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Benefits of Using Liquid Sources of Potassium Fertilizer in Northern Highbush Blueberry

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Abstract

Fertigation with N increases growth and production relative to granular N applications in northern highbush blueberry (*Vaccinium corymbosum* L.), but little information is available on whether there is any benefit to fertigating with other nutrients. The objective of this study was to evaluate the use of K for fertigation. An initial study was done in a greenhouse to identify appropriate combinations of liquid N and K sources for fertigation using potted plants of 'Duke' blueberry. The results indicated that the concentration of K in the soil solution increased by 25% with potassium sulfate (K_2SO_4) and by 39% with potassium thiosulfate (KTS) and, depending on the soil type, was highest when KTS was applied with urea or ammonium sulfate. Leaf K was affected by K as well as N fertilizers and, on average, was greater with than without K in both an optimum and high pH soil and with KTS than with K_2SO_4 in the latter soil. A second study was conducted to compare fertigation to granular application of K fertilizer using a mature planting of 'Duke' blueberry. Treatments included fertigation (once a week from April to August) with water-soluble K_2SO_4 or KTS, a single application (April) of granular K_2SO_4, and no K fertilizer. Each K fertilizer was applied at a total rate of 84 kg/ha K_2O per year. After 2 years, the treatments have had no effect on yield or fruit quality. However, fertigation with K_2SO_4 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 K_2SO_4, while granular K_2SO_4 resulted in higher concentration of K than any other treatment at 15 cm from the drip emitter (edge of the wetting front). The fertigated treatments also had greener leaves (based on SPAD meter readings), greater whole-plant leaf K concentrations, and nearly twice as much extractable K in the soil as the non-fertigated treatments. Additional measurements are underway to determine whether K fertigation will have any effect on yield or fruit quality over the long term.

Index words: *Vaccinium corymbosum*, drip irrigation, fertigation, nitrogen, plant nutrition, potassium, soil nutrients.

Introduction

Fertigation, the process of applying soluble fertilizers through an irrigation system, is becoming a common practice in many fruit and vegetable crops, including highbush blueberry (*Vaccinium* sp.). Recent studies in northern highbush blueberry revealed that fertigation with various liquid sources of NH_4-N, including ammonium sulfate, urea, and urea sulfuric acid, produced more growth and greater yield than using conventional granular N fertilizers (Bryla and Machado, 2011; Ehret et al., 2014; Vargas and Bryla, 2015). Application of other nutrients by fertigation could also be beneficial for production of blueberries, but information on doing so has been limited (Bryla and Strik, 2015).

Potassium is typically the second most abundant nutrient in plants after N (Marschner, 2012). A study on nutrient uptake in a new planting of 'Bluecrop' blueberry indicated that the total K requirements during the first 2 years was 12.5 kg/ha (Bryla et al., 2012). This was equivalent to approximately 19% of the total K fertilizer applied (i.e., 67 kg/ha of K each spring). Mature plants require much more K due to high K content in the fruit (0.9–1.9 kg/ha of K are removed with each ton of berries), as well as to leaf senescence and pruning (Bryla and Strik, 2015). The current recommendation for mature blueberry plantings is to apply 84−112 kg/ha of K_2O when soil K is <100 ppm or leaf K is below 0.2%, and to apply 0−84 kg/ha of K_2O when soil K is 100−150 ppm or leaf K is 0.2−0.4% (Hart et al., 2006). This recommendation is derived from anecdotal evidence collected from commercial plantings irrigated by sprinklers and fertilized using granular fertilizers. While this has been the traditional method of managing blueberries, fertigation using a liquid K fertilizer could increase movement of K in the soil profile and ensure continuous supply of the nutrient required for plant growth and fruit production (Burt et al., 1998).

