Potassium Fertigation and Organic Acids

Improving soil and plant nutrition in highbush blueberry.

Dr. David Bryla, Scott Orr, David Leon

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Summary: *Fertigation is becoming a common practice in many fruit and vegetable crops, but information on the best fertilizers for this practice is limited. Here, we evaluated the use of potassium (K) for fertigation in highbush blueberry. Potassium is the second most abundant nutrient in the crop after nitrogen (N), and a considerable quantity is removed with the berries during harvest each year. The products tested included water-soluble K sulfate and fluid K thiosulfate, as well as three K products with organic acids. Each product was safe and improved soil and plant nutrition, but none of them had any effect on fruit production after two years of use in our plantings in Oregon. Organic acids fertilizers retained more available K in the soil than K sulfate and could be useful at sites with K deficiency.*

Blueberry production has increased rapidly in recent years due to strong consumer demand for the fruit and good market prices. Currently, there are over 330,000 acres of cultivated blueberries (Vaccinium sp.) grown worldwide. Nearly 80% of the crop is produced in North and South America, but plantings are expanding into less traditional growing regions, including Mexico, Peru, Spain, Morocco, South Africa, China, and South Korea. By 2021, total global production is predicted to exceed 2.5 billion pounds of blueberries.

Unlike most crops, blueberries are limited to acidic soils (pH 4.2 to 5.5) and use primarily the ammonium ($NH4^{+}$) form of N over nitrate-N. Previously, 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 highbush blueberries. We also discovered that organic acids (i.e. humic and fulvic 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 a 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 fruit 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. Younger leaves near the shoot tip may develop interveinal chlorosis similar to Fe deficiency.

Potassium is usually applied to blueberries as K sulfate (K_2SO_4, also called sulfate of potash or SOP). Potassium chloride (muriate of potash or MOP) is not recommended because the plants are very sensitive to chloride. Other potential sources of K include monopotassium 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. NO_3-N) for blueberries.

The current project was carried out in two phases. The first phase was initiated in 2015 and was conducted in the greenhouse to identify appropriate fluid N and K formulations for blueberry. The second phase was initiated in April 2016 using two mature plants of blueberry. The first planting was used to determine whether fertigation with water-soluble K_2SO_4 or fluid KTS was more effective than the conventional practice of using a granular source of K_2SO_4, and the second was employed to assess the potential of using K fertilizers with organic acids or their derivatives for fertigation. In each case, we used Duke northern highbush blueberry, which is an early-season cultivar and one of the most popular grown worldwide.

Methodology

Greenhouse study. Young plants of Duke blueberry were transplanted into 1-gallon pots filled with either Willamette silt loam (fine-silty mixed super-active mesic Pachic Ultic Argixerolls) or Malabon silty clay loam (fine, mixed, super-active, mesic Pachic Ultic Argixerolls) soil. Willamette soil is usually low in pH and is often excellent for growing blueberries. Malabon soil, in contrast, tends to be higher in pH and is often marginal for blueberry production (Table 1). After a month of establishing the plants in the greenhouse, treatments were arranged in a completely randomized design and included a combination of the two soil types (Willamette and Malabon), five fluid N sources {ammonium sulfate, ammonium thiosulfate (ATS), urea, urea ammonium nitrate (UAN), and urea triazone (slow-release N fertilizer); 0.10 g/L N}, and two fluid N sources (K_2SO_4 and KTS; 0.15 g/L K_2O). Each treatment was replicated five times. Since KTS is not recommended for use with acidified fertilizers, urea sulfuric acid was not included in the study. The plants were fertigated three times per week with each combination of K and N fertilizer, plus a modified Johnson's solution (without N or K) to avoid limitations of other nutrients.

Soil solution was collected weekly using

Table 1. Analysis of soils from the greenhouse and field studies on 'Duke' blueberry.

	Greenhouse study		Field Studies[1]	
Soil analysis	Willamette silt loam	Malabon silty clay loam	Study 1	Study 2
pH (H2O 1:1)	4.9	6.3	5.8	6.0
Organic matter (%)	3.7	2.4	3.1	3.7
Soil nutrients (mg/kg)[2]				
Available N				
NO_3-N	5.6	16.1	1.2	1.1
NH_4-N	2.2	2.3	3.1	3.3
Anions				
Bray I P	107	29	19	29
SO_4 S	12	14	23	11
Exchangeable cations				
K	214	230	154	180
Ca	1257	2246	1878	1933
Mg	237	516	682	693
Na	58	60	47	56
Extractable minors				
B	0.39	0.46	0.58	0.58
Cu	1.6	5.0	8.2	6.5
Fe	508	495	289	311
Mn	69	75	37	46
Zn	2.0	2.6	3.9	7.1
Al	1338	864	940	956

[1]Malabon silty clay loam.

[2]With exception of P, nutrients were tested using the Mehlich III extraction procedure.

Table 2. Effects of different liquid sources of N and K fertilizer on growth and leaf N and K in potted plants of 'Duke' blueberry. Plants were grown in soil considered excellent (Willamette) or marginal (Malabon) for blueberry.

