NITROGEN MANAGEMENT IN BLUEBERRIES

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ABSTRACT

Three field trials were conducted in Corvallis, OR from 2006 to 2011 to evaluate nitrogen (N) fertilizer practices for establishment of highbush blueberry (*Vaccinium corymbosum* L.). In the first trial, planted in April 2006, we compared the effects of N fertigation (injection of fertilizer through a drip system) to conventional granular fertilizer application in 'Bluecrop' blueberry and found that fertigation produced more growth and less salt injury in young plants than granular fertilizers, but fertigation required ≥135 lbs/A of N to reach maximum plant growth potential during the first 2 years after planting. More N was needed by fertigation because NH_4-N, the preferred form of N by blueberry, is immobile in soil. Unlike granular fertilizer, which was applied by hand around the base of the plants, much of the injected fertilizer wound up between the young plants and therefore was unavailable for plant uptake. In the second trial, planted in October 2008, we examined the effects of fertigation using three different methods of water placement in six cultivars of blueberry, including 'Earliblue', 'Duke', 'Bluecrop', 'Draper', 'Elliott', and 'Aurora', and found that two laterals of drip, which is now a common practice in blueberry, was worse in each cultivar than a single line. Drip emitters with two lines placed the NH_4-N fertilizer too far from the roots of the young plants and resulted in low leaf tissue N levels. The third and most recent trial was planted with 'Draper' in October 2010. The objective of this study was to identify fertilizer practices that increase N uptake and plant productivity during establishment, including humic acids, controlled-release fertilizers, and small but safe application of granular fertilizer shortly after planting. We hypothesized that any fertilizer method that increases availability of soil N in the root zone during establishment will also likely improve early growth and production. After 1 year, we found once again that drip placement was important, where fertigation with one or two laterals located near the base of the plants produced more growth than two laterals located 8 inches from each side of the plants, even when granular or slow-release fertilizer was applied in early spring prior to fertigation. Fertigation with humic acid fertilizer or urea sulfuric acid also produced better growth than liquid urea commonly used in blueberry.

INTRODUCTION

Nitrogen is the most common nutrient applied to highbush blueberry. Because blueberry is adapted to acidic soil conditions and prefers the ammonium form of nitrogen (N) (Eck, 1988; Korcak, 1988), ammonium sulfate is usually used when soil pH is 5 or higher and urea is used when soil pH is less than 5 (Hart et al., 2006). Current guidelines recommend applying 0.6-0.9 oz. of N per plant each year during the first 4 years after planting (Hart et al., 2006). Bañados et al. (2012) found in 'Bluecrop' blueberry that 50 $kg \cdot ha^{-1}$ (45 lbs/A) of N produced more growth and fruit production during the first 2 years after planting than either 100 or 150 $kg \cdot ha^{-1}$ (90 or 135 lbs/A) of N or no N fertilizer. This low rate of N, applied by hand as a granular around the drip line of each plant, was the best N fertilizer treatment at a planting density 1742 plants per acre; higher rates may be required in the establishment year for greater planting densities, until the plant canopies fill the in-row area. Different rates may also be needed when plants are fertigated.

Drip is commonly used to irrigate blueberry in numerous growing regions, including southeastern and northwestern United States and Canada, South America, Europe, Australia, and Africa (Strik and Yarborough, 2005). A major advantage of drip is the capability to fertigate, i.e. inject water-soluble fertilizers during irrigation (Kafkafi and Tarchitzky, 2011). Numerous fertilizers are used for fertigation in blueberry, including liquid forms of ammonium sulfate and urea, urea ammonium nitrate, and low pH products such as urea sulfuric acid. Humic acids are also increasing in popularity in blueberry.

The objectives of the present set of studies were to identify the optimum timing, fertilizer source, rate, and placement of N application for drip fertigation of highbush blueberry during the first 2 years of establishment.

METHODS

Three trials were conducted at the Oregon State University Lewis-Brown Horticultural Research Farm in Corvallis, OR. The first trial was planted in Apr. 2006, the second was planted in Oct. 2008, and the third was planted in Oct. 2010. Soil at the site is a Malabon silty clay loam that was acidified to pH 5.5 using elemental sulfur and amended with 3-3.5 inches of douglas fir sawdust (*Pseudotsuga menziesii* Franco) incorporated to a depth of ≈8 inches prior to planting. Plants were spaced 2.5 x 10 ft. apart and grown on 3 to 4-m wide raised beds. The beds were mulched with 2 inches of sawdust after planting, and grass alleyways were maintained between the beds.