Potassium is usually applied to blueberry as K_2SO_4 (also called sulfate of potash or SOP) (Hart et al., 2006). Potassium chloride (muriate of potash or MOP) is not recommended because the plants are very sensitive to chloride (Hart et al., 2006). Other potential sources of K include monopotassium phosphate, which is largely a source of P, and KTS. The latter may be particularly useful in high pH soils because thiosulfate is readily oxidized by *Thiobacillus* and other soil bacteria to produce sulfuric acid (Parker and Prisk, 1953; Starkey, 1935). 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 blueberry.

The objective of the present study was to evaluate the use of K for fertigation in northern highbush blueberry. The project was carried out in two phases. The first phase was initiated in 2015 and was conducted in the greenhouse to identify appropriate combinations of liquid N and K sources for fertigation. The second phase was initiated in April 2016 using a mature planting and was done to determine whether fertigation was more effective than the conventional practice of using a granular K fertilizer. In both cases, we used 'Duke' northern highbush blueberry, which is an early season cultivar and one of the most popular grown worldwide.

Materials and Methods

Greenhouse study. Young plants of 'Duke' blueberry were obtained from a nursery in 72-cell flats and transplanted into 3.8-L pots filled with either Willamette silt loam (fine-silty mixed superactive mesic Pachic Ultic Argixeroll) or Malabon silty clay loam (fine, mixed, superactive, mesic Pachic Ultic Argixerolls) soil. Willamette soil is usually low in pH and is often excellent for growing blueberries; Malabon soil, on the other hand, tends to be higher in pH and is often marginal for blueberry production (Table 1). After a month of establishing the plants in a greenhouse, treatments were arranged in a completely randomized design and included a combination of the two soil types (Willamette and Malabon), five liquid 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 liquid K sources (K_2SO_4 and KTS; 0.15 g/L K_2O). Each treatment was replicated five times with one plant per replicate. 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 (Johnson et al., 1957).

Soil solution (10 mL/pot) was collected weekly using small (10-cm long ´ 1-mm diameter) hydrophilic porous polymer soil moisture samplers (Eijkelkamp Soil & Water, Giesbeek, The Netherlands). Each sample of solution was analyzed for pH using a multimeter (Omega Engineering, Inc., Stamford, CT) and for K and other nutrients using an inductively coupled plasma optical emission spectrometer (ICP-OES) (Optima 3000DV; Perkin Elmer, Wellesley, MA). 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 at 70 °C, weighed, and analyzed for total N using a combustion analyzer (Model CNS-2000, LECO Corporation, St. Joseph, MI) and for other nutrients using the ICP-OES [following microwave digestion in 70% (v/v) nitric acid] (Gavlak et al., 2005).

Field study. The field study was conducted at the Oregon State University Lewis-Brown Horticultural Research Farm in Corvallis, OR. The planting was established in April 2004 on Malabon silty clay loam soil (Table 1). Plants of 'Duke' blueberry were spaced 0.8-m apart on rows of raised beds (0.4-m high in the middle by 1.2-m wide at the base) centered 3.0-m apart. The beds were mulched every other year with Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) 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 1 L/h emitters every 45 cm. The tubing was laid approximately 20 cm from the base of the plants and was covered with the sawdust mulch. Irrigation was scheduled as needed based on daily estimates of crop ET obtained from a nearby AgriMet weather station (https://www.usbr.gov/pn/agrimet/) (Bryla, 2011).

Treatments were arranged in a randomized complete block design and included 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 (KTS®; 0–0–25–17S; pH 7.4–8.0; 1.5 kg/L). 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 84 kg/ha K_2O per year, and all treatments, including those with granular K or no K, were fertigated with liquid ammonium sulfate (9–0–0–10S) at a total rate of 170-225 kg/ha N per year. Ammonium polyphosphate (10–34–0) was also applied by fertigation at a total rate of 45 kg/ha P_2O_5 in 2017. Granular K fertilizer was spread uniformly on each side of the rows in April, and the liquid fertilizers 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 low and slightly low, respectively (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 (Strik et al., 2014; 2017). Availability of other extractable soil nutrients were adequate (SO_4-S, B, Cu, and Mn) or high (Ca and Mg) (Horneck et al., 2011).