	Willamette silt loam				Malabon silty clay loam			
N source	No K	K_2SO_4	KTS	Avg.1	No K	K_2SO_4	KTS	Avg.1
Total dry wt (g/plant)								
Ammonium sulfate	8.0	6.4	6.6	7.0 ab	5.8	6.7	7.2	6.6 a
Ammonium thiosulfate	5.7	6.8	6.5	6.3 c	7.3	6.1	5.8	6.4 ab
Urea	7.1	7.3	7.7	7.4 a	6.7	5.5	6.5	6.2 b
Urea ammonium nitrate	6.4	7.4	6.8	6.8 b	5.9	6.2	6.4	6.2 b
Urea-triazone	7.1	6.2	7.0	6.8 b	5.3	5.1	6.8	5.7 c
Avg.1	6.8 a	6.8 a	6.9 a		6.2 ab	5.9 b	6.5 a	
Leaf N (%)								
Ammonium sulfate	1.55	1.43	1.42	1.47 a	1.33	1.22	1.28	1.27 ab
Ammonium thiosulfate	1.32	1.42	1.41	1.38 b	1.21	1.35	1.40	1.32 a
Urea	1.34	1.32	1.28	1.31 c	1.17	1.26	1.24	1.22 b
Urea ammonium nitrate	1.38	1.37	1.29	1.34 bc	1.18	1.15	1.38	1.24 b
Urea-triazone	1.21	1.38	1.45	1.35 bc	1.17	1.12	1.05	1.11 c
Avg.1	1.36 a	1.38 a	1.37 a		1.21 b	1.22 b	1.27 a	
Leaf K (%)								
Ammonium sulfate	0.48	0.48	0.63	0.53 b	0.52	0.59	0.57	0.56 a
Ammonium thiosulfate	0.48	0.62	0.63	0.58 a	0.54	0.65	0.60	0.60 a
Urea	0.42	0.45	0.48	0.45 c	0.36	0.51	0.52	0.47 b
Urea ammonium nitrate	0.54	0.50	0.51	0.52 b	0.37	0.47	0.55	0.46 b
Urea-triazone	0.45	0.50	0.57	0.50 b	0.40	0.51	0.52	0.48 b
Avg.1	0.47 c	0.51 b	0.56 a		0.44 b	0.55 a	0.55 a	

[1]Values followed by the same letter within a column or row are not significantly different at the 5% probability level.

K_2SO_4 – potassium sulfate; KTS – potassium thiosulfate.

Table 3. Effects of method and source of K fertilizer on pH and concentration of K, Ca, Mg, and S in soil solution under and at 6 inches from a drip emitter in a mature planting of 'Duke' blueberry.[1]

	pH		K (ppm)		Ca(ppm)		Mg (ppm)		S (ppm)	
K treatment[2]	Under drip emitter	6" from drip emitter	Under drip emitter	6" from drip emitter	Under drip emitter	6" from drip emitter	Under drip emitter	6" from drip emitter	Under drip emitter	6" from drip emitter
No K	5.7 ab[3]	5.0 a	8 b	10 b	62 b	87	35 b	57	127 b	53 b
K_2SO_4 (granular)	6.0 a	4.5 b	10 b	64 a	62 b	119	35 b	72	127 b	164 a
K_2SO_4 (fertigation)	5.0 c	4.2 c	49 a	21 b	93 a	127	49 a	80	236 a	101 ab
KTS (fertigation)	5.1 bc	4.4 bc	54 a	16 b	85 a	139	46 ab	78	235 a	121 ab

[1]Average of samples collected weekly from May 3 to August 9, 2016.
[2]A total of 75 lb K_2O per acre was applied to each K fertilizer treatment; K_2SO_4 – potassium sulfate; KTS – potassium thiosulfate.
[3]Values followed by the same letter within a column are not significantly different at the 5% probability level; no letters indicate the effects of the K fertilizers were nonsignificant.

Table 4. Effects of method and source of K fertilizer on soil pH and extractable soil cations in a mature planting of 'Duke' blueberry.1,2

			Soil cations (mg/kg)					
	Soil pH		K		Ca		Mg	
K treatment[3]	Under drip emitter	Between emitters	Under drip emitter	Between emitters	Under drip emitter	Between emitter	Under drip emitter	Between emitters
2016								
No K	4.8	—	109 b[4]	—	1559	—	652	—
K_2SO_4 (granular)	5.0	—	110 b	—	1528	—	637	—
K_2SO_4 (fertigation)	4.5	—	251 a	—	1428	—	641	—
KTS (fertigation)	4.7	—	218 a	—	1344	—	593	—
2017								
No K	4.6	5.0	110 b	140 b	1576 a	1920	636 a	731
K_2SO_4 (granular)	4.5	5.1	177 a	175 ab	1399 ab	1981	585 ab	731
K_2SO_4 (fertigation)	4.4	4.7	146 ab	201 a	1487 ab	1782	639 a	696
KTS (fertigation)	4.4	5.1	194 a	166 ab	1303 b	1747	538 b	674

[1]Soil samples were collected in October 2016 and 2017.
[2]The treatments had no effect on other soil nutrients, including NH_4-N, NO_3-N, P, SO_4-S, B, Cu, Mn, or Zn.
[3]A total of 75 lb K_2O per acre was applied to each K fertilizer treatment; K_2SO_4 – potassium sulfate; KTS – potassium thiosulfate.
[4]Values followed by the same letter within a column are not significantly different at the 5% probability level; no letters indicate the effects of the K fertilizers were nonsignificant.

