# DOES POST-HARVEST NITROGEN APPLICATION AFFECT BLUEBERRY YIELD OR COLD-HARDINESS?

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## ABSTRACT

In central Washington, nitrogen (N) management in blueberries typically consists of all N being applied prior to harvest. For early cultivars, such as Duke, this means all fertilizer is applied before the end of June, leaving a long period of growth with no supplemental N. To evaluate the potential for splitting N fertilizer applications into pre- and post-harvest timings, we conducted an experiment in a randomized complete block design with four replicates on a commercial, organically managed 'Duke' blueberry field for three years (2018 - 2020). Treatments were 100, 80, 70 or 60% of the N fertilizer (140 kg/ha) applied pre-harvest and the remaining 0, 20, 30, or 40% applied post-harvest. All treatments were made using WISErganic 3-2-2 (WISErg, Redmond, WA) liquid fertilizer in a simulated drip application on a weekly basis. Yield was determined by hand picking fruit from the center three plants in each 16-plant plot. Fruit from each plant was weighed and a subsample of at least 100 g of ripe fruit were collected and fruit quality assessed by measuring soluble solids, pH, titratable acidity, and fruit firmness. Soil and leaf tissue samples were collected to evaluate plant nutritional status in August of each year, after all fertilizer applications were complete. Since late season applications of N may reduce acclimation, each year cold-hardiness was monitored through late fall to early spring. Timing of the N applications did not affect yield, fruit quality, or leaf tissue N status but cold-hardiness decreased with increasing lateness of N applications. However, since plants remained cold-hardy to a temperature far below the average monthly temperature minimums for the region, later season application of N would not be a risk.

## INTRODUCTION

Historically in northern highbush blueberry (*Vaccinium coryumbosum* L.) production in the Pacific Northwest, all nitrogen (N) fertilizer is applied prior to harvest (Hart et al., 2006). Post-harvest N fertilizer applications may stimulate excessive vegetative growth that can reduce floral bud set for the following season and increase the risk of winter injury by delaying acclimation (Caruso and Ramsdell, 1995; Hart et al., 2006). However, early season blueberry cultivars planted in a region with a long growing season may have two or more months of growth after harvest. While soils with high concentrations of organic matter may be able to release N post-harvest to benefit plant growth, soils with low organic matter content may not effectively release N, making post-harvest N fertilizer applications beneficial.

Bañados et al. (2012) observed that dry weight allocation and N derived from fertilizer continues to increase in leaves and shoots after harvest in highbush blueberry through Sept. in Oregon. These observations suggest that post-harvest fertilization with N in perennial crops like blueberries may contribute to the N storage pool in plant tissues that could be used later via reallocation according to plant needs in subsequent years. Abbott and Gough (1987) also observed that root growth in highbush blueberry occurs post-harvest, often in late July or early Aug. as soil temperature decreases. Bañados et al. (2012) also noticed total N concentrations and N derived from fertilizer increased in root tissues during this period, further supporting the idea that there may be benefits of post-harvest N applications in blueberry.

The objective of this study was to evaluate splitting N fertilizer across a combination of pre- and post-harvest applications in early season blueberry grown on low organic matter soils in central Washington. In addition to impact on yield and fruit quality, we evaluated how crop cold hardiness might be affected.

## MATERIALS AND METHODS

An on-farm study was established in Prosser, Washington in Feb. 2018 on a commercially managed organic 'Duke' field (lat. 46º16'24.7" N, long. 119º44'56.5" W). The soil is classified as a Warden silt loam (coarse-silty, mixed, superactive, mesic Xeric Haplocambids) (USDA-NRCS, 2019) and the plants were in their eighth growing season, established on raised beds (approximately 0.3 m high) mulched with apple (*Malus ×domestica* Borkh.) and sweet cherry (*Prunus avium* L.) wood chips. Planting rows were in a north-south orientation with plants spaced 0.76 m apart within the row and 2.7 m between rows (4873 plants/ha).

