Seasonal Variation in Mineral Nutrient Concentration of Primocane and Floricane Leaves in Trailing, Erect, and Semierect Blackberry Cultivars

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Abstract. Floricane-fruiting blackberry (Rubus L. subgenus Rubus, Watson) cultivars, ‘Marion’, ‘Black Diamond’, ‘Onyx’, ‘Columbia Star’ (early-season trailing types), ‘Ouachita’ (erect, midseason), and ‘Triple Crown’ and ‘Chester Thornless’ (semierect, late season) were studied for 2 years to determine whether these cultivars and types of blackberry should be sampled at a certain stage of development or time of season to best evaluate plant nutrient status. Leaf nutrient standards are based on primocane leaves in most countries, but there is interest in using floricane leaves. Primocane leaves were sampled every 2 weeks from late May through early October, whereas leaves on fruiting laterals (floricane) were sampled every 2 weeks from early May through fruit harvest. Leaves were analyzed to determine the concentration of macronutrients and micronutrients. The pattern of change in primocane leaf nutrient concentration varied between the trailing and the later-fruiting erect and semierect types, particularly for P, K, Ca, Mg, B, and Mn, where leaf levels were higher in the late season for the erect and semierect cultivars (except for P and K which were lower). Nutrient concentrations in floricane leaves decreased during growth and development of the lateral and fruiting season for N, P, K, and S, but increased for most other nutrients in all blackberry types. Floricane leaf N and K declined most rapidly during the fruit development period in all cultivars. Sampling of floricane leaves is not recommended, particularly for trailing types, as there are no sufficiency standards. In primocane leaves, the nutrients that did not show significant changes in concentration during the currently recommended sampling period of late July to early August were N, Mg, K, Ca, S, B, Mn, and Zn, but only in 2014. Leaf P, Fe, and Al were stable during this period in both years. In contrast, when sampling in mid to late August, leaf N, Mg, Fe, Mn, and Al were stable in both years and leaf K, Ca, S, B, Cu, and Zn were stable in one of the 2 years. We thus propose changing the recommended sampling time to mid to late August for these diverse blackberry cultivars. The current sufficiency standards for primocanes did not encompass the blackberry types and cultivars studied here, suggesting the standards may need to be revised for this region.

About 6000 ha of blackberry (Rubus L. subgenus Rubus, Watson) were harvested in the United States in 2012, with 42% of this production located in Oregon (U.S. Department of Agriculture, 2014). Oregon is the leading producer of trailing blackberry in the United States but also produces erect and semierect blackberry. Atlantic blackberry differed considerably (Strik and Finn, 2012). In Oregon, the fruiting season of trailing cultivars ranges from late June through July with erect and semierect types fruiting from late July through August and early August through early October, respectively. All of these blackberry types produce biennial canes. The primocanes of these floricanes-fruiting cultivars are vegetative in their first year of growth. In their second year, when they are called floricanes, they flower, fruit, and then senesce. In trailing types, primocanes are not self-supporting and are trained along the ground under the floricanes canopy until trained to the trellis after fruit harvest and florican pruning. By contrast, the primocanes of erect and semierect types are self-supporting and are summer pruned (tipped) to encourage branching. Summer pruning of primocanes affects leaf nutrient levels in primocane-fruiting blackberry (Strik, 2015).

Commercial blackberry growers are encouraged to develop fertilization programs based on general guidelines for nitrogen (N) fertilizer, in which rates increase from the planting year to maturity (Hart et al., 2006). Adjustments of fertilizer N and other macronutrients and micronutrients are based on the periodic soil nutrient analysis, observations of plant growth, and annual leaf tissue analysis (Bolda et al., 2012; Bushway et al., 2008; Fernandez and Ballington, 1999; Hart et al., 2006; Krewer et al., 1999). In floricanes-fruiting blackberry and raspberry, leaf sampling of primocanes in mid to late-season informs growers of plant nutrient requirements for fruit production the following season, when the primocane becomes a florican.