Trial 1: 'Bluecrop' blueberry was planted in a field with 16 different N fertilizer treatments. The treatments were arranged in a split-plot design and included four methods of fertilizer application (split fertigation, weekly fertigation, and two non-fertigated controls) and four fertilizer rates (0, 45, 90, and 135 lbs/A of N). Each treatment plot consisted of one row of eight plants and was replicated six times. Liquid urea (20N−0P−0K) was injected during split and weekly fertigations. Split fertigation was applied three times from April to June, while weekly fertigation was applied from leaf emergence in mid-Apr. to late-July. Non-fertigated controls were fertilized with granular ammonium sulfate (21N−0P−0K−24S) and irrigated by drip or microsprinklers (to simulate overhead sprinkler irrigation). Canopy cover was estimated on 30 Aug. 2006 (year 1) and 28 Aug. 2007 (year 2) from digital images taken above the plants using an ADC multispectral camera (TetraCam Inc., Chatsworth, CA). Soil solution was extracted from each treatment using hydrophilic porous soil moisture samplers (Eijkelkamp Agrisearch Equip., Giesbeek, The Netherlands) and analyzed for electrical conductivity and ammonium and nitrate concentrations (Ore. St. Univ. Central Analytical Lab., Corvallis, OR). Leaf samples were collected on 28 July 2006 and 29 July 2007 and analyzed for N using a CN analyzer (LECO Corp., St. Joseph, MI). Soil was collected 27 Sept. 2007 and analyzed for pH (1 soil: 1 water v/v).

Trial 2: Six cultivars of highbush blueberry, including 'Earliblue', 'Duke', 'Bluecrop', 'Draper', 'Elliott', and 'Aurora' were arranged in randomized complete block design in five replicated plots of eight plants each. Plots were either fertigated weekly (from mid-Apr. to mid-July) with two laterals of drip tubing located 8 inches on each side of the plants or with a single lateral of KISSS (Kapillary Irrigation Subsurface System) tape (KISSS America Inc., Longmont, CO) located near the base of the plants. The drip tubing had 0.25 gal/h in-line pressure-compensating emitters spaced every 18 inches. The KISSS tape is a specialized product designed to distribute water and fertilizer more evenly than drip. The product consisted of a line of drip tape sewn between a layer of geo-textile fabric on the bottom and thick black plastic on top. The drip tubing and KISSS tape were located on top of the beds and covered with sawdust mulch to reduce soil evaporation. The fertilizer was liquid urea (20N−0P−0K) applied at a total annual rate of 90 or 180 lbs/A of N with drip and 180 lbs/A of N with KISSS. Leaves were collected 7 Aug. 2009 (year 1) and 10 Aug. 2010 (year 2) and analyzed for N. Shoots were winter-pruned and weighed in Feb. 2010 and Jan. 2011 following the first 2 years after planting.

Trial 3: 'Draper' blueberry was planted in a field with 12 different fertilizer treatments. The treatments were arranged in randomized complete block design and included four different fertilizer placements, six alternative fertilizers, one treatment to examine the impact of using no pre-plant N fertilizer, and one treatment to determine whether late-season applications of N fertilizer affect fruit set or increase winter injury in blueberry. Granular ammonium sulfate was mixed into the soil with the sawdust prior to planting at a rate 90 lbs/A of N (n.b., one treatment had no pre-plant N; see below). Each treatment plot consisted of one row of six plants and was replicated five times. Each plot was irrigated using one or two laterals of drip tubing or one lateral of KISSS tape per row. The fertilizer placement treatments were fertigated using liquid urea (20−0−0) injected weekly, beginning at bud break in mid-April to fruit bud set in late-July. A total of 100 $kg \cdot ha^{-1}$ N was applied. In treatments with two drip laterals per row, drip lines were either fixed at 8 inches from each side of the plants or placed near the base of plants the first year after planting and moved 8 inches from the plants the following year. The former treatment requires less labor but the later treatment applies water and fertilizer close to the plants after planting and moves it outward once the root system develops. A single line of drip costs half as much as two fixed lines but may be inadequate and/or may become pinched between canes as the plants mature. The KISSS tape costs about three times as much as a single line of drip but as already mentioned distributes the water and fertilizer more evenly than drip and therefore may increase root development and efficiency of water and nutrient uptake. Six alternative methods of fertilizer application included 1) fertigation with urea sulfuric acid (N-pHURIC®), 2) two small split application of granular urea in April and May (following rain events) at a rate 10 lbs/A of N each, followed by weekly injections of liquid urea for a total of 90 lbs/A of N applied by the end of July, 3) a single application of controlled-release polymer coated urea at a rate of 54 lbs/A of N alone or 4) controlled-released urea followed by weekly injections of liquid urea in June and July, 5) weekly injection of Actagro® products, which include humic acids and 10N−23P−0.1K fertilizer, and 6) weekly injection of the same 10N−23P−0.1K fertilizer but no humic acids (a control for the Actagro® treatment). The two remaining treatments included fertigation with 90 lbs/A of N (liquid urea) and two lines of drip (moved in year 2) but with either 1) no pre-plant N fertilizer or 2) the fertigation period extended to mid-September. Leaf samples were collected in 5 Aug. 2011 (year 1) and analyzed for total N. One plant per plot was excavated in Oct. 2011, separated into root, shoot, and leaf components, and oven-dried and weighed.