Soil 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 30–40 cm) (Bryla et al., 2017). The samplers were inserted vertically under and at 15 cm 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, K, and other nutrients following the same procedures used in the greenhouse trial.

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 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 for nutrients as described earlier. Leaf samples (six leaves from the center six plants in each plot) were likewise analyzed for nutrients in early August each year, and one plant from each plot was harvested destructively and analyzed for nutrients in October 2017.

Leaf chlorophyll was also quantified nondestructively in June 2017 using a SPAD-502 chlorophyll meter (Konica Minolta, Japan). Measurements were taken at mid-canopy, on single, healthy, fully expanded leaves. Triplicate readings were recorded from each side of the row of each replicate and averaged (24 measurements/treatment).

Soil cores were collected in October each year and sent to a commercial laboratory (Brookside Laboratories Inc., New Bremen, OH) for analysis of pH and soil nutrients. Samples were taken beneath a drip emitter, as well as between emitters during the second year (2017), to a depth of 15 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.

Statistical analysis. Data were analyzed using PROC GLM in SAS (Ver. 9.4, SAS Institute Inc., Cary, NC). Residuals were tested for normality using the Shapiro-Wilk test, and data were log transformed and reanalyzed where necessary to meet criteria for normality and homogeneity of variance. Means were separated the 0.05 level using Fisher's protected least significant difference (LSD) test.

Results and Discussion

Suitable sources of N and K fertilizer for fertigation of northern highbush blueberry. Fertigation with ATS or KTS reduced pH of the soil solution by at least a unit within 1–3 weeks of the first application of the fertilizer (Fig. 1). However, the combination of these two fertilizers was very acidic (pH < 4.5 within 8 weeks), even for blueberry (note that soil solution pH in these soils is typically about a unit higher than soil pH; Bryla et al., 2010). 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 (Fig. 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 with 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 than without K fertilizer in both soils and with KTS than with K_2SO_4 in the Willamette soil (Table 2).

Fertigation vs. granular application of K fertilizer. Neither liquid nor granular K had any effect on yield or leaf K concentration during the first year of application (data not shown). 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 (Hart et al., 2006). However, fertigation with K_2SO_4 or KTS resulted almost immediately 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 K_2SO_4, while application of granular K_2SO_4 resulted in a higher concentration of K than any other treatment at 15 cm from the drip emitters (Table 3). Apparently, K applied by fertigation remained near the drip emitters, while granular K_2SO_4 dissolved on the soil surface and penetrated near the edge of the wetting front. By the end of the first season, the fertigation treatments 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 visibly greener as indicated by slightly 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 (Hart et al., 2006). It was not until the plants were harvested destructively in October that we saw any differences in leaf K. At this point, we sampled all of the leaves on a given plant and found that K concentration was greater when plants were grown with than 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 fertilizers 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 (Marschner, 2012). It is interesting to note 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).

Conclusions

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 (4.5–5.5) and with ammonium sulfate on soils with pH > 5.5. However, we found no benefit to date from either K fertigation or granular K on fruit production. The fertilizers had an immediate effect on pH and availability of K and other nutrients in the soil solution and, after 2 years, are beginning to influence the nutrient status of the plants.

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

	Greenhouse study		
Soil analysis[1]	Willamette silt loam	Malabon silty clay loam	Field study[2]
pH (H_2O 1:1)	4.9	6.3	5.8
Organic matter (%)	3.7	2.4	3.1
Soil nutrients (mg/kg)[3]			
Available N			
NO_3-N	5.6	16.1	1.2
NH_4-N	2.2	2.3	3.1
Anions			
Bray I P	107	29	19
SO_4-S	12	14	23
Exchangeable cations			
K	214	230	145
Ca	1257	2246	1878
Mg	237	516	682
Na	58	60	47
Extractable minors			
B	0.39	0.46	0.58
Cu	1.6	5.0	8.2
Fe	508	495	289
Mn	69	75	37
Zn	2.0	2.6	3.9
Al	1338	864	940