Leaf sampling for tissue nutrient analysis is recommended for primocanes from May to August (Bolda et al., 2012), “following harvest” (Fernandez and Ballington, 1999), the first week of August (Bushway et al., 2008), or late July to early August (Hart et al., 2006). The recommended nutrient sufficiency levels are similar among these currently available nutrient management guides and all have the same standards and sampling time recommendations regardless of the blackberry type. Strik (2015) recommended that primocane-fruiting blackberry be sampled at the early green-fruit stage (about 8 weeks after summer pruning) than a particular calendar date and suggested the leaf sufficiency range for phosphorus (P) and potassium (K) may need to be lowered for this crop.

Primocane leaf nutrient levels have been shown to vary over the growing season in erect (Clark et al., 1988) and trailing (Mohadjer et al., 2001) floricanes-fruiting blackberry, primocane-fruiting blackberry (Strik, 2015), and floricanes-fruiting raspberry (Hughes et al., 1979; John and Daubeny, 1972; John et al., 1976; Kowalenko, 1994; Wright and Waister, 1980). Although florican leaves in blackberry have been shown to change over the fruiting season, standards for this leaf tissue type have only been developed in Brazil (Pereira et al., 2015).

Cultivars of blackberry (Fernandez-Salvador et al., 2015a, 2015b, 2015c; Dixon et al., 2016; Harkins et al., 2014; Strik, 2015) and raspberry (John and Daubeny, 1972; John et al., 1976) differed in primocane leaf nutrient levels when sampled in midseason. By contrast, Clark et al. (1988) found no difference among three erect blackberry cultivars in leaf nutrient levels and speculated that this was because of their similar parentage.

The objective of this study was to evaluate the impact of sample date on primocane leaf nutrient concentration in trailing, erect, and semierect blackberry cultivars with a goal of establishing the ideal sampling time for these crops. In addition, we studied the impact of sampling time during fruiting lateral development and fruiting on the nutrient concentration in the floricanes to assess whether this might offer an alternative sampling method in these types of blackberry.
Materials and Methods

Study site. The study was conducted in 2013 and 2014, in a mature planting at Oregon State University’s North Willamette Research and Extension Center, Aurora, OR [lat. 45°16′47″N, long. 122°45′23″W; USDA hardiness zone 8b (U.S. Department of Agricultural Research Service, 2014)]; the weather records for this site can be viewed at U.S. Department of Interior (2014)]. The soil is mapped as a Willamette silt loam, classified as a fine-silty, mixed, superactive, mesic, Pachic, Ultic, and Argixeroll.

Plants were established in Spring 2010 except for ‘Triple Crown’ (planted Oct. 2010) and ‘Columbia Star’ (planted Sept. 2011) at 1.5 m in the row with 3 m between rows (2222 plants/ha). A permanent grass cover crop grew between the rows. The row area was maintained (bare soil) with preemergent herbicides and hoeing, as needed. Plants were irrigated with a single line of drip tubing (UniRam; Netafim USA, Fresno, CA) containing pressure-compensating emitters (1.9 L h⁻¹ in-line) spaced every 0.6 m.

Soil testing. Soil samples were collected on 12 Nov. 2013 and 21 Oct. 2014 using a 2.4-cm diameter, 0.5-m long, slotted, open-side, chrome-plated steel soil probe (Soil Sampler Model Hoffer; JBK Manufacturing, Dayton, OH). Soil was sampled to a depth of 0.3 m at the center of the row, 0.3 m from the crown between plants and within the water emitter drip zone or fertilization area. A pooled sample was collected for the site (not replicated) and was sent for analysis of macronutrient and micronutrient concentration and pH to Brookeside Laboratories Inc. (New Bremen, OH) (Table 1).

Cultivars. Four trailing blackberry cultivars (‘Black Diamond’, ‘Columbia Star’, ‘Marion’, and ‘Onyx’), one erect type (‘Ouachita’), and two semierect types (‘Chester Thornless’ and ‘Triple Crown’) were studied.

