2019 PROGRESS REPORT

Project No: 3455-3644

Title: Impacts of Post-Harvest Nitrogen Cut-Off Times in 'Duke' Blueberry

Initiated:2018 **Current Year:** 2019 **Terminating Year:** Requesting 2022

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Objective:
Determine the impact of nitrogen fertilization cut-off times on plant growth, yield, fruit bud set, and cold hardiness in an early-fruiting blueberry cultivar (i.e. Duke) grown in eastern Washington.

Procedures:
This experiment was established in an organic 'Duke' blueberry field located in Prosser, WA, in 2018. The planting was eight years old when the experiment was established. The experimental design is a randomized complete block with each treatment replicated four times. Plants are spaced 2.5 feet apart within the row with 16 plants in each treatment plot (with data collected on the inner 12 plants). All treatments were applied using WISErganic (3-2-2; WISErganic Corporation, Redmond, WA) as the fertilizer source. Fertilizer was applied at a constant rate (125 lbs N/acre) but varied with the timing of application. Treatments applied from 2018-2019 include:

1) Control (100% of N applied pre-harvest; standard grower practice)
2) 80/20 (80% of N applied pre-harvest, remaining 20% applied post-harvest)
3) 70/30 (70% of N applied pre-harvest, remaining 30% applied post-harvest)
4) 60/40 (60% of N applied pre-harvest and remaining 40% applied post-harvest)

Fertilizer applications began at ~5 to 10% bloom and occurred weekly. The control treatment received a total of 10 fertilizer applications per year (all pre-harvest); the 80/20 treatment received 12 fertilizer applications per year (10 pre-harvest, 2 postharvest); the 70/30 treatment received 14 fertilizer applications per year (10 pre-harvest, 4 post-harvest); and the 60/40 treatment will received 16 fertilizer applications per year (10 pre-harvest, 6 post-harvest).

Data collected includes:

- Soil pH (1:1), nitrate (NO_3-N), ammonium (NH_4-N), electrical conductivity (EC) concentrations, and organic matter content– determined from samples collected Mar. 20, 2018, Sept. 5, 2018, and Aug. 28, 2019
- Leaf tissue macro- and micro-nutrient concentrations – determined Aug. 2018 and 2019
- Plant vigor – number of whips and mid-canopy lateral length (determined monthly from June-Sept. 2018 and May-Sept. 2019)
- NDVI (Normalized Differential Vegetative Index) and GDVI (Generalized Difference Vegetative Index) determined from aerial images collected using MicaSense® multispectral cameras mounted on a UAV – collected in 2018; 2019 data are being processed and analyzed
- Yield and fruit quality [average berry mass, firmness, °Brix, and total titratable acidity (TA)] in June 2018 and 2019; fruit quality data in 2019 is being processed
- Fruit bud set - determined visually Nov. 2018 and 2019 by counting the number of fruiting buds on 8 laterals per plot at mid canopy height
- Cold hardiness – evaluated monthly starting Oct. to Dec. 2018 and 2019 using the polar pod method; 2019 data are being collected and analyzed

2019 PRELIMINARY RESULTS:

Soils Data: Year effects were observed for all soil variables with the exception of EC, which also showed no treatment effects (Table 1). Soil pH was similar across treatments but was lower in 2019 than 2018. Both soil NO_3-N and NH_4-N increased in 2019, but this could be due to sample timing and no treatment effects were observed. Organic matter was also greater in 2019 and may be attributed to sampling. Still, no treatment effects were observed.

Leaf Tissue Data: Leaf tissue data showed yearly effects, but no treatment effects were observed (Tables 2 and 3). All tissue nutrient concentrations were within the recommended range except for copper. Despite this, no signs of deficiency were observed and tissue nutrient ranges were within the normal ranges described by Daveport and DeVetter (2019).

Plant Vigor: Shoot growth data showed lots of variability and no treatment effects were observed (Fig. 1). Similarly, not differences in whip production were observed across the years and treatments (Table 4).

