Potassium Fertigation In Highbush Blueberry

Increases availability of K and other nutrietns in the root zone.

Drs. David Bryla and Scott Orr

The Fluid Journal • Official Journal of the Fluid Fertilizer Foundation • Summer 2017 • Vol. 25, No. 3, Issue #97

▼ DOWNLOAD

Summary: *Fertigation with nitrogen (N) increases growth and production relative to granular N applications in blueberry, but little information is available on whether there is any benefit to fertigating with other nutrients. The plants were grown on raised beds and irrigated using two lines of drip tubing per row. Treatments were initiated in 2016 and included fertigation (once a week from April to August) with sulfate of potash (SOP) or potassium thiosulfate (KTS), a single application (April) of granular SOP, and no K fertilizer. Each K fertilizer was applied at a total rate of 75 lb. K_2O per acre. Throughout the growing season, fertigation with SOP or KTS resulted in lower pH and higher concentrations of K, Ca, Mg, and S in soil solution under the drip emitters than either no K or granular SOP, while granular SOP resulted in higher concentration of K than any other treatment at 6 inches from the drip emitters (edge of the wetting front). By the end of the first season, the fertigation treatments contained nearly twice as much extractable K, but less Ca and Mg in the soil than the non-fertigated treatments. However, none of the treatments had any effect on yield or leaf K concentration to date, which could be due to the fact that changes in blueberry tissue K usually occur a year or two after K fertilizer is applied. More time is needed to determine the benefits of fertigation with K in blueberries.*

Objective: *The objective of this study was to compare fertigation to granular application of K fertilizer in a mature blueberry planting.*

Consumption of blueberries has increased rapidly in recent years due to new markets and promotion of their health benefits. Currently, there are nearly 300,000 acres of cultivated blueberries (Vaccinium sp) grown worldwide and global demand for the fruit is expected to at least triple in the next decade. Over 80% of the crop is produced in North and South America, but plantings are expanding into less traditional growing regions, including Mexico, Brazil, Peru, southern Europe, northern and southern Africa, Asia, and Australia. By 2019, total global production is predicted to reach 1.7 billion pounds of blueberries.

Blueberries are a long-lived perennial crop (30+ years) categorized as a calcifuge (plant that does not tolerate alkaline soil), well-adapted to acidic soil conditions (pH 4.2-5.5). Plants acquire primarily the NH4 form of N over NO_3-N and tolerate relatively low levels of P, K, Ca, and Mg in the soil and high concentrations of plant-available metals such as Mn and Al. Recently, we determined that drip fertigation with various fluid NH_4-N sources, including ammonium sulfate, urea, and urea sulfuric acid, produced more growth and greater yield than conventional granular fertilizers in high-bush blueberries. We also discovered that humic acids used in combination with fluid N fertilizers during fertigation nearly doubled root production during the first 2 years after planting relative to using the N fertilizers only. Many blueberry growers are now using fertigation, even in colder growing regions such as Michigan, where sprinklers are required for frost protection. In this case, growers are investing in dual-irrigation systems to enable them to irrigate and fertigate by drip and use the sprinklers primarily for frost protection and fruit cooling.

Currently, we are evaluating fertigation with other nutrients in blueberries, including cations such as K. Despite relatively low cation requirements in the crop, K deficiency can occur in blueberries. Factors contributing to deficiency include poor soil drainage, drought, very low soil pH, and heavy crop loads.

Plants in sandy soils with low organic matter content are particularly susceptible to K deficiency. Symptoms include leaf cupping and scorched leaf margins that often resemble drought damage in blueberries. Younger leaves near the shoot tip may develop interveinal chlorosis similar to Fe deficiency. Application of K fertilizer increased yield of 'Bluecrop' blueberries in Michigan when soil K was very low but had no effect on yield of 'Jersey' blueberries when soil K was higher (>100 ppm).