Production system. The trailing cultivars were grown in an alternate year production system (Strik and Finn, 2012), but only plants in the fruiting or “on year” were sampled in 2013 and 2014. Plants were trained on a two-wire vertical trellis system in each row with the wires attached to steel posts at 1.0 and 1.6 m above the ground. New primocanes were trained along the ground in the row, under the floricane (not replicated) and was sent for analysis of macronutrient and micronutrient concentration and pH to Brookeside Laboratories Inc. (New Bremen, OH).

Table 1. Soil nutrient pH, organic matter content, and nutrient levels when sampled in Nov. 2013 and Oct. 2014 at Oregon State University’s North Willamette Research and Extension Center, Aurora, OR (unreplicated).

| Yr  | pH   | Organic matter (%) | NH₄ N  | NO₃ N  | P⁰ | K  | Ca | Mg | S  | B  | Fe | Mn | Cu | Zn | Al |
|-----|------|--------------------|--------|--------|-----|----|----|----|----|----|----|----|----|----|----|----|
| 2013| 5.5  | 2.9                | 8.5    | 1.5    | 395 | 333| 934| 240| 19 | 0.48| 354| 34 | 9.4| 3.8| 1375|
| 2014| 5.8  | 3.1                | 5.5    | 4.2    | 278 | 312| 1159| 284| 22 | 0.43| 365| 35 | 8.8| 3.9| 1296|

*P tested using Bray I method (Brookeside Laboratories Inc., New Bremen, OH).

Data analysis. The treatments were arranged in a completely random design with three replicates of three-plant plots. Data were analyzed by tissue type (primocane or floricanes) separately, as our goal was not to compare canes, but to determine changes in leaf nutrient concentration over the sampling period and assess optimal sampling times. In addition, there is evidence that floricanes and primocanes are independent in blackberry (Bryla and Strik, 2008). On each sample date, leaf nutrient data were first analyzed for the effect of year and cultivar using PROC MIXED (SAS version 9.3) with year as the main effect (n = 2) and plot as the subplot effect (n = 4) with a Satterthwaite approximation used, as needed, for main effect comparisons.

Three sample dates (from late July to late August) that bracketed the recommended tissue nutrient sampling time for blackberry in our region (Hart et al., 2006), were analyzed to determine the effect of year, cultivar, and sample date. Mean comparisons were performed using least-square means. Contrasts were used to determine differences between early- and late-fruiting types (trailing vs. erect and semierect) as well as differences between erect and semierect types during this period.

PROC UNIVARIATE and the Shapiro–Wilk procedure were used to assess normality of the data for all the aforementioned analyses. As the tissue concentration of many nutrients was not normally distributed, a log transformation was used to improve homogeneity of variance and to assess proportional effects. Data were back transformed for presentation.

Results and Discussion

Rate of development and fruiting season. Key phenological stages and fruiting season are presented for the cultivars studied for each tissue sample date (Table 2). There were no observed differences among key phenological stages between years (data not shown). The trailing cultivars Black Diamond, Columbia Star, and Onyx had the earliest fruiting seasons, followed by the erect cultivar Ouachita and then the semierect cultivars Triple Crown and Chester Thornless (Table 2).

Year effect. There was a significant main effect of year on primocane leaf nutrient concentration of the cultivars studied on many sample dates through the season for all nutrients (data not shown). In general, the concentration of N, S, B, Fe, and Al was higher and that of P, Mg, K, Ca, Mn, and Cu was lower on one or more sample dates in 2013 than in 2014.

Table 2. Primocane leaf nutrient concentration when sampled in Nov. 2013 and Oct. 2014 at Oregon State University’s North Willamette Research and Extension Center, Aurora, OR (unreplicated).