Yield: No differences in plant yield across the years and treatments were observed (Table 4). However, yield tended to increase with later fertilizer cut-off times (P-value = 0.157). While this P-value doesn't meet our statistical significance boundary of $\alpha = 0.05$, it is nevertheless close and warrants continuation of the trail especially given the long response time of perennial plants to different nutrient management practices.

Fruit Quality: Berry mass was unaffected by treatment (Table 4). Firmness differed by year and was lower in 2019 due to a later harvest time. Firmness in the 80/20 treatment was lower than the remaining treatments, including the control. Additional years of data are required to better monitor how firmness is impacted by our fertilizer treatments. Fruit chemistry variables of °Brix and TA collected in 2019 are being processed. Data from 2018 showed °Brix was highest in the 60/40 treatment and no differences in TA were found.

Fruit Bud Set: No treatment nor year effects were observed for fruit bud set (Table 4). Fruit bud set measured in Nov. 2018 and 2019 ranged from 53-55%.

Cold Hardiness: Some treatment effects were observed for cold hardiness in 2018 (Fig. 2). However, they were inconsistent across the sampling times. Temperatures in which damage was observed were lower than historical averages for Prosser (Fig. 3), suggesting the likelihood of bud damage due to the late nitrogen fertilizer cut off times in our experiment and applied to mature 'Duke' is unlikely. Additional years of data should validate this and be complemented with spring cold hardiness assessments, which is proposed in our next submission.

ANTICIPATED BENEFITS AND INFORMATION TRANSFER:
The results from this experiment will provide information that allows for the creation of data-driven nutrient management guidelines for eastern Washington organic blueberry. This will help growers and crop advisors create informed nutrient management plans and addresses some of the basic questions of organic nutrient management in this unique blueberry production area. Project results for 2018 and 2019 are also part of Amit Bhasin's MS thesis. Results have and will continue to be shared with grower cooperators, at regional horticulture events (e.g. Small Fruit Conference), and at national horticulture meetings (e.g. American Society for Horticultural Sciences). Information will also be published online on the Small Fruit Horticulture Website (http://smallfruits.wsu.edu/) and in peer-reviewed journals. Furthermore, data will be used to generate extension fact sheets on organic blueberry nutrient management for eastern Washington once multi-year data that validates experimental results are generated.

OUTPUTS:

- Bhasin, A., 2019. Evaluating organic nitrogen fertilizer sources, rates, and timing in northern highbush blueberry grown in high pH soils of eastern Washington. MS thesis, Washington State University.
- Bhasin, A. (presenter), J.R. Davenport, G.A. Hoheisel, and L.W. DeVetter. 2019. Fine-tuning organic nitrogen fertilizer sources, rates, and cut-off times in organic highbush blueberry. Washington Small Fruit Horticulture Conference. Lynden, WA
- Bhasin, A. (presenter), J.R. Davenport, G.A. Hoheisel, and L.W. DeVetter. 2019. Exploring the potential of postharvest nitrogen applications in northern highbush blueberry. American Society for Horticultural Science Conference. Oral Presentation. Las Vegas, NV.
- Bhasin, A. (presenter), J.R. Davenport, G.A. Hoheisel, and L.W. DeVetter. 2018. Organic blueberry trials in eastern Washington. Oregon State University Blueberry Field Day. Aurora, OR.
- Bhasin, A. (presenter), J.R. Davenport, G.A. Hoheisel, and L.W. DeVetter. 2018. Fine-tuning organic nitrogen fertilizer sources, rates, and cut-off times in organic highbush blueberry. Washington Small Fruit Horticulture Conference. Lynden, WA.

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TABLES AND FIGURES

Table 1. Soil pH (1:1), nitrate (NO_3-N), ammonium (NH_4-N), electrical conductivity (EC) concentrations, and organic matter content in soil growing 'Duke' blueberry treated with different organic nitrogen (N) fertilizer application timings in eastern Washington. Baseline soil data were collected on Mar. 20, 2018 and remaining sample dates were Sept. 5, 2018 and Aug. 28, 2019.