Table 5. Effects of method and source of K fertilizer on concentration of K, Ca, and Mg in the leaves, new shoots, and crown of mature 'Duke' blueberry plants.1

	K concentration (%)			Ca concentration (%)			Mg concentration (%)		
K treatment[2]	Leaves	New Shoots	Crown	Leaves	New Shoots	Crown	Leaves	New Shoots	Crown
No K	0.52 b[3]	0.35	0.17	0.57	0.52	0.06 ab	0.19	0.85	0.024 b
K_2SO_4 (granular)	0.68 a	0.39	0.18	0.52	0.59	0.08 a	0.19	0.86	0.031 a
K_2SO_4 (fertigation)	0.64 a	0.38	0.16	0.53	0.60	0.06 ab	0.19	0.90	0.027 ab
KTS (fertigation)	0.65 a	0.40	0.16	0.53	0.54	0.05 b	0.19	0.89	0.023 b

[1]The plants were harvested destructively in October 2017, following 2 years of treatment.
[2]A total of 75 lb K_2O per acre was applied to each K fertilizer treatment; K_2SO_4 – potassium sulfate; KTS – potassium thiosulfate.
[3]Values followed by the same letter within a column are not significantly different at the 5% probability level; no letters indicate the effects of the K fertilizers were nonsignificant.

small (10 cm long by 1 mm diameter) hydrophilic porous polymer soil moisture samplers and was analyzed for pH, EC, NH_4-N, NO_3-N, K, and other nutrients. The samplers were installed vertically midway between the plant and the edge of the pot. At 60 days after the treatments were initiated, the plants were harvested destructively and divided into individual plant parts (leaves, stems, and roots). Each part was oven-dried, weighed, and analyzed for N by combustion analysis and for other nutrients by ICP.

Field studies. The field studies were conducted at the Oregon State University Lewis-Brown Horticultural Research Farm in Corvallis, OR. The plantings were established in April 2004 (study 1) and October 2008 (study 2) on Malabon silty clay loam soil (Table 1). Plants at both sites were spaced 2.5 feet apart on rows of raised beds (15 inches high in the middle by 4 feet wide at the base) that were 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 0.25 gph emitters every 18 inches (study 1) or 0.5 gph emitters every 12 inches (study 2). The tubing was laid approximately 8 inches from the base of the plants and covered with the sawdust mulch. Irrigation was scheduled as needed, based on daily estimates of crop ET obtained from a nearby AgriMet weather station.

Treatments in the first study were arranged in a randomized complete block design with four K treatments, including no K fertilizer (control), a single application of granular K_2SO_4, and fertigation with K_2SO_4 (SoluPotasse®, 0-0-51-18S; dissolved in deionized water at a concentration of 80 g/L) or KTS® (0-0-25-17S; pH 7.4-8.0, 12.2 lbs./gal). Each treatment was replicated four times with three rows 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./acre K_2O per year, 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 150-200 lbs./acre N per year. Granular K fertilizer was spread uniformly on each side of the rows in April, and the fluid fertilizers (both K and N) were injected weekly from April to August using positive displacement injectors. Prior to the study, plant growth and production were relatively weak at the site due to poor soil conditions. At the beginning of the growing season in 2016, soil pH was slightly high for blueberry, while extractable soil P and K were slightly low (Table 1). Northern highbush blueberry usually does 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 was adequate (S, B, Cu, and Mn) or high (Ca and Mg).

Treatments in the second study were arranged in a randomized complete block design with four K treatments, including fertigation with K_2SO_4 (SoluPotasse®, 0-0-51-18S, dissolved in deionized water at a concentration of 100g/L), SUPER POTASSIUM® (formerly SUPER K) (0-0-40 and organic acid derivatives; 12.27 lbs./gal, derived from K hydroxide, pH > 13.5), BUFFER K® (0-0-25 and organic acid derivatives, 10.71 lbs./gal, derived from K carbonate, K hydroxide, and K thiosulfate; pH 7.0-8.0), and Katalyst FS® (0-0-30 and 3.5% organic acids, 11.4 lbs./gal; derived from K hydroxide, pH 9.0-9.5). Each K fertilizer was injected through the drip system using a positive displacement injector and applied weekly from April to August at a total rate of 75 lbs./acre K_2O per year. The treatments were replicated five times and contained a row of eight plants per replicate. Plants in each treatment were also fertigated with fluid ammonium sulfate (9-0-0-10S) at a total rate of 150-200 lbs./acre N per year. Although soil pH was also high initially in this planting (Table 1), production at the site was normal for Duke blueberry in the region (6 to 8 ton/acre).