Recently, we examined nutrient uptake in a new planting of 'Bluecorp blueberries and found that the total K requirements during the first 2 years after planting was only 13.5 lbs K_2O per acre. This was equivalent

Table 1. Effect of method and source of K fertilizer on soil pH and extractable soil nutrients in a mature planting of 'Duke' blueberry. Soil samples were collected initially prior to treatment on April 2016 and after treatment at the end of the growing season in October 2016. A total of 75 lb K_2O per acre was applied to each K fertilizer treatment.

K treatment	Soil pH	Extractable soil nutrients (ppm)							
		NO_3-N	NH_4-N	P	K	Ca	Mg	S	Mn
Initial[1]	5.7	3.1	1.2	27	154	1878	682	23	37
No K	5.0	5.1	1.1	45	111	1748	612	14	43
SOP (granular)	5.6	4.4	2.4	33	125	2055	735	16	41
SOP (fertigation)	4.4	8.1	11.2	59	188	1217	508	28	48
KTS (fertigation)	4.6	17.2	9.1	45	200	1335	529	22	53

SOP – sulfate of potash (potassium sulfate); KTS – potassium thiosulfate.

Table 2. Effect of method and source of K fertilizer on pH, EC, and concentration of K in the soil solution in a mature planting of 'Duke' blueberry.1 Soil solution samples were collected under and at 6 inches from a drip emitter. A total of 75 lb K_2O per acre was applied to each K fertilizer treatment.

	pH		EC (dS/m)		K concentration (ppm)	
K treatment	Under drip emitter	6 inches from drip emitter	Under drip emitter	6 inches from drip emitter	Under drip emitter	6 inches from drip emitter
No K	5.7 ab	5.0 a	1.21 b	1.02 b	8 b	10 b
SOP (granular)	6.0 a	4.5 b	1.18 b	1.30 ab	10 b	64 a
SOP (fertigation)	5.0 c	4.2 c	2.09 a	1.59 a	49 a	21 b
KTS (fertigation)	5.1 bc	4.4 bc	1.90 a	1.55 a	54 a	16 b
Significance	*	**	**	†	**	**

[1]Average of samples collected weekly from May 3 to August 9, 2016.

Mean separation in a column by LSD at 5% level.

†,*,**Significant at $P \leq 0.10$, 0.05, and 0.01, respectively.

SOP – sulfate of potash (potassium sulfate); KTS – potassium thiosulfate.

Table 3. Effect of method and source of K fertilizer on concentration of Ca, Mg, and S in the soil solution in a mature planting of 'Duke' blueberry. [1]Soil solution samples were collected under and at 6 inches from a drip emitter. A total of 75 lb K_2O per acre was applied to each K fertilizer treatment.

K treatment	Ca concentration (ppm)		Mg concentration (ppm)		S concentration (ppm)	
	Under drip emitter	6 inches from drip emitter	Under drip emitter	6 inches from drip emitter	Under drip emitter	6 inches from drip emitter
No K	62 b	87	35 b	57	127 b	53 b
SOP (granular)	62 b	119	35 b	72	127 b	164 a
SOP (fertigation)	93 a	127	49 a	80	236 a	101 ab
KTS (fertigation)	85 a	139	46 ab	78	235 a	121 ab
Significance	*	NS	†	NS	**	†

1Average of samples collected weekly from May 3 to August 8, 2016

Mean separation in a column by LSD at 5% level.

NS, †,*,**Non-significant and significant at $P \leq 0.10$, 0.05, and 0.01, respectively.

SOP – sulfate of potash (potassium sulfate); KTS – potassium thiosulfate.

to approximately 19% of the total K fertilizer applied. Mature plants require much more K due to high K content in the fruit (0.3 – 0.7%). A good field will produce an average of 10 tons or more or of blueberries per acre. That means 9-21 lbs K_2O per acre will be removed from the field during harvest each year, and approximately 20 lbs K_2O per acre will be lost during leaf fall and pruning. The current recommendation for mature blueberry planting is to apply 75 – 100 lbs K_2O per acre when soil K is <100 ppm or leaf K is below 0.2%, and to apply 0 - 75 lbs K_2O per acre when soil K is 100 – 150 ppm or leaf K is 0.2 - 0.4 %. This recommendation is derived from anecdotal evidence collected from commercial plantings irrigated by sprinklers and fertilized using granular fertilizers. However, most new fields are irrigated by drip and fertigated using fluid fertilizers. Blueberry roots are much more restricted with drip than with sprinklers, and therefore, plants could be easily exposed to nutrient limitations of diffusion-limited ions with slow soil-release rates, such as K+. Fertigation using a fluid K fertilizer would ensure continuous supply of the nutrient for plant growth and fruit production and would increase movement of K in the soil profile.