<table>
<thead>
<tr>
<th>Yr</th>
<th>Ppm</th>
<th>NH₄ N</th>
<th>NO₃ N</th>
<th>P⁰</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>S</th>
<th>B</th>
<th>Fe</th>
<th>Mn</th>
<th>Cu</th>
<th>Zn</th>
<th>Al</th>
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</thead>
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<td>2013</td>
<td>5.5</td>
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*P tested using Bray I method (Brookeside Laboratories Inc., New Bremen, OH).
Approximate stage of development on each date:

<table>
<thead>
<tr>
<th>Type of Fruiting</th>
<th>Blackberry Type and Cultivar</th>
<th>First bloom to first red</th>
<th>First red to first green</th>
<th>First green to first red</th>
<th>First red to first black</th>
<th>Harvest</th>
<th>End of harvest</th>
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</thead>
<tbody>
<tr>
<td>Floricane-fruiting</td>
<td>Black Diamond</td>
<td>Late red to first red</td>
<td>Late red to first green</td>
<td>Late green to first red</td>
<td>Late red to first black</td>
<td>Harvest</td>
<td>End of harvest</td>
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<td>Floricane-fruiting</td>
<td>Columbia Star</td>
<td>Early green</td>
<td>Early green to early red</td>
<td>Early red to first red</td>
<td>Early red to first black</td>
<td>Late harvest</td>
<td>Late harvest</td>
</tr>
<tr>
<td>Floricane-fruiting</td>
<td>Marion</td>
<td>Early bloom</td>
<td>Early bloom to early green</td>
<td>Early green to early red</td>
<td>Early green to first red</td>
<td>Late to first red</td>
<td>Late to first black</td>
</tr>
<tr>
<td>Floricane-fruiting</td>
<td>Onyx</td>
<td>Early bloom</td>
<td>Early bloom to early green</td>
<td>Early green to early red</td>
<td>Early green to first red</td>
<td>Late to first red</td>
<td>Late to first black</td>
</tr>
<tr>
<td>Semierect</td>
<td>Triple Crown</td>
<td>Early bloom</td>
<td>Early bloom to early green</td>
<td>Early green to early red</td>
<td>Early green to first red</td>
<td>Late to first red</td>
<td>Late to first black</td>
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<td>Semierect</td>
<td>Chester Thornless</td>
<td>Early bloom</td>
<td>Early bloom to early green</td>
<td>Early green to early red</td>
<td>Early green to first red</td>
<td>Late to first red</td>
<td>Late to first black</td>
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</tbody>
</table>

There was an effect of year on primocane leaf nutrient concentration of the cultivars studied on many sample dates for all the nutrients (data not shown). The concentrations of K, B, Fe, Zn, and Al were generally higher, whereas N, P, Mg, Ca, S, and Mn were lower on at least one sample date in 2013 than in 2014.

The pattern of the change in primocane and floricanefruit nutrient concentration within each cultivar was relatively similar through the season between years (data not shown), but there was an effect of year and cultivar, and sometimes an interaction between year and cultivar found for several nutrients and sample dates. We have chosen not to show both years of data for seven cultivars and 11 primocane and 7–11 floricanefruit sample dates. Instead, we are presenting data for the 2014 growing season to show the pattern of change over time. In Table 3, we present year by cultivar interactions for primocanes on select dates that bracket the range in current tissue nutrient sampling recommendations (Hart et al., 2006).

**Primocane leaf nutrient concentration.**

There was a significant effect of cultivar on primocane leaf N concentration in early spring and toward the later part of the growing season (Fig. 1). ‘Black Diamond’, ‘Columbia Star’, ‘Marion’, and ‘Onyx’ had lower leaf N in mid-June than the erect and semierect cultivars, whereas ‘Chester Thornless’ and ‘Triple Crown’ had a higher and lower leaf N, respectively, in the late summer and autumn. Leaf N declined from spring to summer in all the cultivars and was then variable (‘Chester Thornless’) or remained relatively stable (all others).

Leaf P declined through the season in ‘Ouachita’, ‘Triple Crown’, and ‘Chester Thornless’, whereas concentrations increased in late summer in most of the trailing cultivars to levels significantly higher than in the erect and semierect cultivars (Fig. 1). ‘Onyx’ was similar to the other trailing cultivars until mid-August when the P concentration in primocane leaves declined to levels similar to those measured in ‘Chester Thornless’.