The solution was extracted in the field using the same brand of soil moisture samplers used in the greenhouse. These samplers are ideal for blueberry because the plants have a very shallow root system (typically no deeper than a foot). We inserted the samplers vertically under and at 6 inches from a drip emitter (edge of wetting front) 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 in April prior to any treatment, then weekly each day after fertigation in May through August, and once in September and October after the plants were no longer fertigated. Each sample was analyzed for pH using a multimeter, and for K and other nutrients by ICP.

Ripe berries were hand-picked and weighed from each plot twice per season (mid and late June in 2016 and late June and early July in 2017). One hundred

Table 6. Effects of fertigating with potassium sulfate (K2SO4) and three K fertilizers containing organic acids (Katalyst) or their derivatives (SUPER POTASSIUM and BUFFER K) on soil pH and extractable soil nutrients in a mature planting of 'Duke' blueberry.1,2

		Soil P	Soil cations (mg/kg)			Soil B
K treatment[3]	Soil pH	(mg/kg)	K	Ca	Mg	(mg/kg)
2016						
K_2SO_4	5.7 ab4	46 a	167 c	1737 b	721	0.44 a
SUPER POTASSIUM	5.9 a	35 b	184 bc	1974 ab	757	0.35 ab
BUFFER K	5.8 ab	38 ab	241 a	2049 a	772	0.34 ab
Katalyst	5.6 b	41 ab	210 ab	2051 a	738	0.23 b
2017						
K_2SO_4	5.4	27	160 b	1910	754	0.28
SUPER POTASSIUM	5.5	27	224 a	2019	738	0.27
BUFFER K	5.5	28	226 a	2007	712	0.26
Katalyst	5.4	27	207 a	1862	701	0.25

[1]Soil samples were collected in October 2016 and 2017.
[2]The treatments had no effect on other soil nutrients, including $NH_{4-}N$, $NO_{3-}N$, $SO_{4-}S$, Cu, Mn, or Zn.
[3]A total of 75 lb K_2O per acre was applied per year to each K fertilizer treatment.
[4]Values followed by the same letter within a column are not significantly different at the 5% probability level; no letters indicate the effects of the K fertilizers were nonsignificant.

Table 7. Effects of fertigating with potassium sulfate (K_2SO_4) and three K fertilizers containing organic acids (Katalyst) or their derivatives (SUPER POTASSIUM and BUFFER K) on leaf and berry nutrient concentrations in a mature planting of 'Duke' blueberry.1,2

	Leaf nutrients					Berry Nutrients		
K treatment[3]	K (%)	Ca (%)	Mg (%)	B (ppm)	Mn (ppm)	K (%)	Ca (%)	Mg (%)
2016								
K^2SO^4	0.50	0.79 ab[4]	0.27 ab	37 b	143 b	0.53	0.037	0.079 a
SUPER POTASSIUM	0.50	0.94 a	0.29 a	43 b	141 b	0.53	0.034	0.078 ab
BUFFER K	0.51	0.90 a	0.26 bc	56 a	146 b	0.52	0.036	0.068 bc
Katalyst	0.50	0.69 b	0.25 c	47 ab	177 a	0.53	0.036	0.061 c
2017								
K^2SO^4	0.44	0.67 a	0.28 a	15 b	84	0.52	0.035 ab	0.040 a
SUPER POTASSIUM	0.44	0.64 ab	0.25 ab	18 ab	80	0.50	0.037 a	0.040 a
BUFFER K	0.42	0.60 ab	0.23 b	20 a	80	0.53	0.035 ab	0.040 a
Katalyst	0.44	0.58 b	0.23 b	17 ab	78	0.52	0.029 b	0.037 b

[1]Berry samples were collected at harvest in July and leaf samples were collected in early August.
[2]The treatments had no effect on the concentration of other nutrients, including N, P, S, Cu, Fe, or Zn in the leaves and N, P, S, B, Cu, Fe, Mn, or Zn in the berries.
[3]A total of 75 lb K_2O per acre was applied per year to each K fertilizer treatment.
[4]Values followed by the same letter within a column are not significantly different at the 5% probability level; no letters indicate the effects of the K fertilizers were nonsignificant.

Table 8. Effects of fertigating with potassium sulfate (K_2SO_4) and three K fertilizers containing organic acids (Katalyst) or their derivatives (SUPER POTASSIUM and BUFFER K) on berry weight and yield in a mature planting of 'Duke' blueberry.[1]				
	Berry wt (g)		Yield (ton/acre)	
K treatment[2]	2016	2017	2016	2017
K_2SO_4	1.77 b3	1.80	6.6	4.9
SUPER POTASSIUM	1.91 a	1.85	6.8	4.9
BUFFER K	1.87 ab	1.87	8.0	6.1
Katalyst	1.91 a	2.01	8.4	5.7

[1]Berries were harvested twice in July in 2016 and 2017.
[2]A total of 75 lb K_2O per acre was applied per year to each K fertilizer treatment.
[3]Values followed by the same letter within a column are not significantly different at the 5% probability level; no letters indicate the effects of the K fertilizers were nonsignificant