Plots were established in a randomized complete block with four replications with each plot consisting of 16 plants in a single row, resulting in a plot size of 18 m X 0.76 m. Fertilizer applications began in at approximately 10% bloom, on 17 April 2018, 25 April 2019, and 9 April 2020. Using the organic fertilizer WISErganic (WISErg Corporation, Redmond, WA, 3N-0.9P-1.6K), a liquid fertilizer derived from digested plant materials, was applied to provide 130 $kg{\cdot}ha^{-1}$ N. The rate of fertilizer applied each week was adjusted to apply the following treatments: 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); and 4) 60/40 (60% of N applied pre-harvest, and remaining 40% applied post-harvest). Each year the control treatment received a total of 10 fertilizer applications (all pre-harvest), the 80/20 treatment received 12 fertilizer applications (10 pre-harvest, 2 post-harvest), the 70/30 treatment received 14 fertilizer applications (10 pre-harvest, 4 post-harvest), and the 60/40 treatment received 16 fertilizer applications (10 pre-harvest, 6 post-harvest). Fertilizer applications were suspended the week before, during and one week post harvest.

Plants were fertilized in a simulated drip application by applying the product around the crown of the plants and near the root zone under the dripline. Plants were irrigated throughout the growing season and sufficient irrigation water was provided to ensure the fertilizer moved into the rootzone. Soil temperature was monitored using HOBO® loggers (Onset Computer, Bourne, MA) installed at 30 cm depth in the control treatment plots. Temperature data were recorded every 20 minutes. Also, air temperature data were taken from AgWeatherNet station installed at IAREC, Prosser, WA (Fig. 1)

Total yield (kg/plant) was determined by hand harvesting the center three plants per plot on 26 June 2018, 9 July 2019, and 2 July 2020, with fruit from each plant weighted separately. A random sample of 50 fully ripe berries were sampled from each plot for analysis of fruit quality. Average berry mass and firmness were evaluated within 48 hours of harvesting from 30 fully ripe berries per plot. Berries were weighed on a precision weighing scale (Mettler Toledo PB 303-S/Fact, Mettler Toledo, Columbus, OH, US). Firmness was measured using a FirmTech II (Bioworks Inc., Wamego, KS) with maximum and minimum compression forces of 200 g (1.96

N) and 15 g (0.15 N), respectively. Piston speed was configured to 6 mm·s$^{-1}$. All berries were then frozen at -23˚C until fruit quality analyses could be conducted. Soluble solids concentrations (°Brix) were determined using a digital refractometer (H19680, Hanna Instruments, Woonsocket, RI) from juice collected after manually crushing 50 berries per plot and straining through cheesecloth. Initial juice pH and titratable acidity were measured using a digital titrator with a pH probe (HI-84532, Hanna Instruments, Woonsocket, RI).

Cold-hardiness of floral buds was evaluated after all three growing seasons using a custom built “polar pod” machine. The polar pod machine consisted of individual chambers each wrapped with temperature controlling heating pads around them which regulate the temperature for each chamber to temperatures appropriate for the time of season. In Oct. 2018, polar pod temperatures were set at -13° C to -19° C. In Nov. and Dec. pods were kept at -17° C to - 23° C and - 19° C to - 28° C, respectively (Gwen Hoheisel, personal communication). Samples were removed at -1° C interval within each temperature range. Each pod contained three lateral shoots from each plot and each lateral contained three fully developed floral buds wrapped in aluminum foil. Lateral shoots were collected from each plots in the morning (~ 0600 hr) and pre-processed by removing the vegetative buds and additional wood. Buds were exposed to the low temperature treatment for 24h, then thawed for 24h at room temperature (23° C), and dissected to count the number of dead and alive flowers per bud (Mills et al., 2006).

Leaf tissue samples for tissue nutrient analyses were collected on 13 Aug. 2018, 27 Aug. 2019, and 25 Aug. 2020 from the inner ten plants per plot. Four fully expanded leaves, two from each side of the plant, were collected from mid-canopy height (n = 40 leaves per plot). Collected leaves were oven-dried at 60º C for 48 hours and ground to <40 mesh with a Wiley Mill (Thomas Scientific, Swedesboro, NJ). Total N in leaf tissues were analyzed using dry combustion (Sweeney, 1989) on a LECO C-N-S analyzer (LECO CHN628, LECO Corporation, St. Joseph, MI).

