Effects of Salinity Induced by Ammonium Sulfate Fertilizer on Root and Shoot Growth of Highbush Blueberry

R.M.A. Machado[1], D.R. Bryla[2] and O. Vargas[3]
[1] Departamento Fitotecnia - ICAAM, Universidade de Évora, Évora, Portugal
[2] USDA-ARS, Horticultural Crops Research Unit, Corvallis, OR, USA
[3] Department of Horticulture, Oregon State University, Corvallis, OR, USA

Keywords: *Vaccinium corymbosum*, biomass allocation, electrical conductivity, nitrogen, plant dry matter, salt stress

Abstract

Ammonium sulfate fertilizer is commonly used in highbush blueberry (*Vaccinium corymbosum* L.) but often causes salt damage, particularly in young plants, when high rates are applied. Three experiments were done to determine the sensitivity of 'Bluecrop' blueberry to ammonium sulfate and identify the salinity threshold at which plant growth was affected. In the first experiment, plants were grown in pots and fertigated two to three times per week with 0, 0.25, 0.75, and 1.5 g·L^{-1} ammonium sulfate solution. Electrical conductivity of the solutions (EC_w) increased linearly with fertilizer rate and averaged 0.1, 0.5, 1.5, and 3.0 dS·m^{-1}, respectively. Plants fertigated with 1.5 g·L^{-1} ammonium sulfate produced less leaves and roots and had a lower leaf to stem dry weight ratio than those fertilized with 0 or 0.25 g·L^{-1}, which indicates that root and leaf growth in blueberry was sensitive to EC_w > 1.5 dS·m^{-1}. In the second experiment, plants in pots were fertilized with ammonium sulfate or urea at a frequency of three times per week, weekly, or every 28 days, using the same total amount of nitrogen (N) in each treatment over a 4-week period. In this case, plant growth was higher with ammonium sulfate than with urea but also higher, regardless of fertilizer source, when plants were fertilized more frequently. In the third experiment, plants were grown in the field with no N fertilizer or with ammonium sulfate or urea applied by weekly fertigations or by a triple-split application of granular fertilizer at a total rate of 133 kg·ha^{-1} N during the third year after planting. Yield in the plants was greater with fertigation or with granular urea than with granular ammonium sulfate, the latter of which resulted in EC_w levels in the soil solution as high as 13 dS·m^{-1}. In the field, fertilizer programs and practices such as fertigation that maintain EC_w < 2 dS·m^{-1} are recommended for highbush blueberry.

INTRODUCTION

Ammonium sulfate is commonly used to fertilize highbush blueberry (Williamson et al., 2006). This fertilizer is usually preferred because the plants favor ammonium-N (NH_4-N) over nitrate-N (NO_3-N), and application of the fertilizer helps maintain soil pH in the proper range (4.0 to 5.2) for blueberry (Harmer, 1944). The fertilizer, however, has a high salt index (3.25) among N sources (Bunt, 1988) and can potentially lead to salt damage when high rates are applied (Caruso and Ramsdell, 1995). In general, electrical conductivity in irrigation water or soil solution (EC_w) increases linearly as more ammonium sulfate is added while pH decreases exponentially (Fig. 1). Urea is also used in blueberry and, because it increases pH, is recommended when soil pH is < 5.0 (Hart et al., 2006).

The objective of the present study was to determine the effects of ammonium sulfate and urea fertilizer on shoot and root growth and yield of highbush blueberry and identify the salinity thresholds for growth and production. We hypothesized that frequent fertilizer applications with low concentrations of fertilizer would result in less salinity than less frequent applications with high concentrations and therefore would increase plant growth and production in blueberry.

MATERIALS AND METHODS

Three experiments were conducted on 'Bluecrop' blueberry (*Vaccinium corymbosum* L.), including two on 1-year-old plants in the greenhouse and one on established plants in the field.