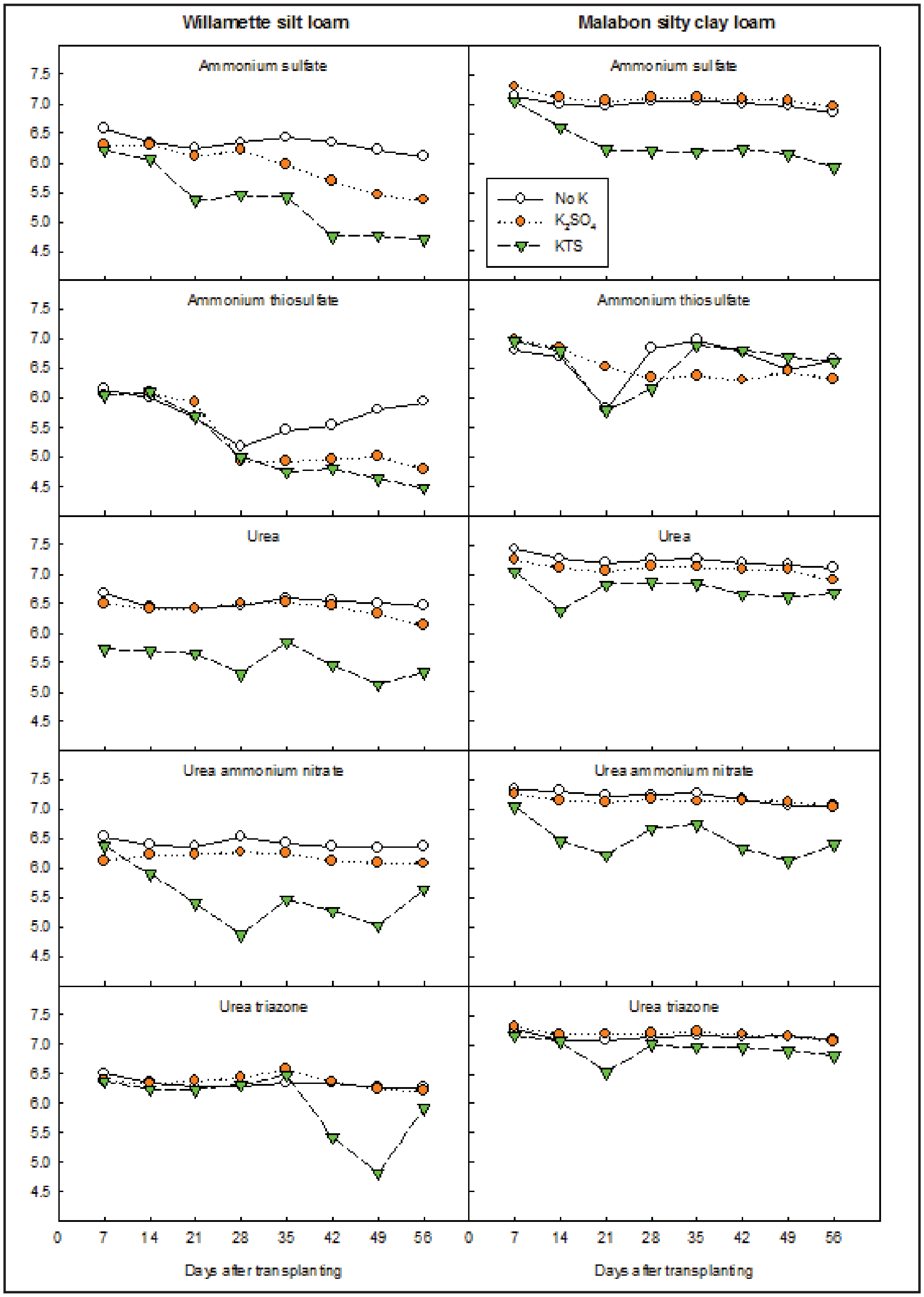

Figure 1. Effects of different liquid sources of N and K fertilizer on the pH of the soil solution in potted plants of 'Duke' blueberry. Plants were grown in soil considered excellent (Willamette) or marginal (Malabon) for blueberry.

berries were also randomly sampled from the plots on each date and weighed to determine the average berry weight. Each sample was then dried, ground, and analyzed in-house for N by combustion analysis and for other nutrients by ICP. Leaves were likewise analyzed for nutrients in early August each year (both studies), and one plant from each plot was harvested destructively and analyzed for nutrients in October 2017 (study 1 only).

Soil cores were collected in October each year and sent to Brookside Laboratories for analysis of pH and soil nutrients. Samples were taken beneath a drip emitter (as well as between emitters during the second year of study 1) to a depth of 8 inches 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.

Results

Suitable sources of N and K. Fertigation with ATS or KTS reduced pH of the soil solution by at least a unit within 1 to 3 weeks of the first application of the fertilizer (Figure 1). The combination of the two was very acidic (pH < 4.5 within 8 weeks), however, even for blueberry (note that soil solution pH in these soils is typically about a unit higher than soil pH). Optimum pH conditions were produced by urea + KTS in the Willamette soil and by ammonium sulfate + KTS in the Malabon soil.