RESULTS AND DISCUSSION

Trial 1: Liquid urea (20-0-0) applied weekly by fertigation produced more growth in young plants (years 1 and 2) than triple-split applications of liquid urea (applied by fertigation) or granular ammonium sulfate (in plants irrigated by microsprinklers or drip), but fertigated plants required more N fertilizer to reach maximum canopy cover or plant size (Table 1). More N was likely needed by fertigation because NH_4^+-N is immobile in soil, and unlike granular fertilizer, which was applied by hand around the base of the plants, much of the injected fertilizer wound up between the young plants and therefore was unavailable for root uptake. Indeed, granular fertilizer resulted in much higher leaf and soil N concentrations but also led to high levels of salt stress in the plants (Bryla and Machado, 2011). Soil pH was also reduced by higher N applications but was unaffected by fertilizer type. Thus, urea applied during fertigation was as suitable as granular ammonium sulfate for reducing soil pH. Fertigation, however, required more N per hectare than granular fertilizer to optimize growth in highbush blueberry during establishment.

Table 1. Canopy cover of 'Bluecrop' blueberry fertilized by weekly fertigation, split fertigation, or granular fertilizer (irrigated by microsprinklers or drip) at rates of 0, 45, 90, and 135 lbs/A of N during the first 2 years after planting (Trial 1).[1]

	Canopy cover (%)			
Treatment	0 N	45 N	90 N	135 N
		Year 1		
Fertigation				
Weekly	4	8	10	13
Triple-split	4	10	12	10
Granular fertilizer				
Microsprinklers	5	10	10	11
Drip	5	10	12	9
		Year 2		
Fertigation				
Weekly	11	25	31	40
Triple-split	10	28	29	30
Granular fertilizer				
Microsprinklers	11	23	25	25
Drip	9	20	27	22

[1] Data are from Bryla and Machado (2011).

Trial 2: In the second trial on six cultivars of blueberry, we found that a single lateral of KISSS tape produced the same or higher levels of leaf N than the more conventional practice of using two drip lines per row in year 1 (Table 2), and consequently resulted in larger plants (based on pruning weights) in four of the cultivars, including 'Earliblue, 'Bluecrop', 'Elliott', and 'Aurora' (Table 3). Thus, more N was available with KISSS. This may have been due to more even distribution of water and fertilizer relative to drip but was more likely due to the position of the drip lines. With KISSS, N was applied near the base of the plants, and since ammonium-N is relatively immobile in soil, application with drip may have placed the fertilizer too far from the roots. However, increasing the N rate with drip from 90 to 180 lbs/A of N improved leaf N and plant growth considerably (low vs. high N; Tables 2 and 3). By year 2, the high N drip treatment produced higher leaf N levels than KISSS but resulted in little difference in most cultivars in visual plant size or pruning weight. Pruning weight was also similar between drip treatments fertigated with low and high N. Interestingly, leaf N concentrations were highest both years in the early-season cultivars, 'Earliblue' and 'Duke', and lowest in the late-season cultivars, 'Elliott' and 'Aurora' (Table 2).