In the first greenhouse experiment, plants were transplanted to 8-L pots filled with a 1:1 (v/v) mixture of peat and douglas fir (*Pseudotsuga menziesii* Franco) pine bark. To monitor new root growth, the root ball was wrapped in 1-mm wire mesh screen prior to transplanting. The plants were fertilized weekly with one of four different concentrations of ammonium sulfate solution supplemented with macro- and micronutrients (Table 1). Treatments were arranged in a completely randomized design with nine replicates per treatment. Each solution was applied two to three times per week as needed for a total of 8 weeks. Shoots were then cut at the soil surface, separated into leaf and stem components, oven-dried at 70°C, and weighed. New roots were washed from the potting mix and likewise dried and weighed.

In the second greenhouse experiment, plants were transplanted to 4-L pots filled with the same peat and pine bark mix as in Experiment 1 and fertigated with ammonium sulfate or urea mixed in modified Johnson's nutrient solution (Kosola et al., 2007). The fertilizers were applied three times per week, weekly, or every 28 days. The concentration of the fertilizers was adjusted so that each treatment received the same amount of total N (and other essential nutrients) within a 28-day period (Table 2). Treatments were arranged in a randomized complete block design with five replicates per treatment. Soil solution was collected weekly in each pot using 10-cm long hydrophilic porous polymer soil moisture samplers (Eijkelkamp Agrisearch Equipment, Giesbeek, The Netherlands) and analyzed for pH, electrical conductivity (EC_w), and NH_4- and NO_3-N (Ore. St. Univ. Central Analytical Laboratory, Corvallis, OR, USA). The samplers were installed vertically midway between the plant and the edge of the pot. Plants were harvested at 30 days after the treatments were initiated. Shoots, stems, crown, and roots were oven-dried and weighed and analyzed for N using a combustion analyzer (LECO Corp., St. Joseph, MI, USA).

The field experiment was conducted in 2008 during the third year after planting at the Oregon State University Lewis-Brown Horticultural Research Farm in Corvallis, OR, USA (see Bryla and Machado (2011) for details). Treatments included plants grown with no N fertilizer and those fertilized with ammonium sulfate or urea at a rate of 133 $kg \cdot ha^{-1}$ N. The fertilizers were either applied 1) weekly (15 April-15 August) by fertigation to plants irrigated by a single lateral of drip tubing located near the base of the plants or 2) in three equal applications (15 Apr., 15 May and 15 June) of granular fertilizer banded on each side of the row to plants irrigated by microsprinklers. The drip tubing had 1.9 L h^{-1} inline pressure-compensating emitters spaced every 0.3 m. Two soil moisture samplers were installed vertically near a drip emitter in the fertigated plots and in the fertilizer band in the granular-fertilized plots. Soil solution was collected weekly from 17 April-27 June and monthly from 15 July-15 October and analyzed for pH, EC_w, and NH_4- and NO_3-N. Fruit were harvested on 17, 23, and 30 July 2008, sorted to remove any unmarketable (unripe or damaged) fruit, and weighed.

Data were analyzed by analysis of variance and means were separated at 0.05 level using Duncan's New Multiple Range Test.

RESULTS AND DISCUSSION

Experiment 1

Leaf and new root dry weight were significantly affected by fertilizer rate ($P \leq 0.05$) and were lower when 1.5 $g \cdot L^{-1}$ of ammonium sulfate was applied than when 0 (leaf) or 0.25 (roots) $g \cdot L^{-1}$ was applied (Fig. 2). Plants fertilized with 0.75 and 1.5 $g \cdot L^{-1}$ also had lower leaf:stem ratios and allocated relative less biomass to new roots than plants given 0.25 $g \cdot L^{-1}$ (data not shown). Reductions in leaf:stem ratios were due to less leaf growth and to leaf senescence. Older leaves tended to become necrotic and drop from plants fertilized with 0.75 and 1.5 $g{\cdot}L^{-1}$ ammonium sulfate (EC_w=1.5-3.0 $dS{\cdot}m^{-1}$; Table 1), which is a common symptom of salt stress in blueberry (Caruso and Ramsdell, 1995). Bryla and Machado (2011) and Bañados et al. (2012) observed similar symptoms of salt stress in 'Bluecrop' blueberry when plants were fertilized with ammonium sulfate at rates of 100-200 $kg{\cdot}ha^{-1}$ N during the first year after planting in the field.