Treatments	Soil pH (1:1)	Soil NO_3-N ($mg \cdot kg^{-1}$)	Soil NH_4-N ($mg \cdot kg^{-1}$)	EC ($dS \cdot m^{-1}$)	OM (%)
Baseline average^{z}	6.1	13.6	3.2	-	
Year					
2018	5. 4 a^{w}	23.51 b	6.02 b	2.86	2.38 b
2019	5.0 b	98.43 a	24.07 a	2.77	5.17 a
Treatment (T)^{y}					
Control	4.9 b	50.53	14.18	2.89	3.45
80/20	5.3 ab	68.33	16.82	2.83	3.34
70/30	5.4 a	50.30	13.30	2.82	4.51
60/40	5.2 ab	74.73	16.42	2.72	3.82
Significance^{x}					
Y	0.012	0.0001	0.0001	0.155	0.0001
T	0.01	0.550	0.932	0.290	0.234
Y × T	0.981	0.524	0.719	0.619	0.397

^{z}Baseline average soil pH, NO_3-N, and NH_4-N before starting fertilizer N applications.

^{y}Fertilizer treatments that varied in the timing of N application included the control with 100% of N applied pre-harvest (standard grower practice), 80/20 (with 80% of N applied pre-harvest and the remaining 20% applied post-harvest), 70/30 (with 70% of N applied pre-harvest and the remaining 30% applied post-harvest), and 60/40 (with 60% of N applied pre-harvest and the remaining 40% applied post-harvest).

^{x}P-value with significance at $\alpha = 0.05$.

^{w}Means followed by the same letter within a year, treatment, or treatment × year interactions are not statistically different ($P \geq 0.05$).

Table 2. Leaf macronutrient concentration in 'Duke' blueberry treated with different organic nitrogen (N) fertilizer application times in eastern Washington. Data were collected on Aug. 13, 2018 and Aug. 28, 2019.

Treatments	N[z] (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)
Tissue standards[y]	**1.25–1.75**	**0.08-0.15**	**0.40-0.50**	**0.50-0.85**	**0.11-0.17**	**0.12-0.15**
Year (Y)						
2018	1.53 b[v]	0.10	0.51 b	0.95 a	0.29 a	0.16
2019	1.63 a	0.10	0.70 a	0.81 b	0.25 b	0.15
Treatment (T)[x]						
Control	1.59	0.10	0.60	0.89	0.27	0.16 ab
80/20	1.57	0.10	0.61	0.84	0.26	0.14 b
70/30	1.59	0.10	0.60	0.89	0.27	0.16 ab
60/40	1.58	0.11	0.62	0.90	0.29	0.17 a
Significance[w]						
Y	0.002	0.448	<0.0001	<0.0001	<0.0001	0.551
T	0.982	0.260	0.842	0.44	0.120	0.026
Y × T	0.329	0.519	0.647	0.743	0.804	0.574

[z]N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; S = sulfur.
[y]Recommended sufficiency range for blueberry (Davenport and DeVetter, 2019).
[x]Fertilizer treatments that varied in the timing of N application included the control with 100% of N applied pre-harvest (standard grower practice), 80/20 (with 80% of N applied pre-harvest and the remaining 20% applied post-harvest), 70/30 (with 70% of N applied pre-harvest and the remaining 30% applied post-harvest), and 60/40 (with 60% of N applied pre-harvest and the remaining 40% applied post-harvest).
[w]*P*-value with significance at $\alpha = 0.05$.
[v]Means followed by the same letter within a treatment, year or year × treatment interaction are not statistically different ($P \geq 0.05$).

Table 3. Leaf micronutrient concentration in 'Duke' blueberry treated with different organic nitrogen (N) fertilizer application times in eastern Washington. Data were collected on Aug. 13. 2018 and Aug. 28, 2019.