Table 2. Leaf N concentrations in six blueberry cultivars fertigated with 90 (low N) or 180 (high N) lbs/A of N by drip or 180 lbs/A of N by KISSS (Trial 2).

	Leaf N (%)					
	Year 1			Year 2		
Cultivar	Drip (low N)	Drip (high N)	KISSS	Drip (low N)	Drip (high N)	KISSS
Earliblue	1.49	1.81	1.91	1.52	1.78	1.66
Duke	1.50	1.86	1.81	1.44	1.64	1.52
Bluecrop	1.61	1.72	1.71	1.55	1.56	1.63
Draper	1.39	1.74	1.73	1.30	1.50	1.37
Elliott	1.47	1.59	1.73	1.48	1.48	1.36
Aurora	1.40	1.63	1.65	1.42	1.41	1.31
Avg.	1.48	1.72	1.76	1.45	1.56	1.48

Table 3. Winter-pruning weights from six blueberry cultivars fertigated with 90 (low N) or 180 (high N) lbs/A of N by drip or 180 lbs/A of N by KISSS (Trial 2).

	Fresh pruning weight (kg/plant)					
	Year 1			Year 2		
Cultivar	Drip (low N)	Drip (high N)	KISSS	Drip (low N)	Drip (high N)	KISSS
Earliblue	0.016	0.024	0.032	0.34	0.36	0.39
Duke	0.035	0.046	0.048	0.42	0.45	0.48
Bluecrop	0.023	0.028	0.047	0.49	0.51	0.46
Draper	0.038	0.043	0.034	0.36	0.35	0.36
Elliott	0.017	0.030	0.043	0.43	0.43	0.52
Aurora	0.035	0.061	0.071	0.44	0.54	0.45
Avg.	0.027	0.039	0.046	0.41	0.44	0.44

Trial 3: Plant dry weight was significantly different among the fertilizer treatments in 'Draper' blueberry (Table 4). Total plant dry weight was greatest in plants fertilized by humic acid or urea sulfuric acid and lowest, regardless of fertilizer source, in plants fertilized using two lines of drip fixed away from the plants. As in trial 2, the fixed drip lines appeared to limit N availability to the plant roots. The plants were chlorotic in these treatments (data not shown), and in all but the plants initially fertilized with controlled release fertilizer and later fertigated with liquid urea, had lower leaf N levels than those fertigated with one drip line, two drip lines located near the plants, or KISSS (Fig. 1).

Table 4. Effects of fertilizer placement [1 line of drip, 2 lines of drip (moved or fixed), or KISSS], alternative fertilizers [liquid urea, granular + liquid urea, urea-sulfuric acid, humic acids + 10N−23P−0.1K, 10N−23P−0.1K only, controlled-released fertilizer (CRF), or CRF + liquid urea], no pre-plant fertilizer, and late-season fertilizer application on plant dry weight of 'Draper' blueberry following the first year after planting (Trial 3).

Treatment[1,2]	N rate (lbs/A)	Dry weight (g/plant)			
		Leaves	Stems	Roots	Total
2 lines (moved), humic acids + NPK	90	106 a	110 a	68 a	284 a
2 lines (moved), urea sulfuric acid	90	98 ab	96 ab	61 ab	256 ab
2 lines (moved), NPK	90	79 a-c	84 a-c	65 ab	228 a-c
2 lines (moved), liq. urea	90	75 b-d	86 a-c	65 ab	226 a-c
1 line, liq. urea	90	64 c-e	86 a-c	64 ab	214 a-d
2 lines (moved), liq. urea, no pre-plant N	90	65 c-e	80 a-c	67 ab	213 a-d
KISSS, liq. urea	90	67 c-e	79 bc	58 ab	204 b-d
2 lines (moved), late-season N	90	66 c-e	79 bc	56 ab	201 b-d
2 lines (fixed), granular urea + liq. urea	20 + 70	52 c-e	60 c	58 ab	170 cd
2 lines (fixed), CRF + liq. urea	54 + 36	54 c-e	64 c	48 ab	166 cd
2 lines (fixed), CRF	54	44 de	61 c	52 ab	157 cd
2 lines (fixed), liq. urea	90	39 e	61 c	49 b	148 d