On average, the concentration of K in the soil solution increased by 25% with K_2SO_4 and by 39% with KTS and, depending on the soil type, was highest when KTS was applied with urea or ammonium sulfate (Figure 2). The concentrations of Ca and Mg also increased in the soil solution when the K fertilizers were applied and, on average, were 20-21% greater with KTS than K_2SO_4 (data not shown).

After 8 weeks, total dry weight of the plants was greater with urea than with ammonium thiosulfate, urea ammonium sulfate, or urea triazone in the Willamette soil and with ammonium sulfate than with any of the urea fertilizers in the Malabon soil (Table 2). Total dry weight was also greater when the plants were fertigated with KTS than with K_2SO_4 in the Malabon soil. However, neither of the K sources produced more growth than no K in either soil. Blueberry plants are well fertilized in the nursery and, therefore, are unlikely to be limited by any nutrient other than N very soon after planting. Analysis of leaf nutrients indicated that leaf N was greater with ammonium sulfate and or ammonium thiosulfate than with the urea fertilizers in both of the soils (Table 2). Leaf K was likewise affected by the N fertilizers and, on average, was greater with K fertilizer than without it in both soils and with KTS than with K_2SO_4 in the Willamette soil (Table 2).

Fertigation vs. granular application. Neither fluid nor granular K had any effect on yield or leaf K concentration during the first year of application. This was not surprising given the fact that the study was conducted on mature plants and changes in tissue K usually occur a year or two after K fertilizer is applied to a perennial crop such as blueberry However, fertigation with K_2SO_4 or KTS resulted almost immediately in low pH and higher concentrations of K, Ca, Mg, and S in soil solution under the drip emitters than either no K or granular K_2SO_4, while application of granular K_2SO_4 resulted in a higher concentration of K than any other treatment at 6 inches from the drip emitters (Table 3). Apparently, K applied by fertigation remained near the drip emitters. Granular K_2SO_4, on the other hand, must have dissolved on the soil surface and penetrated near the edge of the wetting front. By the end of the first season, the fertigation treatment contained approximately twice as much extractable soil K under the drip emitters than the non-fertigated treatments (Table 4).

By the following year, plants fertigated with K were greener as indicated by higher SPAD meter readings than those grown with no K or granular K_2SO_4 (46 vs. 43). However, once again, none of the K treatments had any effect on yield or leaf K concentration (data not shown). In this case, leaf K was measured on new leaves in early August, which is the recommendation for leaf tissue analysis in blueberry. It was not until the plants were harvested destructively in October that we saw any differences in leaf K. At that point, we sampled all of the leaves on the plant and found that K concentration was greater when plants were grown without K fertilizer, regardless of whether it was applied by fertigation or as a granular product (Table 5). Each fertilizer also tended to increase the concentration of K in new shoots. Evidently, K was more than adequate at the site, and any extra K from the fertilizer was stored primarily in shoots and older leaves on the plants. Typically, highly mobile nutrients such as N, K, and Mg are maintained at fairly constant concentrations in the youngest expanded leaves and vary considerably with nutritional status of the plant in older leaves. It is interesting to note