Experiment 2

Leaf and root dry weights were significantly affected by fertilizer source ($P{\leq}0.01$ and 0.05, respectively), while dry weights of all plant parts were significantly affected by fertilizer frequency ($P{\leq}0.01$). There were no significant interactions, however, between fertilizer source and frequency on plant dry weight. On average, plants fertilized with ammonium sulfate produced greater leaf and root dry weights than those fertilized with urea and produced greater dry weight in all plant parts when fertilized 3 days per week or weekly than when fertilized every 28 days (Fig. 3). Ammonium sulfate also resulted in higher total plant N uptake than urea as well as significantly higher tissue N concentrations ($P{\leq}0.05$) in both the roots (1.92 vs. 1.70%) and crown (1.21 vs. 1.07%), whereas frequency had no effect on N uptake and resulted in higher N concentrations in each plant part when plants were fertilized every 28 days than when fertilized three times per week or weekly (data not shown). Thus, while plants fertilized with urea may have been N limited, this was not the case with fertilizer frequency. In fact, N in the soil solution at 22 days after transplanting was much higher when plants were fertilized every 28 days (Table 3). Electrical conductivity was likewise higher in the treatment, and although leaf necrosis was not observed in any treatment in Experiment 2, it exceeded the level of 3.0 $dS{\cdot}m^{-1}$ that resulted in a reduction plant growth in Experiment 1 (Table 3). The results indicate that more frequent fertigation may be beneficial regardless of N source in blueberry and reduces the potential risk of salinity stress often associated with high fertilizer concentrations.

Experiment 3

Ammonium sulfate resulted in higher EC_w than urea under field conditions, particularly when granular fertilizer was applied (Table 4). With granular ammonium sulfate, EC_w reached levels as high as 13 $dS{\cdot}m^{-1}$ following the first split application, 10 $dS{\cdot}m^{-1}$ following the second application, and 8 $dS{\cdot}m^{-1}$ following the third application, which is 5-fold higher, on average, than the level considered safe for blueberry (Patten et al.,1989; Muralitharan et al., 1992). In comparison, EC_w remained <2 $dS{\cdot}m^{-1}$ during weekly fertigations with either N fertilizer source and never exceeded 4 $dS{\cdot}m^{-1}$ with granular urea. As a result, plant growth (Bryla and Machado, 2011) and yield (Table 4) was significantly greater in plants fertigated with ammonium sulfate or urea or with granular urea than in those given granular ammonium sulfate. Interestingly, fertigation with ammonium sulfate also resulted in higher leaf N concentrations than fertigation with urea (Table 4), which was a similar to the higher N level observed in the crown and roots when plants were fertilized with ammonium sulfate than with urea in Experiment 2. The results indicate that fertigation and/or use of urea reduces the potential risk of salinity stress and may result in more growth and yield than granular ammonium sulfate. The results also indicate that granular fertilizer resulted in higher levels of NO_3-N in soil solution (Table 4). Since blueberry prefers NH_4-N over NO_3-N and NO_3-N is very mobile in soil, more NO_3-N was likely leached over the winter in plots fertilized with granular fertilizer than in those in which the fertilizer was applied by fertigation.

ACKNOWLEDGEMENTS

We thank Amber Shireman and Rick Moes for technical assistance and the Oregon Blueberry Commission for financial support.