Table 4. Effect of method and source of K fertilizer on concentration of leaf nutrients in a mature planting of 'Duke' blueberry. Leaf samples were collected in August 2016. A total of 75 lb K_2O per acre was applied to each K fertilizer treatment.

K treatment	Leaf tissue concentration						
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Mn (ppm)
No K	1.28	0.076	0.57	0.47	0.174 b	0.141 b	99 b
SOP (granular)	1.37	0.078	0.60	0.53	0.204 ab	0.159 a	106 ab
SOP (fertigation)	1.36	0.073	0.57	0.53	0.206 ab	0.151 ab	133 a
KTS (fertigation)	1.31	0.074	0.55	0.52	0.211 a	0.146 ab	117 ab
Significance	NS	NS	NS	NS	*	*	**

Mean separation in a column by LSD at 5% level.

NS, *,**Non-significant and significant at P ≤ 0.05 and 0.01, respectively.

SOP – sulfate of potash (potassium sulfate); KTS – potassium thiosulfate.

Table 5. Effect of method and source of K fertilizer on yield and fruit quality in a mature planting of 'Duke' blueberry. Fruit were harvested in late June and early July 2016. A total of 75 lb K_2O per acre was applied to each K fertilizer treatment.

K treatment	Yield (kg/plant)	Berry wt (g)	Brix	TA (%)	Sugar:acid
No K	2.18	1.72	12.8	0.41	31
SOP (granular)	2.00	1.73	13.4	0.45	30
SOP (fertigation)	2.87	1.92	12.6	0.46	27
KTS (fertigation)	2.20	1.71	13.4	0.42	32
Significance	NS	NS	NS	NS	NS

NSNon-significant.

TA – titratable acidity; SOP – sulfate of potash (potassium sulfate); KTS – potassium thiosulfate.

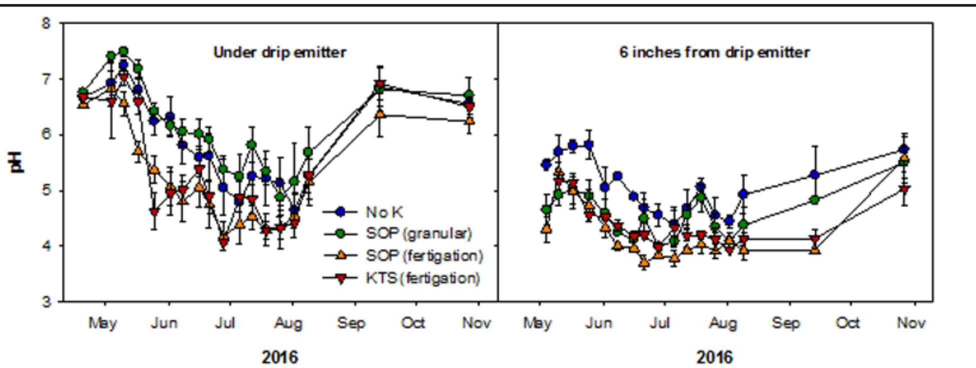

Figure 1. Effect of method and source of K fertilizer on pH of the soil solution in a mature planting of 'Duke' blueberry. Soil solution samples were collected under and at 6 inches from a drip emitter throughout the growing season. A total of 75 lb K_2O per acre was applied to each K fertilizer treatment. Granular K was applied all at once on April 28, while K fertigation was done weekly from May 2 to August 1. Each symbol represents the mean of four replicates and the error bars represent ±1 SE. SOP – sulfate of potash (potassium sulfate); KTS – potassium thiosulfate.