Data were first evaluated for normality and equal variance using Shapiro-Wilk and Levene’s test, respectively. Significant interactions between treatment, year, and treatment by year were analyzed for using analysis of variance (ANOVA) with a Tukey’s Honest Significant Difference (HSD) *posthoc* test for multiple comparisons using RStudio (R Core Team, Ver. 1.1.456; RStudio, Inc., Vienna, Austria).

**RESULTS AND DISCUSSION**

Crop yield and the fruit quality factors firmness and berry mass varied with year but there were no differences with the timing of N fertilizers (Table 1). The yield trends show a slight but not statistically significant trend for increased yield when 30 or 40 percent of the N was applied post-harvest. Additionally, leaf N concentration differed by year but not by timing of N fertilizer application (Table 1). This suggests that including some post-harvest N fertilizer applications could be an advantage to early season blueberries grown in this region, supporting both above and below ground growth (Bañados et al., 2012).

Late season N applications frequently raise the concern about late season growth being tender and predisposing plants to reduced cold hardiness. There was decreased cold hardiness in Oct., Nov, and Dec. 2018 when a greater proportion of the N was applied post-harvest (Fig. 1). However, after the 2019 and 2020 growing season, cold hardiness did not show a clear trend of being lower with later season applied N (Table 2). Perhaps equally important is how the cold hardiness compares to the temperatures found in this region during the cold months. In October

2018 (Fig. 2) and 2020 (Table 2), there was no significant drop in cold hardiness unless temperatures were below -17ºC. For November (2018 and 2019, Fig. 2 and Table 2) the outdoor air temperature had to reach -19ºC before there was at least 10% bud damage. Looking at long term (18 year) temperatures recorded for the area (Fig. 1), the lowest temperatures in October, November and December were 2, -2, and -6ºC, respectively. This suggests that post-harvest N application is not likely to adversely affect cold hardiness in this region.

The overall conclusion from this work is that there could be an advantage to applying a proportion of N fertilizer post-harvest in early season blueberry and concerns of reduced hardiness to temperatures relevant for the region were not realized. Our results suggest that up to 40% of the N may be applied post-harvest.

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Table 1: Blueberry yield and quality as well as leaf tissue nitrogen (N) concentration after treatment with different post-harvest nitrogen (N) fertilizer application times in Prosser, Washington, 2018-2020. Treatments included 60/40 with 60% of N applied pre-harvest and the remaining 40% applied post-harvest, 70/30 with 70% of N applied pre-harvest and the remaining 30% applied post-harvest, 80/20 with 80% of N applied pre-harvest and the remaining 20% applied post-harvest, and control with 100% of N applied pre-harvest (standard grower practice).

| Parameter | Yield (kg/plant) | Berry mass (g/berry) | Firmness (g/mm deflection) | Leaf Total N[x] (%) |
|---|---|---|---|---|
| Year | | | | |
| 2018 | 6.62 b[z] | 1.7 b | 199 a | 1.63 a[z] |
| 2019 | 7.08 b | 2.8 a | 156 c | 1.53 b |
| 2020 | 8.44 a | 1.9 b | 176 b | 1.50 b |
| Fertilizer | | | | |
| 60/40 | 7.89 | 2.1 | 178 | 1.55 |
| 70/30 | 7.53 | 2.1 | 172 | 1.57 |
| 80/20 | 6.89 | 2.2 | 179 | 1.55 |
| Control | 7.08 | 2.2 | 178 | 1.55 |
| *Significance* [y] | | | | |
| Year (Y) | 0.0001 | 0.003 | 0.002 | 0.001 |
| Treatment (T) | 0.245 | 0.737 | 0.811 | 0.895 |
| Y X T | 0.703 | 0.005 | 0.851 | 0.807 |

Table 2: Percent floral bud injury of 'Duke' blueberry after treatment with different post-harvest nitrogen (N) fertilizer application times in Prosser, Washington. Treatments included 60/40 with 60% of N applied pre-harvest and the remaining 40% applied post-harvest, 70/30 with 70% of N applied pre-harvest and the remaining 30% applied post-harvest, 80/20 with 80% of N applied pre-harvest and the remaining 20% applied post-harvest, and control with 100% of N applied pre-harvest (standard grower practice). Data presents percent floral bud injury for buds exposed to progressively colder temperatures on 4 Nov. 2019, 18 Nov. 2019, 20 Feb. 2020, and 26 Oct. 2020.