Literature Cited

Bañados, M.P., Strik, B.C., Bryla, D.R. and Righetti, T.L. 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 Machado, R.M.A. 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.
Bunt, A.C. 1988. Media and Mixes for Container Grown Plants. Unwin Hyman, Ltd., London, UK.
Caruso, F.L. and Ramsdell, D.C. 1995. Compendium of Blueberry and Cranberry Diseases. APS Press, St. Paul, Minn.
Harmer, P.M. 1944. Soil reaction and growth of blueberry. Soil Sci. 9:133-144.
Hart, J., Strik, B., White, L. and Yang, W. 2006. Nutrient management for blueberries in Oregon. Ore. State Univ. Ext. Serv. Pub. EM 8918.
Kosola, K.R., Workmaster, B.A.A. and Spada, P.A. 2007. Inoculation of cranberry (*Vaccinium macrocarpon*) with the ericoid mycorrhizal fungus *Rhizoscyphus ericae* increase nitrate influx. New Phytol. 176:184-196.
Muralitharan, M.S., Chandler, S.F. and Van-Steveninck, R.F.M. 1992. Effects of sodium chloride and sodium sulfate on growth and solute composition of highbush blueberry (*Vaccinium corymbosum*). Aust. J. Plant Physiol. 19:155-164.
Patten, K., Neuendorff, E., Nimr, G., Haby, V. and Wright, G. 1989. Cultural practices to reduce salinity/sodium damage of rabbiteye blueberry plants (*Vaccinium ashei* Reade). Acta Hort. 241:207-212.
Williamson, J., Krewer, G., Pavlis, G. and Mainlan, C.M. 2006. Blueberry soil management, nutrition, and irrigation. In: N.F. Childers and P.M. Lyrene (eds.), Blueberries. For Growers, Gardeners, Promoters, Dr. Norman F. Childers Horticultural Publications, Gainesville, Fla., USA.

Tables

Table 1. Ammonium and sulfate ions, pH, and electrical conductivity of four different rates of ammonium sulfate fertilizer applied to ‘Bluecrop’ blueberry (Expt. 1).

Ammonium sulfate ($g \cdot L^{-1}$)	Ion concentration (meq/L)		pH	Electrical conductivity ($dS \cdot m^{-1}$)
	NH_4^+	SO_4^{2-}		
0	0	0	7.28[1]	0.1[1]
0.25	2.2	1.1	7.25	0.5
0.75	8.4	4.2	7.16	1.5
1.5	17.9	9.0	7.08	3.0

[1] Electrical conductivity and pH of the base modified Johnson’s nutrient solution (Kasola et al., 2007).

Table 2. Ammonium sulfate and urea fertilizers applied at three different frequencies to ‘Bluecrop’ blueberry (Expt. 2).

Application frequency	N per application ($g \cdot L^{-1}$)	Ammonium sulfate[1] ($g \cdot L^{-1}$)	Urea[2] ($ml \cdot L^{-1}$)
Three times per week[3]	0.1	0.47	0.44
Weekly	0.3	1.41	1.32
Every 28 days	1.2	5.66	5.29

[1] Granular (21-0-0).
[2] Liquid (20-0-0).
[3] Fertilizer was applied on Mondays, Wednesdays, and Fridays.

Table 3. Ammonium-N (NH_4-N), nitrate-N (NO_3-N), pH, and electrical conductivity (EC_w) of soil solution collected in pots grown with 'Bluecrop' blueberry plants fertilized with ammonium sulfate or urea at a frequency of three times per week (Monday, Wednesday, and Friday), weekly, or every 28 days (Expt. 2).[1]

	NH_4-N (mg L^{-1})	NO_3-N (mg L^{-1})	pH	EC_w (dS m^{-1})
Ammonium sulfate				
Three times per week	4.8	5.7	4.9	1.7
Weekly	16	26	4.9	2.5
Every 28 days	52	91	4.3	3.9
Urea				
Three times per week	0.6	5.2	5.9	1.3
Weekly	12	47	6.6	1.2
Every 28 days	45	390	4.7	3.9

[1] Soil solution was collected at 22 days after the fertilizer treatments were initiated.

