + bX, where Y is the variable you want to predict and X is the rate of the treatment. The values of a and b are provided by the regression analysis. For example, if the regression analysis for the flower weight example above provides the equation Y=5 + 0.4X, Y would be weight of flowers you want to predict and X would be the rate of N. Replace the value 'X' with the N rate you want to use to calculate the predicted weight of flowers. So, at 100 kg/ha of N, the predicted weight of flowers would be 5 + 0.4(100) = 45. The regression equations can be more complex (e.g. $Y=5 + 0.4X – 0.003X^2$) but still require replacing X with the N rate you want to apply.

Results and Discussion:

No significant winter damaged occurred during the first two winters of the trial. The winter of 2017/2018 caused some damage, mainly to the upper portions of the branches. There was no significant difference in winter damage rating among the N rate treatments (Table 1). However, there was a trend towards higher damage in the high N rate treatments, which is a trend that should be investigated further. Damaged plants grew back from secondary buds along the stems and the damage did not appear to impact flowering.

When tracking the N losses and uptake in 2017, soil nitrate (NO_3) concentrations increased over the season for all treatments at both depths and there was no effect of N application rate on these concentrations (Table 2). Nitrate concentrations were low at both dates. Soil ammonium (NH_4) concentrations did not change over the growing season and were also unaffected by N application rate (Table 3). These results suggest the rates of N applied in this trial did not lead to excessive increases in available N in the soil and much of the N applied was probably taken up by the lavender or the grass between the rows.

Nitrogen concentrations in both the flowers and the trimmings were unaffected by N application rate (Table 4). Due to higher flower yields and more plant material trimmed off after harvest in higher N treatments, N removal values increased with increasing N application rates (Table 4). After subtracting the known removal values from the application rates, only the two highest N application rates led to applied N that could not be accounted for with the available data. Very little N was unaccounted for in the highest N application rate. The testing could not account for the amount of N remaining in the rest of the plant. The plants grow every year, suggesting a gradual increase in N locked up in the tissues. The results of the analysis suggest there would be minimal additional losses of N from the system beyond that of unfertilized plots.

The bundle harvest assessment revealed a significant increase in both total weight of bundles harvested over three years and average weight per bundle with increasing N rate (Table 5). The increase in bundle weight occurred despite harvesting a consistent sized bundle in all treatments, which suggests that N must affect flower characteristics other than stem thickness. The height of flowers was analysed in this trial, but no significant differences were found among treatments (data not shown). Other differences in fresh weight may be due to moisture content, number of buds per flower, or the size of buds on the plant.

There was no significant effect of N on the total number of bundles harvested over the three-year period (Table 5). However, when analysing each year separately, there was a significant effect of N in all three years. The effect in the first year was quadratic, increasing with increasing N rates at low N rates and then levelling off or falling at higher N rates (data not shown). In the other two years, the increase was linear, increasing with increasing N rates up to the highest N rate tested (data not shown). When combining the three years of data, the different responses in different years resulted in higher variability in the number of bundles at the higher N rates and lower ability to find statistically significant differences. Overall the data suggests that N application up to 160 kg/ha improves bundle yield. However, there may be diminished returns in some years beyond 80 or 120 kg/ha N.

The weight of flowers per plant harvested for oil distillation was also increased with increasing N application rate (Table 6). This also translated into an increase in oil yield per plant with increasing N application rate. The R^2 values for both relationships were relatively low, suggesting that a linear response does not fit the data well. It appears that yield may hit a plateau beyond 80 kg/ha N. There was no effect of N application rate on the amount of oil per kg of flowers. Prior to this trial the common belief was that higher fertility would lead to lower oil production. This trial shows that oil yield per kg of flowers is not affected by N application rate and is directly correlated changes in flower weight among treatments.

Conclusions

There was the assumption prior to this trial that lavender does not need supplemental fertilization. In the case of N, this trial contradicts that assumption. The addition of N fertilizer increased the yield of both flower bundles and essential oil, the two main raw materials used by lavender growers for direct sales and the development of value-added products. There were no negative effects of N fertilization on yield or quality. However, a non-significant trend towards increasing winter kill with the highest N rate in one year suggests that growers should be cautious in avoiding excessive N application above 160 kg/ha in the absence of additional research. Although most of the yield response was linear, increasing with increasing N application up to the highest rate of N tested, there appeared to be diminishing returns above 80-100 kg/ha. These match the results of previous limited research in Colorado and the recommendations from other jurisdictions. As result it appears that the optimal rate of N for this trial was 80-100 kg/ha or above. Growers should consider this N rate range a starting point, since the response of lavender to N may differ depending on the cultivar, the soil type, the weather conditions, and the growing methods (e.g. solid ground cloth vs grass between rows).

Impacts:

For a grower, the addition of fertilization would increase essential oil yields per hectare per year by 5.19 litres. This volume of *Lavandula angustifolia* essential oil is worth $1,600 on the wholesale market in 2020. Growers can retail essential oil for up to 6 times this value, especially if it is locally sourced, which adds additional value to the oil. Some of this increase would be offset by an increase in labour to collect and process the additional plant material, but the impact of fertilization on a grower’s profitability could be substantial.

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Table 1. Effect of nitrogen (N) application rate on winter damage rating of 'Folgate' lavender in May, 2018.