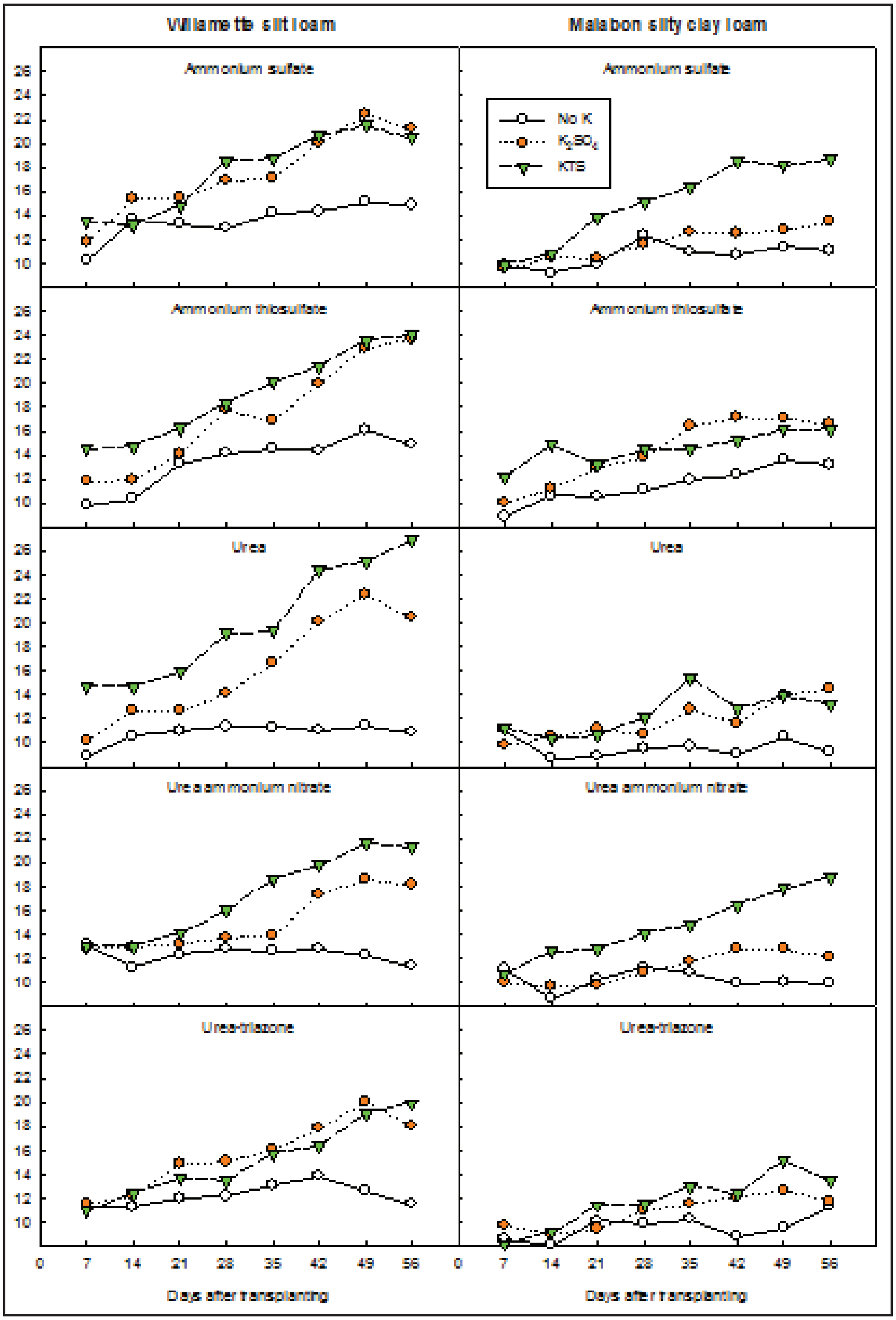

Figure 2. Effects of different liquid sources of N and K fertilizer on the concentration of K in the soil solution in potted plants of 'Duke' blueberry. Plants were grown in soil considered excellent (Willamette) or marginal (Malabon) for blueberry.

that granular application of K_2SO_4 resulted in higher concentrations of Ca and/or Mg in the plant crown than fertigation with KTS and no K (Table 5).

Fertigation with K products containing organic acids. Fertigation with two of the K fertilizers with organic acids or organic acid derivatives, BUFFER K and Katalyst FS, resulted in lower pH and higher concentrations of K^+ in the soil solution than fertigation with K_2SO_4 or the other fertilizer with organic acid derivatives, SUPER POTASSIUM (Figure 3A and B). Both BUFFER K and Katalyst FS have a pH that is about a unit above neutral. In contrast, SUPER POTASSIUM has a pH > 13.5 and, along with BUFFER K, resulted in higher concentrations of Ca2+ and Mg2+ between the emitters than K_2SO_4 or Katalyst FS (Figure 3C and D). The former products have much smaller organic molecules than Katalyst FS, which may have somehow increased availability of divalent cations.

Each of the organic acid fertilizers retained more available K in the soil than K_2SO_4 within a year or two of application (Table 6). BUFFER K and Katalyst FS also resulted in more soil Ca than K_2SO_4 initially, while SUPER POTASSIUM and Katalyst FS resulted in a slight difference in soil pH and less available P and B than K_2SO_4, respectively (Table 6).

None of the organic acid fertilizers had any effect on leaf K concentration relative to K_2SO_4 in either the first or second year of application, but BUFFER K led to a higher concentration of B in the leaves than K_2SO_4 in both years, and Katalyst FS resulted in a higher concentration of Mn in the leaves than any of the other fertilizers in the first year (Table 7). Low pH enhances availability of B and Mn, and as mentioned, these later treatments produced the lowest pH (Figure 3A). However, Katalyst FS also resulted in the lowest leaf Ca concentration among the treatments and, along with BUFFER K, led to a lower concentration of Mg than K_2SO_4 in both the leaves and berries (Table 7). Clearly, Ca and Mg uptakes were somewhat limited by high levels of soil K^+ in these treatments (Fig. 3B), although leaf concentrations of both remained within the recommended range for blueberry.