Potassium is usually applied to blueberries as potassium sulfate (sulfate of potash or SOP). Potassium chloride (muriate of potash) is not recommended because the plants are very sensitive to chloride. Other potential sources of K include mono potassium phosphate, which is largely a source of P, and potassium thiosulfate (KTS). The latter may be particularly useful in high pH soils such as those in California and eastern Oregon and Washington, because thiosulfate is readily oxidized by Thiobacillus and other soil bacteria to produce sulfuric acid. Potassium nitrate is also a popular K fertilizer available for fertigation but it is expensive and a poor N source (i.e. NO3-N) for blueberries.

Methodology

The study was conducted at the Oregon state University Lewis-Brown Horticultural Research Farm in Corvallis, OR using a mature planting of 'Duke' northern high-bush blueberries. 'Duke' is an early-season cultivar and one of the most poplar varieties of blueberry grown worldwide. The planting was established in April 2004 on Malabon silty clay loam (find, mixed, superactive, mesic Pachic Ultic Argixerolls) soil. Plants were spaced 2.5 feet apart on rows of raised beds (15 inches high in the middle by 4 feet wide at the base) centered 10 feet apart. The beds were mulched every other year with Douglas-fir sawdust and grass alleyways were planted and mowed between the beds (industry standard). The plants were irrigated using two lines of drip tubing per row with 0.5 gph emitters every 18 inches. The tubing was laid approximately 8 inches from the base of the plants and covered with sawdust mulch. Irrigation was scheduled as needed, based on daily estimates of crop ET obtained from a nearby AgriMet weather station.

Treatments were initiated in 2016 and arranged in a randomized complete block design with four K treatments, including fertigation with SOP (0-0-52-18S dissolved in deionized water at a concentration of 100 g/L) or KTS (0-0-52-17S, pH 7.4 to 8), a single application of granular SOP, and no K fertilizer.

Each treatment was replicated four times with a row of eight plants per replicate. All measurements were taken on the middle six plants in each plot. The K fertilizers were each applied at a rate of 75 lbs K_2O per acre, and all treatments, including those with granular K or no K were fertigated with fluid ammonium sulfate (9-0-0-10S) at a total rate of 150 lbs N per acre. Granular fertilizer was spread uniformly on each side of the rows prior to a rain storm on April 28, and the fluid fertilizers (both k and N) were injected weekly from May 2 to August 1, using positive displacement injectors.

Soil solution was extracted using hydrophilic porous polymer soil moisture samplers. These samplers are small (10cm long by 1mm diameter) and ideal for blueberries because of its shallow root system. A study of three cultivars in Oregon, including 'Duke', revealed that nearly 80% of the roots were located in the top 10 cm of the soil profile. We inserted the samplers vertically at four locations--under and 3, 6, and 9 inches from a drip emitter--on both sides of a plant in each plot. The sawdust mulch was moved away just before installing the samplers and returned immediately afterwards. Approximately 5-10 mL of soil solution was collected initially on April 21 prior to any treatment, then weekly each day after fertigation in May through August, and finally on August 9, September 13, and October 27 after the plants were no longer fertigated. Little to no solution was usually obtained at the 9-inch locations, indicating the edge of wetting front was around 6 inches from the drip emitters. Each sample was analyzed for pH and EC using a multimeter, and for K and other nutrients by ICP.

Soil cores were collected on April 24 and October 5 and sent to Brookside Laboratories for pH and nutrient analysis. Samples were taken beneath a drip emitter to a depth of 20 cm on both sides of a plant in each plot. These were different plants than those used for soil solution analysis. Again, sawdust was moved away prior to taking the samples and then returned immediately afterwards. Leaves were sampled from each plant on August 5 and then dried, ground, and analyzed in-house for N by combustion analysis and for other nutrients by ICP.

Harvesting of the field occurred on June 14 and 24 which, due to unusually warm weather in the spring, was about 2 weeks earlier than normal in western Oregon. Ripe berries were handpicked on each date and weighed to determine the total yield in each plot. One hundred berries were randomly sampled to determine the average berry weight in each plot. The samples were also analyzed for Brix and titratable acidity, using a digital refractometer and an autotitrator. Titratable acidity was calculated as a percentage of citric acid.