Table 4. Ammonium-N (NH_4-N), nitrate-N (NO_3-N), pH, and electrical conductivity (EC_w) of soil solution averaged over the growing season and leaf nitrogen (N) and yield of 'Bluecrop' blueberry grown in the field with either no fertilizer or with ammonium sulfate or urea. The fertilizers were applied weekly by fertigation through a drip system or banded in a triple-split application of granular fertilizer on the soil surface and watered in with microsprinklers (Expt. 3).

Fertilizer treatment	Soil solution[2]				Leaf N[1] (%)	Yield (kg/plant)
	NH_4-N ($mg \cdot L^{-1}$)	NO_3-N ($mg \cdot L^{-1}$)	pH	EC_w ($dS \cdot m^{-1}$)		
Fertigation						
No fertilizer	0.1 e[2]	4.9 d	7.3 a	0.2 e	1.34 c	0.52 b
Ammonium sulfate	5.9 c	120 b	6.2 c	1.1 c	1.81 a	0.78 a
Urea	1.2 d	64 c	6.1 c	0.7 d	1.64 b	0.77 a
Granular fertilizer						
No fertilizer	0.1 e	3.1 d	6.8 b	0.3 e	1.42 c	0.63 ab
Ammonium sulfate	370 a	140 b	4.3 d	5.8 a	1.66 b	0.52 b
Urea	30 b	220 a	6.8 b	2.1 b	1.65 b	0.74 a

[1] Leaves were sampled 18 August 2008.
[2] Different letters within a column indicate a significant difference among the means at the 0.05 level.

Figures

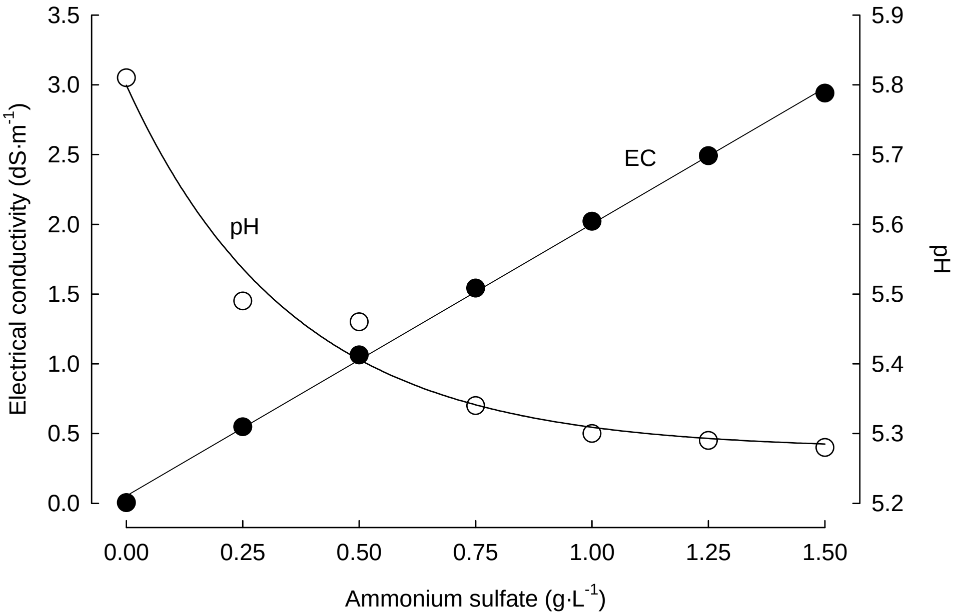

Fig. 1. Effects of ammonium sulfate $[(NH_4)_2SO_4]$ concentration on electrical conductivity (●) and pH (○) in distilled water. Electrical conductivity = 1.988*$[(NH_4)_2SO_4]$ + 0.002 (r^2=0.999; P<0.0001); pH = 5.277 + 0.522*$e^{[-2.798*(NH4)2SO4]}$ (r^2=0.975; P=0.0006).