Leaf K concentration declined from spring to autumn in ‘Ouachita’ (except for one increase in late July) and ‘Triple Crown’, as was reported for primocane-fruiting blackberry by Strik (2015), but in ‘Chester Thornless’ levels were the lowest in late summer. ‘Columbia Star’, ‘Marion’, and ‘Black Diamond’ had the highest leaf K concentration in late summer to autumn (Fig. 1), perhaps because the fruiting season was over in these cultivars (Table 2), although leaf K in ‘Onyx’ was highest in the spring.

Leaf Mg and Ca concentrations increased overall from spring to autumn in the erect and semierect cultivars, although levels did fluctuate during the summer, whereas in trailing cultivars levels were...
Table 3. The effect of year and cultivar on primocane leaf nutrient concentration of floricane-fruiting trailing, erect, and semierect cultivars at the North Willamette Research and Extension Center, Aurora, OR and sampled on three dates in late July–early Aug. 2013 and 2014.

<table>
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<th>K</th>
<th>Ca</th>
<th>S</th>
<th>B</th>
<th>Fe</th>
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</table>

Note: Recommended sufficiency range for blackberry when sampled in late July to early August (Hart et al., 2006); no sufficiency levels are available for aluminum (n/a).

*Means followed by the same letter within treatment or the interaction are not significantly different (LSmeans) (P > 0.05).*

**Sampling dates for 7, 8, and 9 were 29 July, and 12 and 27 Aug. 2013, respectively, and 28 July, and 12 and 25 Aug. 2014, respectively.**

**N = nitrogen; P = phosphorus; Mg = magnesium; K = potassium; Ca = calcium; S = sulfur; B = boron; Fe = iron; Mn = manganese; Cu = copper; Zn = zinc; Al = aluminum.**
relatively flat through the season and were lower in late summer. Peaks in leaf Ca concentration during the season may have been related to variability in leaf sampling caused by summer pruning (tipping) as reported for primocane-fruiting blackberry (Strik, 2015). The trailing blackberry cultivars had a considerably lower leaf S concentration than the erect and semierect cultivars, especially from spring to midsummer (Fig. 1).

The pattern of change in leaf B was similar amongst the blackberry cultivars in the spring to midsummer (Fig. 2). However, leaf B increased rapidly from late July to the end of August in the erect and semierect cultivars to levels significantly higher than in the trailing cultivars, particularly in ‘Chester Thornless’ and ‘Triple Crown’. A similar pattern was observed for leaf Mn. Leaf Cu was relatively stable in the early season except for the semierect cultivars, but increased for all cultivars except ‘Ouachita’ in the late season. Leaf Zn concentration generally increased through the season and was highest (‘Marion’) and lowest (‘Columbia Star’) in the trailing cultivars on many sample dates.

Primocane leaf Fe and Al concentrations were much higher in the trailing cultivars than the other blackberry types likely because there was dust (soil) on these leaves and leaves are not washed before tissue analysis (Hart et al., 2006); trailing blackberry primocanes are not self-supporting and were laying on the soil during the sampling period as opposed to the erect growth habit of ‘Ouachita’, ‘Triple Crown’, and ‘Chester Thornless’.

Sampling time recommendations. The current tissue sampling recommendations for blackberry vary by region (Bolda et al., 2012; Bushway et al., 2008; Fernandez and Ballington, 1999; Hart et al., 2006). Sampling is recommended for a time when tissue nutrient concentrations are relatively stable to minimize variation. Rather than a specific date, Strik (2015) recommended that primocane-fruiting, erect blackberry cultivars be sampled at the bloom to green-fruit stage of growth. In the erect and semierect cultivars we studied, the only nutrients that appeared to have relatively stable concentrations in the late July to early August sampling period were N, K, S, Mn, Zn, and Cu (Figs. 1 and 2). However, by late July to early August, some nutrients started to increase (Ca, Mg, B, and Al) or decrease (P) in concentration.

