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Blueberry yield and soil properties response to long-term fertigation and broadcast nitrogen

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ABSTRACT

The long-term effects of annual applications of nitrogen (N) at varying rates through the broadcast (BROAD) and fertigation (FERT) methods on soil properties and blueberry yield were assessed in British Columbia, Canada. Seven N treatments, including a control (CONT, 0%), were arranged in a randomized complete block design with six replicates. From 2008 to 2012, the N treatments were 50% (BROAD-50 and FERT-50), 100% (BROAD-100 and FERT-100), and 150% (BROAD-150 and FERT-150) of the recommended rate. From 2013 to 2015, as the planting matured, a supplementary 50% was added incrementally to all N rates. The BROAD and FERT methods consisted of 3 and 10 equal-split applications respectively. The FERT rates above 100% increased the NO_3-N concentration in the 0–30 cm soil layer by 2.6 times for FERT-150 and by 3.6 times for FERT-200. However, the BROAD-based N above 100% increased the NH_4-N concentration in the sawdust layer by 1.9 times. The supply of ammonium sulfate via fertigation reduced soil pH and increased soil EC as compared with BROAD; the lowest soil pH (4.2) was observed under FERT-200 in the 0–30 cm layer, while the highest EC (1516 $\mu S\ cm^{-1}$) was found under FERT-150. The maximum berry yield for establishing plants (2010–2012) was 14,908 $kg\ ha^{-1}$ obtained with FERT-150. At plant maturity (2015), the maximum berry yield was 32,444 $kg\ ha^{-1}$ obtained with FERT-100 (57% higher than with CONT). However, berry yield only increased by 32% with FERT-150 and by 11% with FERT-200 as compared with CONT, indicating a negative effect associated with repeated applications of high FERT-based N rates. Correlations between berry productivity and EC showed substantial yield decreases at EC values greater than 760 $\mu S\ cm^{-1}$ in the 0–30 cm layer and greater than 291 $\mu S\ cm^{-1}$ in the 30–60 cm layer, which corresponded to FERT-based N rates above 100%. From these results, we can conclude that fertigating mature plants with ammonium sulfate above the recommended rate is not a sustainable practice for blueberry production, as it reduces yields, increases soil EC above critical levels, and raises the risk of NO_3-N leaching to the aquifer.

1. Introduction

Canada, with more than 72,600 Mg of highbush blueberries harvested in 2016, is the third-largest blueberry producer in the world after the United States and Chile (Brazelton and Young, 2017). British Columbia (BC) produces 40% of Canada's total blueberry harvest, including 95% of its highbush blueberries (Agriculture and Agri-Food Canada, 2015). Highbush blueberry production in BC is expected to increase steadily in the coming years, driven by new exports and a growing consumer trend towards considering and valuing blueberries for their health-promoting benefits (British Columbia Blueberry Council, 2016). To achieve this projected increase while maintaining high fruit quality and minimizing environmental impact, BC blueberry growers need to continually reassess and refine their cultural management practices.

Nitrogen is the key nutrient for blueberry production, but unlike the majority of plants, blueberries prefer ammonium N (NH_4-N) over nitrate N (NO_3-N) (Poonnachit and Darnell, 2004). Studies have shown that blueberry N needs vary with plant growth and development stages; young plants take up increasing amounts of N as the growing season progresses (Bañados et al., 2012), whereas mature plants take up N most efficiently during active growth occurring between bloom and fruit maturity (Retamales and Hanson, 1989). To synchronize N supply with blueberry N needs, growers generally implement split applications of NH_4-N fertilizers during the growing season (Ehret et al., 2014; Bryla et al., 2012).

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In BC and other highbush blueberry–producing regions, granular NH_4-N fertilizers are broadcast (BROAD) at the surface of the layer of sawdust mulch overlying the raised beds where the plants grow. Mulching is a common practice used to reduce the evaporation of soil moisture, improve weed control, and protect the roots against temperature extremes (Julian et al., 2012; Retamales and Hancock, 2012). Studies have also shown that mulch promotes plant growth and has a positive effect on berry yield (Forge et al., 2013; Albert et al., 2010). One major constraint of mulch, however, is its interaction with applied fertilizer N. Sawdust mulch in particular, with its high C:N ratio, can trigger N immobilization, thereby increasing the N requirement of blueberries (Retamales and Hancock, 2012). Mismanagement of granular N fertilizers can result in the death of blueberry plants. Bryla and Machado (2011) showed that 44% to 50% of young blueberry plants died when granular fertilizer was applied at a rate of 150 kg N ha^{-1}. Mulch is relatively permeable to water flow and increases the requirement for rain or irrigation water to solubilize and move N from a surface-applied granular source into the soil below, where most of the roots develop (Holzapfel et al., 2015).

Blueberry plants are shallow-rooted, and fruit production can be reduced by even moderate levels of water stress (Bryla and Strik, 2007; Holzapfel et al., 2004; Mingeau et al., 2001). Irrigation is therefore used in most highbush blueberry fields around the world, including BC (Ehret et al., 2015; Strik and Yarborough, 2005). Recently, drip irrigation has emerged as the preferred method for irrigating blueberry plants. Studies have shown that young plants grown under drip irrigation systems produce more fruit with less water during the establishment years (Ehret et al., 2012; Bryla et al., 2009), while no benefit from high rates of drip irrigation has been reported for growth, yield or fruit quality in older plants (Ehret et al., 2015). By synchronizing blueberry needs for nutrients, particularly N, with the water supply during bloom and maturity, drip irrigation offers an opportunity for fertigation (FERT) (Kafkafi and Tarchitzky, 2011).