Treatments	Zn[z] (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	B (ppm)
Tissue standards[y]	**10-15**	**60-200**	**100-300**	**5-10**	**30-60**
Year (Y)					
2018	19.06	175.18 b[v]	190.06 a	4.12	51.93 b
2019	15.25	201.31 a	162.81 b	3.68	86.68 a
Treatment (T)[x]					
Control	16.88	185.50	182.12	3.75	71.25
80/20	19.38	182.75	158.50	4.62	63.75
70/30	16.12	188.75	180.75	3.65	71.75
60/40	16.25	196.00	184.37	3.65	70.50
Significance[w]					
Y	0.084	<0.004	0.044	0.459	<0.001
T	0.678	0.700	0.463	0.566	0.530
Y × T	0.524	0.060	0.746	0.622	0.905

[z]Zn = zinc; Fe =iron; Mn = manganese; Cu= Copper; B = Boron.

yRecommended sufficiency range for blueberry (Davenport and DeVetter, 2019).

[x]Fertilizer treatments that varied in the timing of N application included the control with 100% of N applied pre-harvest (standard grower practice), 80/20 (with 80% of N applied pre-harvest and the remaining 20% applied post-harvest), 70/30 (with 70% of N applied pre-harvest and the remaining 30% applied post-harvest), and 60/40 (with 60% of N applied pre-harvest and the remaining 40% applied post-harvest).

[w]P-value with significance at α = 0.05.

[v]Means followed by the same letter within a treatment, year or year × treatment interaction are not statistically different ($P > 0.05$).

Table 4. No. of whips, yield, fruit bud set, berry mass, firmness, soluble solid concentrate (°Brix), and titrable acidity of 'Duke' blueberry treated with different organic nitrogen (N) fertilizer application times in eastern Washington, 2018-2019.

	No. of whips/bush	**Average yield (lbs/bush)**	**Fruit bud set (%)**	**Berry mass (g/berry)**	**Firmness (g/mm of deflection)**	**° Brix**	**TA**
Year (Y)							
2018	8	14.53	54	2.86	198.72 a[z]	11.3	0.42
2019	9	15.54	54	2.77	155.71 b		
Treatment (T)							
Control	5	14.00	54	2.89	171.41 a	10.8 b	0.5
80/20	6	13.66	55	2.83	163.91 b	11.3 b	0.4
70/30	6	16.00	53	2.82	170.05 a	11.1 b	0.4
60/40	6	16.47	54	2.72	174.79 a	12.0 a	0.4
Significance[x]							
Y	0.420	0.341	0.881	0.155	0.0001		
T	0.722	0.157	0.579	0.290	0.0001	0.001	0.65
Y X T	0.756	0.595	0.630	0.619	0.246		

[z]Means followed by the same letter within a treatment or interaction are not statistically different ($P \geq 0.05$).
[y]Fertilizer treatments that varied in the timing of N application included the control with 100% of N applied pre-harvest (standard grower practice), 80/20 with 80% of N applied pre-harvest and the remaining 20% applied post-harvest, 70/30 with 70% of N applied pre-harvest and the remaining 30% applied post-harvest, and 60/40 with 60% of N applied pre-harvest and the remaining 40% applied post-harvest).
[x]*P*-value with significance at $\alpha = 0.05$.