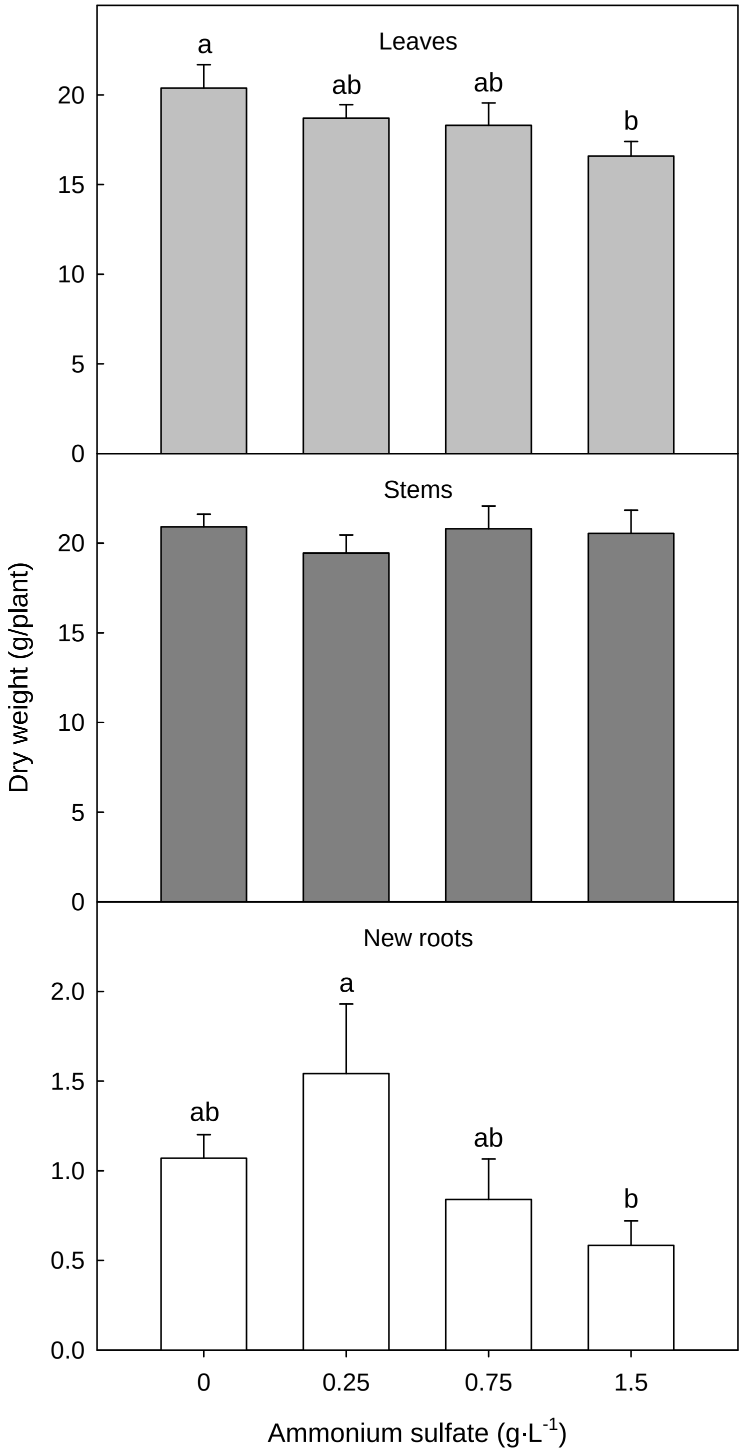

Fig. 2. Effects of four different rates of ammonium sulfate fertilizer on leaf, stem, and new root dry weight in 'Bluecrop' blueberry (Expt. 1). Vertical bars represent 1 SE and n=9. Different letters above the bars indicate a significant difference among the means at the 5% level.