[1]Soil recommendations for northern highbush blueberry in Oregon is pH of 4.5 to 5.5, P > 50 mg/kg, and K >150 mg/kg.
[2]Malabon silty clay loam. [3]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)[2]							
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 (%)[2]							
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 (%)[2]							
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 based on Fisher's protected LSD test.
[2]Total dry weight and leaf N and K were significantly affected by soil type and N and K source ($P < 0.05$) but were not affected any interactions among the treatments.
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 15 cm 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	15 cm from drip emitter	Under drip emitter	15 cm from drip emitter	Under drip emitter	15 cm from drip emitter	Under drip emitter	15 cm from drip emitter	Under drip emitter	15 cm 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 84 kg/ha K_2O 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 based on Fisher's protected LSD test; 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 (fertigat.)	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 (fertigate.)	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 84 kg/ha K_2O 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 based on Fisher's protected LSD test; 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 84 kg/ha K_2O 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 based on Fisher's protected LSD test; no letters indicate the effects of the K fertilizers were nonsignificant.

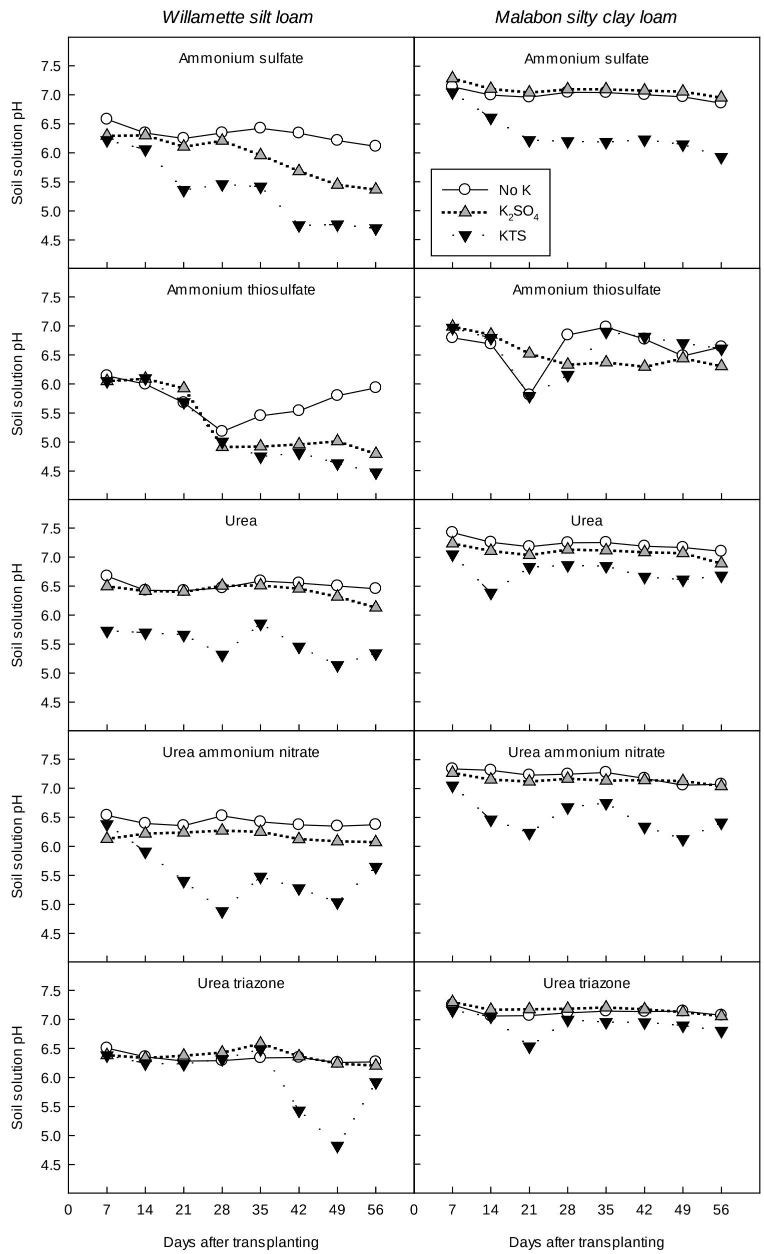

Fig. 1. Effects of different liquid sources of N and K fertilizer on the pH of the soil solution in potted plants of ‘Duke’ blueberry. Plants were grown in soil considered excellent (Willamette) or marginal (Malabon) for blueberry.