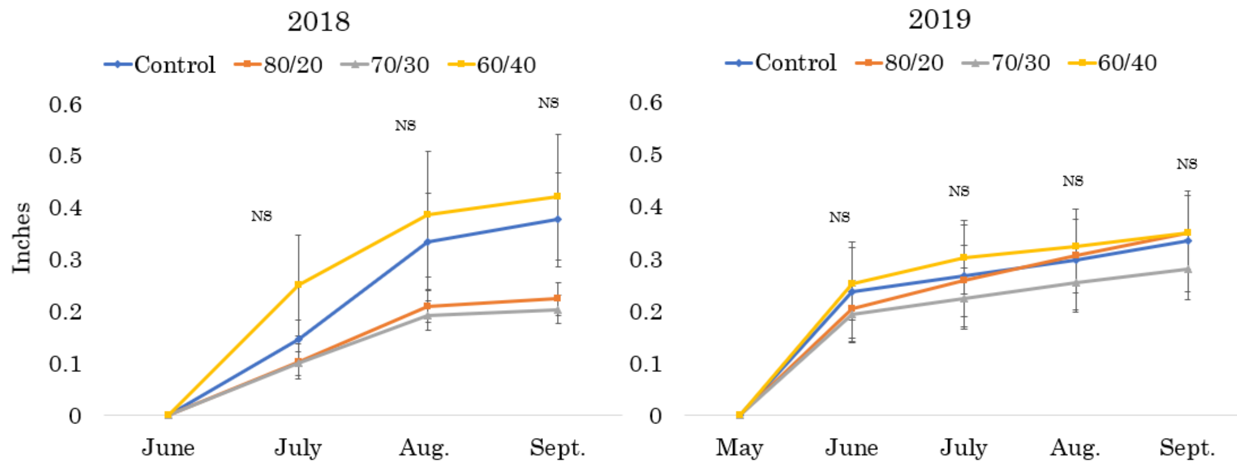

Figure 1. Shoot growth measured form 'Duke' blueberry plants in 2018 and 2019. NS = no statistical differences with α = 0.05.