| | | **Floral bud injury (%)** | | | |
|---|---|---|---|---|---|
| **Date** | **Temperature (°C)** | **60/40** | **70/30** | **80/20** | **Control** |
| 4-Nov-19 | -20 | 1.4 | 8.3 | 8.6 | 14.3 |
| | -21 | 16.9 | 9.0 | 26.2 | 8.8 |
| | -22 | 29.9 | 26.0 | 34.8 | 8.1 |
| | -23 | 22.0 | 27.3 | 47.4 | 41.1 |
| | -24 | 54.2 | 56.8 | 43.8 | 40.6 |
| | -25 | 82.5 | 66.7 | 69.1 | 62.5 |
| | -26 | 72.8 | 88.1 | 85.5 | 85.1 |
| | -27 | 83.8 | 87.5 | 94.1 | 85.7 |
| 18-Nov-19 | -21 | 12.0 | 2.2 | 16.4 | 8.1 |
| | -22 | 34.8 | 24.6 | 13.4 | 9.2 |
| | -23 | 25.9 | 22.7 | 28.6 | 35.9 |
| | -24 | 50.7 | 70.0 | 46.5 | 59.7 |
| | -25 | 52.7 | 75.3 | 63.2 | 80.0 |
| | -26 | 87.9 | 86.7 | 79.1 | 71.2 |
| | -27 | 79.2 | 90.8 | 80.3 | 97.0 |
| 20-Feb-20 | -16 | 1.6 | 12.3 | 35.6 | 13.3 |
| | -17 | 11.9 | 76.3 | 39.3 | 20.8 |
| | -18 | 54.4 | 19.0 | 55.7 | 70.7 |
| | -19 | 86.6 | 90.8 | 36.5 | 71.9 |
| | -20 | 93.2 | 86.9 | 91.2 | 98.2 |

| | | | | | |
|---|---|---|---|---|---|
| 26-Oct.-20 | -15 | 1.6 | 1.5 | 0.0 | 0.0 |
| | -16 | 6.0 | 9.9 | 0.0 | 3.2 |
| | -17 | 1.6 | 4.6 | 8.6 | 1.7 |
| | -18 | 18.3 | 8.1 | 26.4 | 30.4 |
| | -19 | 31.9 | 18.5 | 20.3 | 30.3 |
| | -20 | 44.2 | 57.8 | 31.6 | 36.2 |