Results

Initial site conditions. Plant growth and production were relatively weak at the site due to poor soil conditions. Yields prior to the study typically averaged less than 5 tons per acre in the planting. At the beginning of the growing season in 2016, soil pH was slightly high for blueberries, while extractable soil P and K were slightly low (Table 1). Northern highbush blueberries usually do best when soil pH is between 4.5 and 5.5, and 'Duke' seems to be especially sensitive to high soil pH. Availability of other extractable soil nutrients were adequate (S, B, and Mn) or high (Ca and Mg). Soil CEC was 22 meq/100g, which is fairly common for blueberry fields in western Oregon.

Soil pH & EC. The pH of soil solution collected from under the drip emitters was about a unit lower, on average, with K fertigation than with granular K (Table 2). Similar results were observed in the solutions collected at 3 inches from the emitters (data not shown). The source of soluble SOP used for fertigation in the present study has a small amount of acid in it, likely reducing soil pH under the emitters. KTS was expected to reduce soil pH due to the thiosulfate. Both products reduced pH within a few days or weeks after application and often maintained lower pH under the emitter during fertigation than either no K or granular SOP (Figure 1). By the end of season soil pH, which was also measured under the drip emitters, averaged 4.4 to 4.6 with K fertigation and 5.6 with granular K (Table 1).

Soil solution pH was also lower with K fertigation than with granular K at 6 inches from the drip emitter, but in this case, it was only significant when the plants were fertigated with SOP (Table 2). In general, pH was lower at 6 inches from the emitters than under the emitters (Figure 1). Apparently, H± migrated to the edge of the wetting front in each treatment. However, each K treatment resulted in lower pH than no K at 6 inches from the emitters.

Electrical conductivity of the soil solution was inversely correlated to pH and, on average, was higher with K fertigation than with granular K under the emitters but was similar among the K treatments at 6 inches from the emitters (Table 2). During fertigation, weekly measures of EC under the emitters ranged from 0.6 to 4.5 dS/m with KTS and 0.6 to 3.4 dS/m with SOP. Soil solution EC generally declined with distance from the emitters and was n ever higher than 2.5 dS/m at any location with no K or granular K. Depending on the e age of the plants, blueberries are considered sensitive to EC levels above 2 to 3 dS/m.

Soil, leaf nutrients. Fertigation

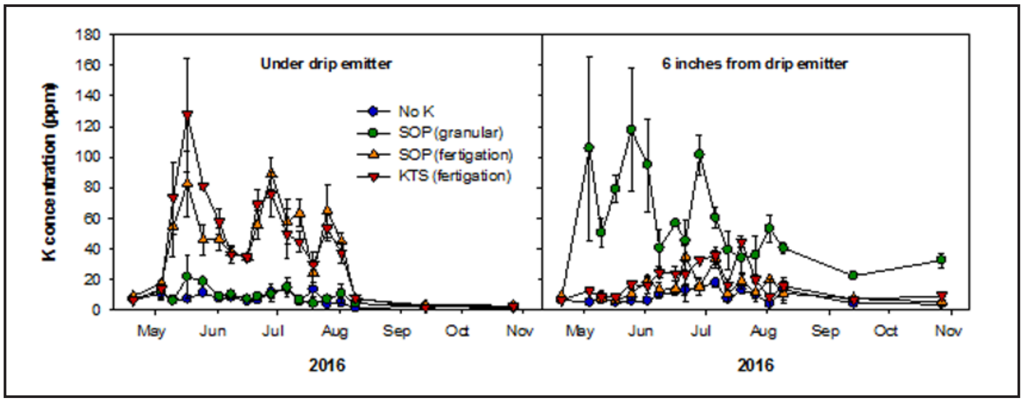

Figure 2. Effect of method and source of K fertilizer on concentration of K in the soil solution in a mature planting of 'Duke' blueberry. Soil solution samples were collected under and at 6 inches from a drip emitter throughout the growing season. A total of 75 lb K2O per acre was applied to each K fertilizer treatment. Granular K was applied all at once on April 28, while K fertigation was done weekly from May 2 to August 1. Each symbol represents the mean of four replicates and the error bars represent ±1 SE. SOP – sulfate of potash (potassium sulfate); KTS – potassium thiosulfate.