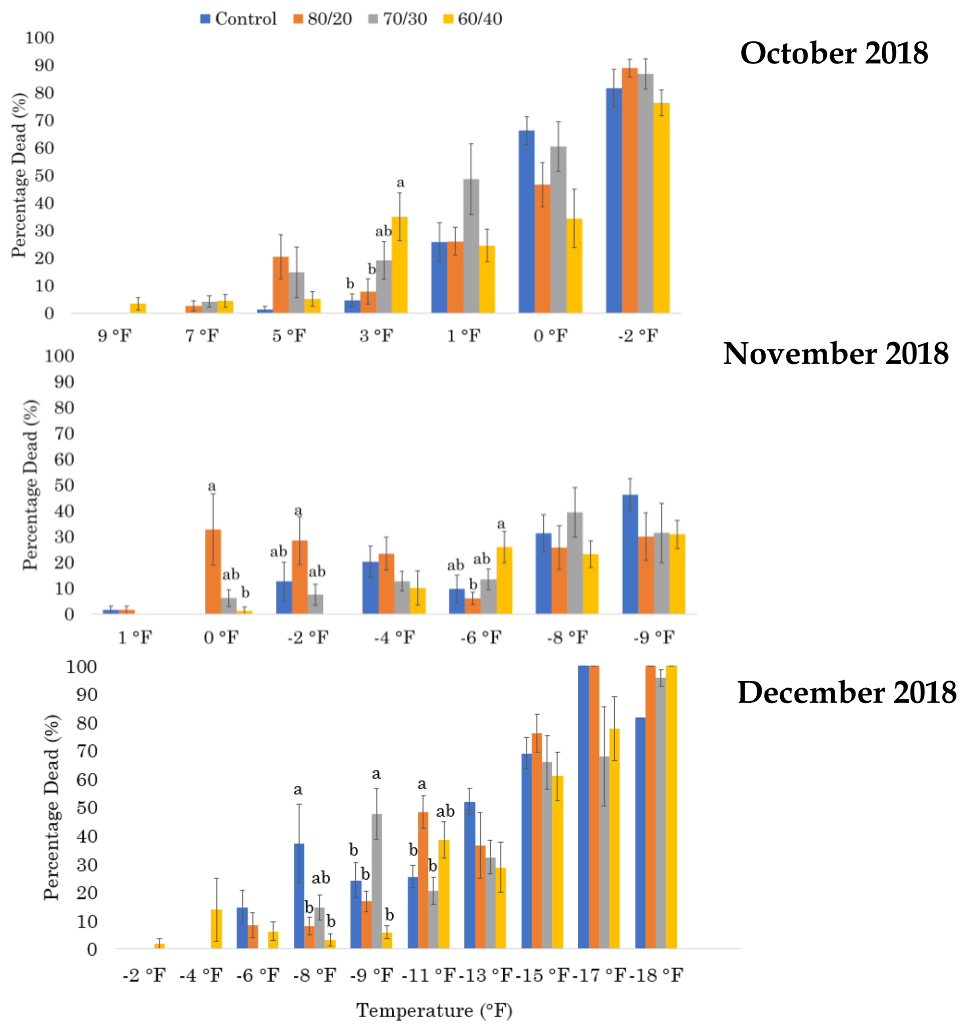

Figure 2. Average percent floral bud death of 'Duke' blueberry when exposed to progressively colder temperatures and treatment with nitrogen fertilizers that varied in the timing of application in 2018. Treatments included a control with 100% of fertilizer nitrogen applied pre-harvest (standard grower practice), 80/20 with 80% of nitrogen applied pre-harvest and the remaining 20% applied postharvest, 70/30 with 70% of nitrogen applied pre-harvest and the remaining 30% applied postharvest, and 60/40 with 60% of nitrogen applied pre-harvest and the remaining 40% applied postharvest in eastern Washington. Error bars represents standard error and bars with different letters denote statistical differences at α = 0.05. Note the x-axis varies for each figure due to progressively colder temperatures that were tested as plants acclimated to winter conditions.

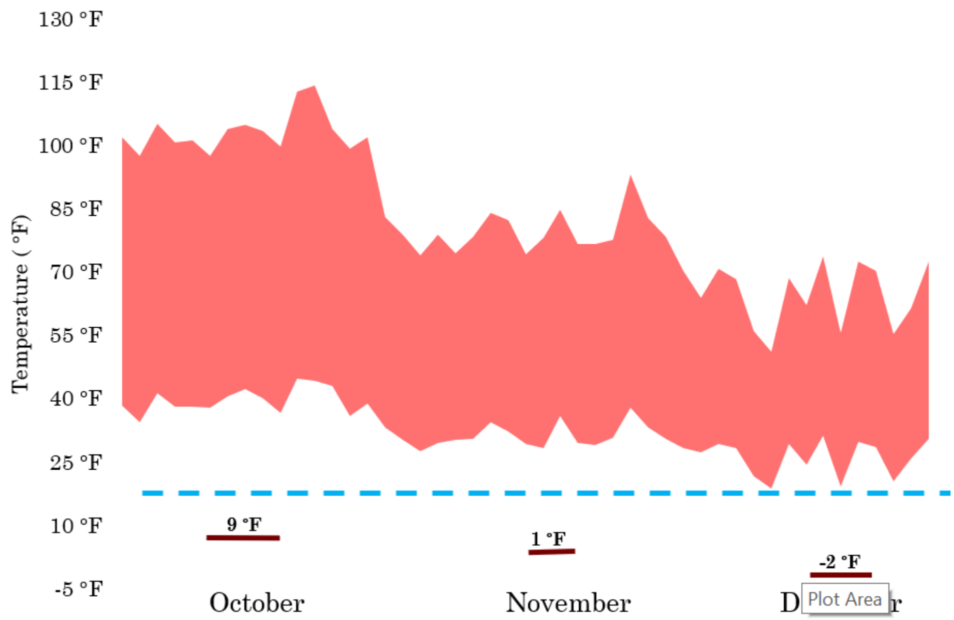

Figure 3. Yearly minimum and maximum temperature (°F) in Oct., Nov., and Dec. from 1990 to 2018. Red bars represent where floral bud damage was observed in experimental buds exposed to progressively colder temperatures in a polar pod in 2018.