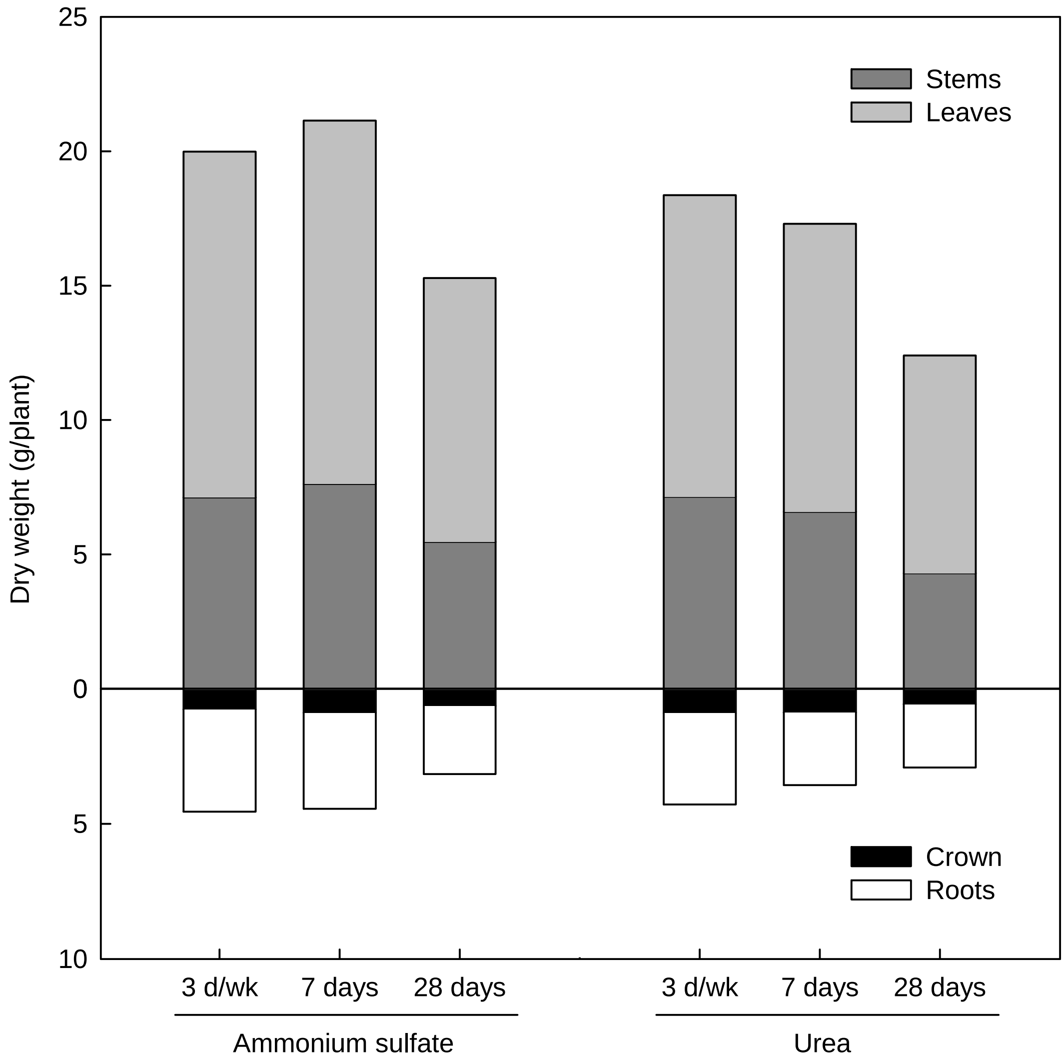

Fig. 3. Effects of fertilizer source and frequency on leaf, stem, crown, and root dry weight in 'Bluecrop' blueberry (Expt. 2). Each bar represents the mean of five replicates.