Tissue nutrient concentrations for the three primocane leaf sampling dates ranging from the end of July to late August of each year were compared for all cultivars (Table 3). We chose these dates to correspond to a range similar to what is currently recommended for sampling in our region (Hart et al., 2006). There was a significant year by sampling date interaction for all nutrients. When comparing sampling in late July to early August (dates 7 and 8 in Table 3), there was no sampling date effect for N, Mg, K, Ca, S, B, Mn, and Zn (only in 2014); P, Fe, and Al in both years; primocane leaf Cu was not stable during this period in either year. However, when the sampling period was mid to late August (dates 8 and 9, Table 3), primocane leaf N, Mg, Fe, Mn, and Al were stable in both years, leaf K, Ca, S, B, Cu, and Zn were stable in one of the years of study.
Although there was no date

Blackberry type did not affect leaf K, there
derived leaf age at sampling in erect black-

Primocane leaf Fe and Mn were
depending on cultivar. ‘Columbia Star’ had a higher leaf Ca than the semierect cultivars (Table 3). There was a sampling date × cultivar interaction during the late July to late August period because leaf Ca increased from mid to late August in the erect and semierect cultivars considerably compared with the trailing cultivars (Fig. 1). Leaf Ca levels were affected by tipping date and
cultivar interaction during the late July to late August sampling period in 2014 but only declined from late July to early August in 2013 before increasing again in late August (Fig. 1). Primocane leaf Fe and Mn were above recommended sufficiency levels on one or more later sampling dates (Table 3), perhaps because of the presence of dust on the leaves (Fe) and a soil pH that was at the low end of the recommended range for blackberry (Hart et al., 2006). All of the other nutrients were within current sufficiency levels during the late July to late August sample period.

Cultivar had a significant effect on the nutrient concentration of primocane leaves when sampled from late July to late August (Table 3). The trailing cultivars had a lower average leaf N than the erect and semierect cultivars (which did not differ). There was a cultivar × date interaction, because leaf N in ‘Onyx’, ‘Columbia Star’, ‘Triple Crown’, and ‘Ouachita’ declined rapidly from mid to late August, whereas leaf N changed relatively little during this period in the other cultivars (Fig. 1). All cultivars except ‘Chester Thornless’ and ‘Onyx’ had an average primocane leaf N concentration below the current recommended standards (when sampling from late July to late August; Table 3).

Average leaf P was below current sufficiency levels in all cultivars in 2013 and in ‘Ouachita’ in 2014 (Table 3). Trailing cultivars had higher leaf P than the erect and semierect cultivars, whereas the erect cultivar, Ouachita, had a lower leaf P than the semierect cultivars. Leaf P increased during the early sampling period for ‘Marion’, ‘Chester Thornless’, and ‘Onyx’, whereas levels remained relatively stable or declined in the other cultivars (Fig. 1).

Leaf Mg concentration was lower in the trailing cultivars than the other types and was higher in the semierect cultivars than in the erect cultivar, Ouachita (Table 3). Although blackberry type did not affect leaf K, there was a strong effect of cultivar. ‘Columbia Star’ had the highest leaf K and ‘Black Diamond’ and ‘Onyx’ the lowest, depending on year. All cultivars had a leaf K below the current sufficiency levels except for ‘Columbia Star’ and ‘Marion’ in 2014 (Table 3). Although there was no date × cultivar interaction during the late July to late August sampling period (Table 3), leaf K was higher in the late season for all trailing cultivars except ‘Onyx’ as compared with the erect and semierect cultivars that were still fruiting at this time (Fig. 1; Table 2). It is possible that uptake of K from the soil preferentially goes to the floricanes during the fruiting period. On average, trailing cultivars had lower leaf Ca than erect and semierect cultivars and ‘Ouachita’ had a higher leaf Ca than the semierect cultivars (Table 3). There was a sampling date × cultivar interaction during the late July to late August period because leaf Ca increased from mid to late August in the erect and semierect cultivars considerably compared with the trailing cultivars (Fig. 1). Leaf Ca levels were affected by tipping date and

Floricane leaf Mg increased from spring to the beginning of the fruiting season in the erect and semierect cultivars, whereas leaf Mg stayed relatively stable in the early-fruiting trailing cultivars (Fig. 3). There was a similar pattern in leaf Ca for all types and cultivars studied with increasing levels through the season. The reason for the decline in leaf Ca in the floricanes of erect and semierect cultivars in late August is not clear, but this decline was not observed in 2013 for these cultivars (data not shown). Floricanes leaf Ca and Mg concentrations likely increased through the season because these leaves were aging, as has been reported in older leaves of raspberry (Hughes et al., 1979) and blackberry (Strik, 2015), and there are relatively low concentrations of these nutrients in trailing blackberry fruit (Dixon et al., 2016; Harkins et al., 2014).