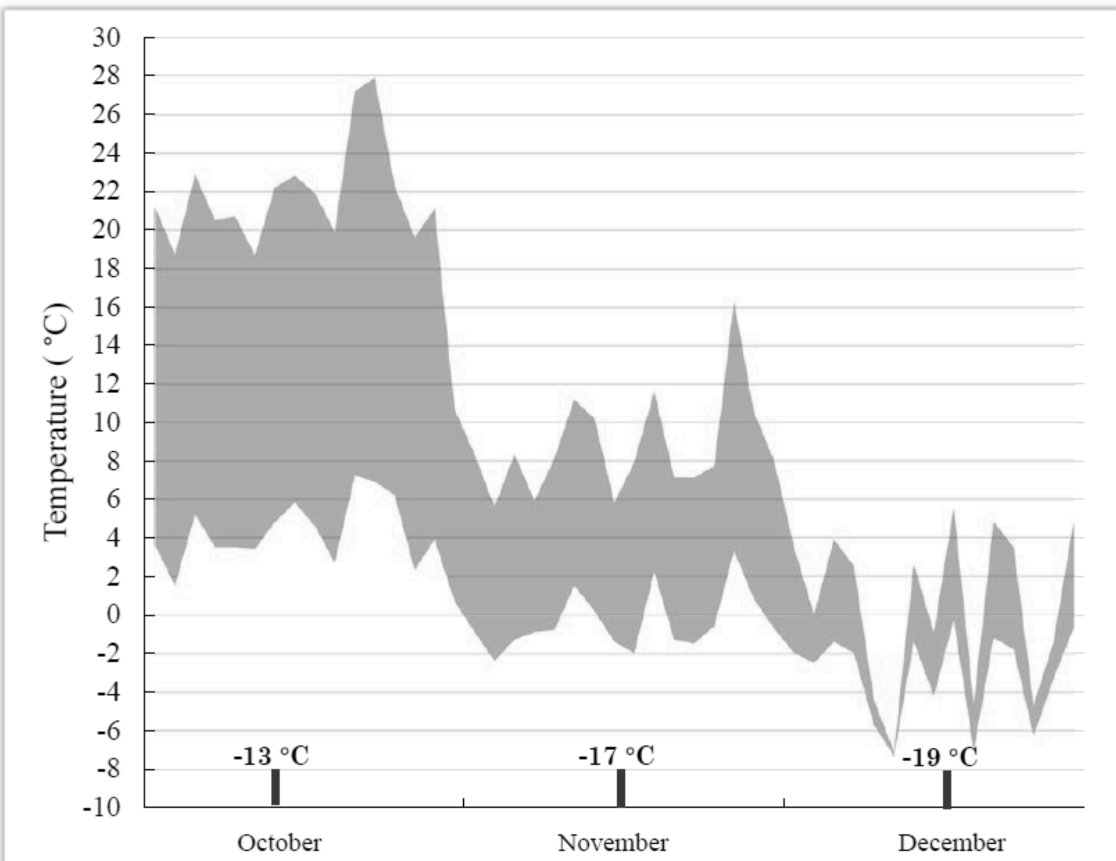


**Figure 1.** Yearly minimum and maximum temperature (°C) in Oct., Nov., and Dec. from 1990 to 2018 for Prosser, WA. Bars represent temperature where damage first occurred in October 2018.

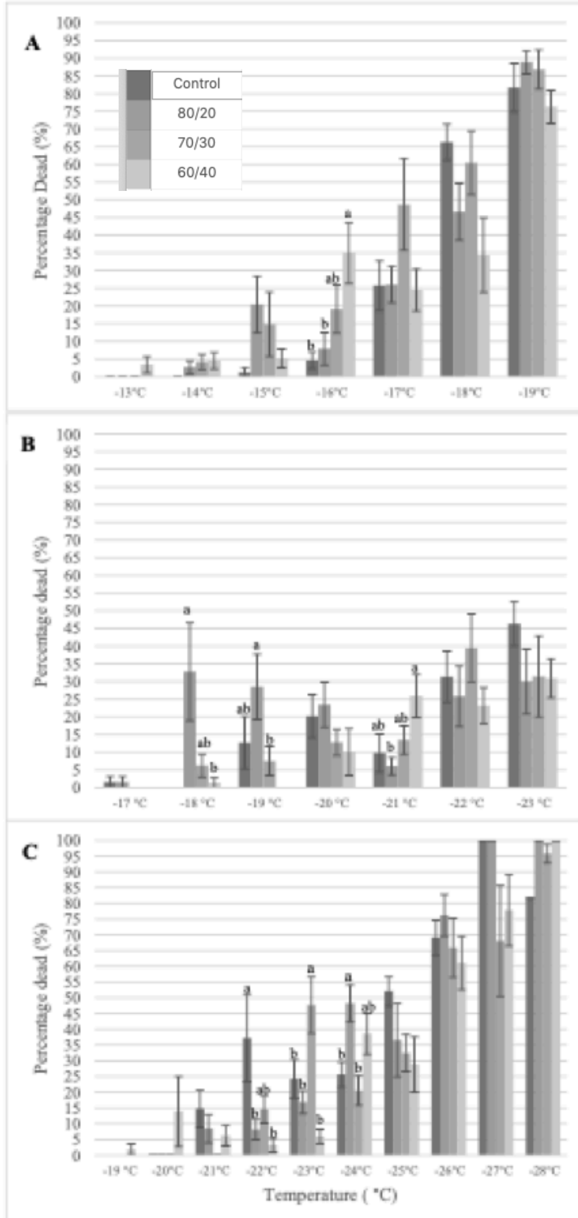


**Figure 2.** Average floral bud death in when exposed to progressively colder temperatures in 'Duke ' blueberry treated with nitrogen (N) fertilizer treatments that varied in the timing of application treatments in 2018. Treatment included Control with 100% of N applied pre-harvest (standard grower 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 in eastern Washington. Error bars represents standard error between treatments. **A** = Oct.; **B** = Nov., **C** = December, all 2018.