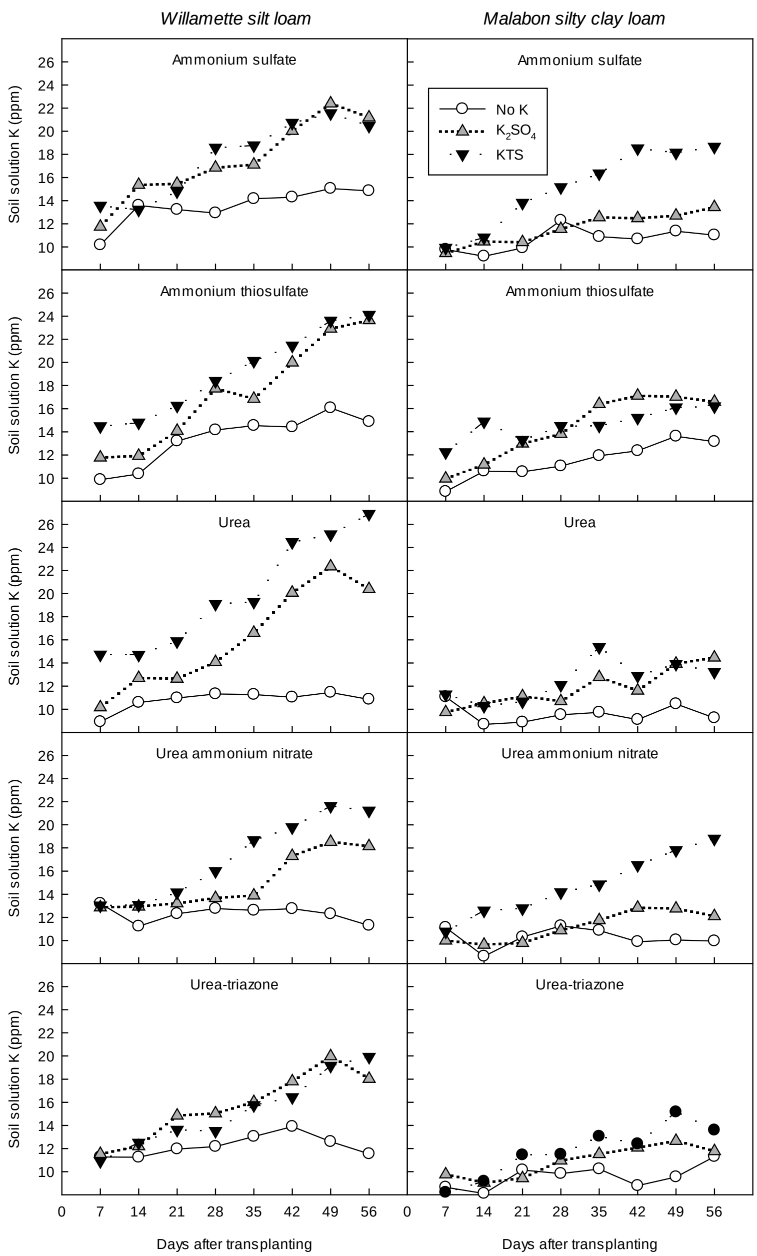

Fig. 2. Effects of different liquid sources of N and K fertilizer on the concentration of K in the soil solution in potted plants of 'Duke' blueberry. Plants were grown in soil considered excellent (Willamette) or marginal (Malabon) for blueberry.