In general, leaf B, Mn, Fe, and Al concentration increased during the floricanes season, with the exception of lower values of leaf B and Mn for the erect and semierect cultivars either just after fruit harvest or during fruit harvest, respectively (Fig. 4). Leaf Cu concentrations decreased slightly in the early season, but increased and were more variable for the later-fruiting cultivars from August to October. Leaf Zn levels declined in May and then increased slightly or remained relatively stable during fruiting, depending on cultivar.

Nutrient sufficiency standards have not been developed for floricanes leaves of any type of blackberry in North America. Because the nutrient concentration in floricanes leaves of trailing cultivars just before fruit harvest (approximately mid-June to 1 July) was greater than published primocane leaf sufficiency levels (Hart et al., 2006) for most nutrients, floricanes-specific standards would
need to be developed. However, we do not recommend floricane leaves be used to manage fertilizer programs as the concentrations of most nutrients were rapidly changing during the lateral and fruit developmental period. By contrast, the floricane leaf concentrations of most nutrients in the erect and semierect cultivars were within the current primocane sufficiency levels (Table 3) when sampled in late July to early August (just before fruiting, Table 2), except for floricane leaf K (lower) and Fe and Mn (higher) (Fig. 4).

Conclusions

Our findings indicate that the growth habit or fruiting season (or both) of the three floricane-fruiting blackberry types as well as the cultivar grown affect primocane tissue nutrient concentrations. We thus recommend blackberry types and cultivars be sampled separately for tissue analysis. We do not recommend sampling floricane leaves to manage fertilizer programs in any blackberry type in North America, as standards for these diverse types have not been developed.

The currently recommended primocane leaf tissue sampling period of late July to early August (Hart et al., 2006) was not consistently ideal for all nutrients in these diverse blackberry cultivars. In our study, all nutrients except Cu were stable when sampling in the late July to early August period in 2014, but only P, Fe, and Al were stable during this period for both years. However, if sampling was delayed slightly, to mid to late August, more nutrients were stable during this period for both years of the study (N, Mg, Fe, Mn, and Al). Considering leaf N is a key nutrient sampled to adjust fertilizer programs, we recommend shifting the recommended primocane sampling time to this slightly later period.

The primocane leaf nutrient concentrations measured in this study were below (P, K, and N) or above (Fe) current standards for our region (Hart et al., 2006). Our findings thus suggest that changing the sufficiency levels for these diverse blackberry types would aid growers in managing their fertilizer nutrient programs, as proposed by Strik and Vance (2016).

Literature Cited


Fig. 3. The effect of sample date over the growing season on the concentration of macronutrients in floricane leaves of trailing (‘Black Diamond’, ‘Columbia Star’, ‘Marion’, and ‘Onyx’), erect (‘Ouachita’), and semierect (‘Chester Thornless’ and ‘Triple Crown’) blackberry at the North Willamette Research and Extension Center, Aurora, OR, 2014. A = nitrogen; B = phosphorus; C = potassium; D = magnesium; E = calcium; F = sulfur. Bars indicate standard error for cultivar.

Fig. 4. The effect of sample date over the growing season on the concentration of micronutrients in floricane leaves of floricane-fruited, trailing (‘Black Diamond’, ‘Columbia Star’, ‘Marion’, and ‘Onyx’), erect (‘Ouachita’), and semierect (‘Chester Thornless’ and ‘Triple Crown’) blackberry at the North Willamette Research and Extension Center, Aurora, OR, 2014. A = boron; B = manganese; C = iron; D = copper; E = zinc; F = aluminum. Bars indicate standard error for cultivar.