A recent work examined the effects of N applications through FERT on newly established blueberry plants in BC. The results showed that N management using FERT should be adjusted as a planting matures (Ehret et al., 2015). Specifically, the growth and yield response to N was higher with FERT than with BROAD application, although soil NO_3-N was higher under FERT than with granular fertilizers, which may have reduced plant NH_4-N availability. However, it is not clearly understood whether repeated annual applications of N through FERT will affect blueberry yields and N-use efficiency (NUE) in mature plants, nor how key soil properties, including soil pH and electrical conductivity (EC), will be affected in the long term. Ammonium sulfate is one of the main granular N fertilizers used in blueberry production in BC. Ammonium sulfate is highly suitable because it breaks down quickly to NH_4-N and helps acidify the soil, two key requirements for blueberry plants. However, this granular fertilizer N is also a source of sulfate that can lead to salt accumulation, which is harmful for blueberry plants. The objective of this study was to assess the effects of annual applications of N at varying rates through the BROAD and FERT methods on soil mineral N (NH_4-N and NO_3-N), soil pH, soil EC and berry yield in a blueberry field in BC, Canada.

2. Materials and methods

2.1. Site description

The long-term experiment was established in 2008 at Agriculture and Agri-Food Canada's Agassiz Research and Development Centre (49°14′N, 121°45′W). The soil at this site is a silt loam soil of the Monroe series (Typic Dystroxerepts under the U.S. Soil Taxonomy; Soil Survey Staff, 2010). This soil originated from a recent alluvial deposit and evolved from a coarse-textured parent material, as evidenced by its weak profile development. It is moderately well-drained and shallow on a flat topography with an average elevation of about 7.6 m above sea level. It received compost derived from lawn clippings and waste from poultry and greenhouse vegetables until 2006. The average chemical characteristics of the topsoil at the beginning of the experiment were as follows: organic matter 5.27% and soil mineral N 29 kg ha^{-1} (Ehret et al., 2014). The average daily temperature ranges from 3.2 °C in December to 18.7 °C in August. The local climate is moderate oceanic, characterized by warm, rainy winters and relatively cool, dry summers with annual rainfall of 1689 mm, 261.9 mm of which falls between May and July.

In spring 2008, the field was ploughed, disked, and amended with elemental sulfur (0-0-0-90S; Terra Link Horticulture Inc., Abbotsford, BC) at a rate of 1120 kg ha^{-1} to adjust the soil pH to 5.0. In September 2008, the field was subsoiled, and raised beds (1 m wide × 0.2 m high) spaced 3.048 m apart were created in a north-south direction using a bed shaper. Two-year-old highbush blueberry plants cv. Duke, purchased from a local commercial nursery (JRT Nurseries, Abbotsford, BC), were planted with an intra-row spacing of 0.914 m (for a plant density of 3590 plants ha^{-1}). This variety is an early-season, late-blooming, high-yield, winter-hardy cultivar with an upright growth of 1.22–1.83 m. Its attractive fruit is medium to large, light blue, and slightly tart. The berries are very firm and retain their quality better than most other varieties. Immediately after planting, the beds were mulched with an 8-cm thick layer of new Western hemlock and Douglas fir sawdust. The mulch material was replenished in the spring every second year (i.e. 2010, 2012 and 2014). All areas between and around the beds were seeded with a mix of 30% fescue and 70% perennial rye grass (Alleyway Agricultural Mix, Richardson Seed, Abbotsford, BC).

2.2. Experimental design and treatments

Three increasing N rates applied either as BROAD or FERT, for a total of seven treatments including a control (CONT, 0 kg N ha^{-1}), were arranged in a randomized complete block design. The N rates were designed to represent a percentage (50%, 150% and 200%) of the annual recommendation (100%) for blueberry based on the BC blueberry production guide (Table 1). The experimental treatments were replicated in six blocks, with individual plots consisting of five measurement plants with a guard plant on each end. From 2008–2012, the three N rates were 50% of the recommended rate (BROAD-50 and FERT-50), 100% of the recommended rate (BROAD-100 and FERT-100), and 150% of the recommended rate (BROAD-150 and FERT-150). Beginning in 2013, as the planting matured, a supplementary amount of

Table 1
Annual nitrogen rates (kg ha^{-1}) applied as a percentage of the amount recommended in the British Columbia blueberry production guide to highbush blueberry (*Vaccinium corymbosum*) during two production periods (2010–2012 and 2013–2015).

Nitrogen rates First period	2010 3rd year	2011 4th year	2012 5th year	Second period	2013 6th year	2014 7th year	2015 8th year
		kg ha^{-1}				kg ha^{-1}	
0%	0	0	0	0	0	0	0
50%	11	25	39	100%	100	111	144
100%	22	50	79	150%	151	167	215
150%	32	75	118	200%	201	222	287