[1]'Drip (1 line)' has one drip line per row with the lateral placed near the base of the plants; 'Drip (2 lines/moved)' has two lines per row with the laterals placed near the base of the plants the first year after planting and moved to 8 inches from each side of the plants the second year; 'Drip (2 lines/fixed)' has two lines per row with the laterals fixed at 8 inches from each side of the plants at planting; and KISSS (Kapillary Irrigation Subsurface System) tape has one line of tape per row with the line located near the base of the plants. The liquid urea source is 20−0−0; urea-sulfuric acid source is N-pHURIC®; CRF (controlled-release fertilizer) is encapsulated urea (45-d release); and the humic acid + NPK is Actagro®.
[2]Nitrogen fertilizer (granular ammonium sulfate) was also applied to each treatment at pre-plant (except the no pre-plant treatment) at a rate of 90 lbs/A of N.

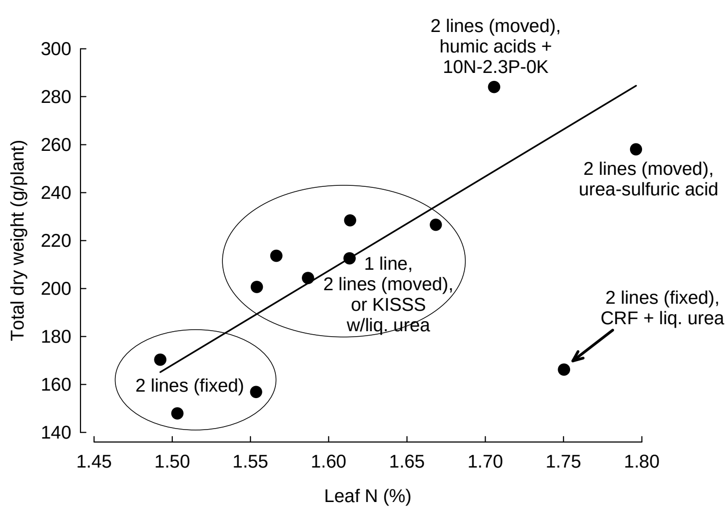

Figure 1. Total plant dry weight in relation to leaf N level in 'Draper' blueberry (Trial 3). See Table 4 for treatment details. Dry wt. = 393*Leaf N - 421 (r^2 = 0.75; P < 0.001).

There were no effects on plant growth of applying pre-plant N fertilizer or applying fertilizer late in the season. It is often recommended that fertilizer N be added to a field prior to planting whenever sawdust is incorporated (standard industry practice) so that normal microbial decomposition can occur without taking N from newly planted blueberries (Hart et al., 2006). It is also recommended to stop N fertilizer applications by midsummer as later applications may reduce fruit bud set and produce late-season growth susceptible to winter injury. However, there is no data to support either supposition, and in this study, we found no benefit or consequence of applying pre-plant N or applying N late in the season in the fertigated plants.

SUMMARY

Based on the results of these trials and personal observations, we recommend using two lines of drip per row, but locating the lines near the base of the plants during first year or two after planting, and then moving them away from the plant the following year. We also recommend fertigation over the use of granular N fertilizers when possible, and using urea sulfuric acid or humic acids in high pH and/or poor quality soils.

REFERENCES

Bañados, M.P., B.C. Strik, D.R. Bryla, and T.L. Righetti. 2012. Response of highbush blueberry to nitrogen fertilizer during field establishment, I. Accumulation and allocation of fertilizer nitrogen and biomass. HortScience 47:648-655.

Bryla, D.R. and R.M.A. Machado. 2011. Comparative effects of nitrogen fertigation and granular fertilizer application on growth and availability of soil nitrogen during establishment of highbush blueberry. Frontiers Plant Sci. 2:1-8.

Eck, P. 1988. Blueberry science. Rutgers Univ. Press, New Brunswick, NJ.

Hart, J., B. Strik, L. White, and W. Yang. 2006. Nutrient management for blueberries in Oregon. Ore. State Univ. Ext. Serv. Pub. EM 8918.

Kafkafi, U. and J. Tarchitzky. 2011. Fertigation: a tool for efficient fertilizer and water management. Intl. Fert. Ind. Assn., Paris.

Korcak, R.F. 1988. Nutrition of blueberries and other calcifuges. Hort. Rev. 10:183-227.

Strik, B.C. and D. Yarborough. 2005. Blueberry production trends in North America, 1992 to 2003 and predictions for growth. HortTechnology 15:391-398.