with SOP or KTS resulted in higher concentrations of K, Ca, Mg, and S in soil solution under the drip emitters than either no K or granular SOP, while granular SOP resulted in higher concentration of K than any other treatment at 6 inches from the drip emitter (Tables 2 and 3). Differences in K wer apparent throughout the growing seaon, particular;u under the drip emitters during fertigation (Figure 2). Evidently, granular SOP dissolved on the soil surface and penetrated near the edge of the wetting front, while K applied by fertigation remained near the drip emitters. Kafkafi and Tarchitsky suggested that, in practice, the exact distribution of K in the soil is relatively unimportant in drip-irrigated plants, since roots can grow and find K in the wetted soil volume. However, most blueberry roots are concentrated under the drip emitters when the plants are irrigated by drip. Fertigation provides a way to effectively deliver K to the roots while minimizing soil K fixation that could otherwise limit the effectiveness of granular application of K fertilizers.

Potassium fertilization had no effect on the concentration of K in the leaf tissue (Table 4). It usually takes a year or two before K fertilizer has any effect on tissue K concentration in blueberries. The treatments also had no effect on concentration of N, P, or Ca in the leaves. However, relative to no K, fertigation with KTS increased the concentration of Mg in the leaves, while fertigation with SOP increased the concentration of Mn in the leaves (Table 4). Typically, high amounts of K in the soil will result in lower concentrations of Mg in the leaves in blueberries, which was not the case in the present study. High concentration of Mn in the leaves, on the other hand, is usually related to low soil pH, and soil pH was lowest when the plants were fertigated with SOP. Granular SOP increased the concentration of S in the leaves relative to no K (Table 4).

Most of the nutrients in the leaves, including K, were at concentrations considered normal for mature blueberry plants in Oregon. However, N and P were below normal in each treatment. The current recommendation is 1.76 to 2.00% N and >0.10% P. Low N could have been due to the fact that the plants broke bud much earlier than usual in 2016, and consequently, N fertigation may have been started too late. Some of the plants were slightly chlorotic after harvest and could have been deficient, but there was no evidence of P deficiency in the planting. Other regions in the United States define P deficiency as below 0.07 to 0.08% P in blueberry leaves. Strik and Vance recently conducted a study on leaf nutrients in conventional and organic blueberries and concluded the standard for P should be lower in Oregon.

Yield, fruit quality. Neither K fertigation nor granular K had any effect on yield or fruit quality during the first year of the study (Table 5). This was not surprising given the limited effects of the treatments on leaf nutrients. Like many perennial crops, blueberries have a large amount of nutrient reserves in their woody tissues and will rely on those reserves for fruit production. We will need at least another year to determine whether K fertilizer has any effect on production or quality in the present study.

Looking ahead

Fertigation with SOP or KTS reduced soil pH and increased the concentration of K, Ca, Mg, and S under the drip emitters, while granular application of SOP resulted in higher concentration of K on the edge of the soil wetting front at 6 inches from the emitters. In both cases, K was available in the soil solution throughout the season, but at different locations. However, since blueberry roots tend to concentrate under the drip emitters, fertigation with K is likely more efficient than granular application of K. So far, there have been no benefits from either K fertigation or granular K on production or fruit quality, but it is still early as changes usually occur a year or two after K fertilizer is applied in blueberries. Additional measurements are under way to study the dynamics of K movement with depth following each fertilizer application and to examine whether there is any impact on K uptake in the leaves and fruit the following year.

Dr. David Bryla is Research Horticulturist and Dr. Scott Orr is Biological Science Technician at the USDA-ARS Horticultural Crops Research Unit in Corvallis, OR.