N Rate (Banded) (kg/ha)	N Rate (kg) per Hectare		Winter Damage Rating[z]
	2016/17	2018	
0	0	0	7.3
40	13	20	6.2
80	27	40	6.8
120	40	60	6.8
160	53	80	4.6
Regression[y]:			
P			NS[y]
R^2			--
Equation			--

[z] Rating scale: 0 = dead, 1 = 1-10% undamaged, 2 = 11-20% damaged and thereon increasing in 10% increments to 10 = 91-100% damaged.
[y] See methods for an explanation of this statistical analysis. NS = regression analysis not significant at P=0.05.

Table 2. Effect of nitrogen (N) application rate on soil nitrate (NO_3) concentrations in spring and fall at two different depths for 'Folgate' lavender in 2017

N Rate (Banded) (kg/ha)	N Rate (kg) per Hectare	Spring NO_3 Concentration (ppm)		Fall NO_3 Concentration (ppm)	
		0-30 cm depth	30-60 cm depth	0-30 cm depth	30-60 cm depth
0	0	0.8	0.0	5.8	1.3
40	13	1.5	0.5	3.4	1.0
80	27	1.3	0.0	3.1	0.8
120	40	1.7	0.0	4.2	1.8
160	53	1.0	0.0	3.3	1.8
Regression[z]:					
P		NS	NS	NS	NS

[z] See methods for an explanation of this statistical analysis. NS = regression analysis not significant at P=0.05.

Table 3. Effect of nitrogen (N) application rate on soil ammonium (NH_4) concentrations in spring and fall at two different depths for 'Folgate' lavender in 2017

N Rate (Banded) (kg/ha)	N Rate (kg) per Hectare	Spring NH_4 Concentration (ppm)		Fall NH_4 Concentration (ppm)	
		0-30 cm depth	30-60 cm depth	0-30 cm depth	30-60 cm depth
0	0	3.5	1.8	3.6	1.9
40	13	3.4	1.7	3.3	1.9
80	27	3.5	1.8	3.3	2.1
120	40	3.5	1.7	2.7	1.7
160	53	3.6	1.8	2.8	1.7
Regression[z]:					
P		NS	NS	NS	NS

[z] See methods for an explanation of this statistical analysis. NS = regression analysis not significant at P=0.05.

Table 4. Effect of nitrogen (N) application rate on flower and trimming N concentrations and N removal values for 'Folgate' lavender in 2017.

N Rate (Banded) (kg/ha)	N Rate (kg) per Hectare	N Conc. (Flowers) (%)	N Conc. (Trimmings) (%)	N Removal (Flowers) (kg/ha)	N Removal (Trimmings) (kg/ha)	Unaccounted N[z] (kg/ha)
0	0	1.42	1.44	13.0	6.8	0.0
40	13	1.44	1.45	14.5	8.4	0.0
80	27	1.41	1.59	18.0	11.6	0.0
120	40	1.45	1.54	17.9	10.9	11.2
160	53	1.48	1.54	18.9	10.7	23.4
Regression[y]:						
P		NS	NS	0.0039	0.0025	
R^2		--	--	0.48	0.70	
Equation		--	--	$6.64 + 1.01N$	$10.7 + 1.01N - 0.53N^2$	

[z] Unaccounted N = N accumulated in the unharvested and untrimmed portions of the plant, the taken up by the grass between rows, or lost from the system.
[y] See methods for an explanation of this statistical analysis. NS = regression analysis not significant at P=0.05.

Table 5. Effect of nitrogen (N) application rate on fresh bundle number and total weight from 25 plants and average weight per bundle of ‘Folgate’ lavender over three harvest periods from 2016 to 2018.

N Rate (Banded) (kg/ha)	N Rate (kg) per Hectare		3-Year Total Bundle Number	3-Year Total Bundle Weight (kg)	3-Year Average Weight per Bundle (g)
	2016/17	2018			
0	0	0	735	20.8	29.1
40	13	20	724	21.3	30.1
80	27	40	952	26.4	30.3
120	40	60	847	27.5	31.3
160	53	80	828	28.5	34.9
Regression[z]:					
P			NS	0.0148	0.0003
R^2			--	0.54	0.59
Equation			--	21.2 + 0.046N	28.6 + 0.032N

[z] See methods for an explanation of this statistical analysis. NS = regression analysis not significant at P=0.05.

Table 6. Effect of nitrogen (N) application rate on average essential oil yield per plant and per kilogram of flowers and weight of flowers per plant for ‘Folgate’ lavender over three harvest periods from 2016 to 2018.

N Rate (Banded) (kg/ha)	N Rate (kg) per Hectare		3-Year Average Oil Yield per Plant (ml)	3-Year Average Oil Yield per Kilogram of Flowers (ml)	3-Year Average Weight of Flowers per Plant (g)
	2016/17	2018			
0	0	0	2.3	8.5	269
40	13	20	2.6	8.8	292
80	27	40	3.2	9.0	361
120	40	60	3.2	9.4	336
160	53	80	3.0	8.5	353
Regression[z]:					
P			0.0188	NS	0.0032
R^2			0.37	--	0.49
equation			2.44 + 0.0053N	--	279 + 0.53N

[z] See methods for an explanation of this statistical analysis. NS = regression analysis not significant at P=0.05.