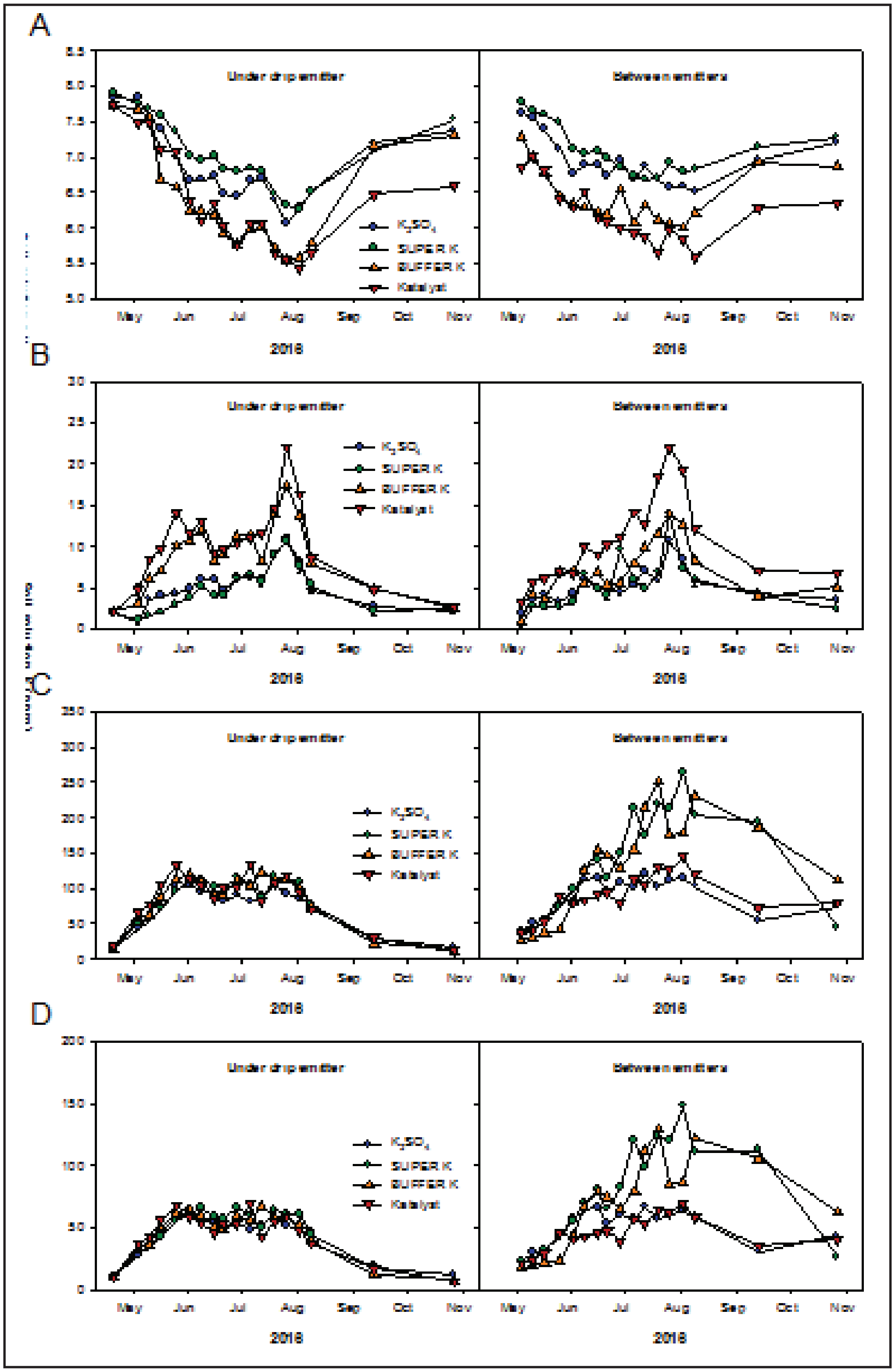

Figure 3. Effects of fertigating with potassium sulfate (K_2SO_4) and three K fertilizers containing humic substances on A) pH and concentration of B) K, C) Ca, and D) Mg in soil solution under and between drip emitters in a mature planting of 'Duke' blueberry. A total of 75 lb K_2O per acre was applied from late April to early August to each K fertilizer treatment. Each symbol represents the mean of four replicates.

SUPER POTASSIUM and Katalyst FS produced slightly heavier berries during the first year of application, but had no effect on yield in either year (Table 8). Perhaps these fertilizers reduced water limitations to berry development via their influence on root growth. Any such benefits would have been less obvious the second year due to heavy pruning and a smaller crop load that year (i.e. 5-6 tons/acre). Further work is needed to understand how these fertilizers affect soil-plant water relations and to determine whether they have any beneficial effects on fruit quality beyond fruit size in blueberry.

Summing Up

Based on our results, KTS appears to be a good source of K for fertigation in blueberry and can be used with urea on soils with optimum pH (4.5 to 5.5) and with ammonium sulfate on soils with pH > 5.5. Fertigating with fertilizers containing organic acids or their derivatives is also useful, particularly for increasing availability and retention of K in the soil. However, we found no benefits to date from either K fertigation or granular K on fruit production in two mature blueberry fields. The fertilizers had an immediate effect on pH and availability of K and other nutrients in the soil solution and after two years are beginning to influence the nutrient status of the plants. We will complete a third and final year of the study this summer.

Dr. Bryla is a Research Horticulturist and Mr. Orr is Biological Science Technician at the USDA-ARS Horticultural Crops Research Unit, Corvallis, OR, 97330, and Mr. Leon is a PhD student in the Department of Horticulture, Oregon State University, 4017 ALS, Corvallis, OR 97331.