A PNW Extension Publication

Nutrient management of raspberries and blackberries in Oregon and Washington

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Introduction

Red and black raspberries and blackberries (*Rubus* sp.) are important crops in Oregon and Washington. Oregon is a leading producer of blackberries and black raspberries in the United States, and Washington is a leader in red raspberries.

Caneberries, also called brambles in some regions, are a group of plants that produce fruit on biennial vegetative shoots known as canes. Most caneberries in Oregon are grown in the Willamette Valley. Northwestern Washington leads the state in red raspberry production.

Northwest growers produce many different types of blackberry (*Rubus* ssp. *Rubus)*, including cultivars that are categorized by growth habit: trailing, erect or semi-erect.

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- **In general, trailing blackberry** cultivars have the earliest fruiting season (late June through July) and are mostly machine-harvested for a processed market. However, some cultivars are hand-picked for the early-season fresh market.
- **Semi-erect blackberries** are mainly grown for the late-season fresh market (late July through early September) but may have processing potential. All trailing and semi-erect cultivars are floricane-fruiting, only producing fruit on canes in their second year of growth.
- **Erect blackberries** are mainly grown for fresh market for the midsummer season (floricane-fruiting cultivars) or in late summer through early fall (primocane-fruiting cultivars that produce fruit on canes in their first year of growth).

The primocanes of erect and semi-erect blackberries are pruned (tipped) in summer to induce branching and increase yield.

Red raspberry (*Rubus idaeus*) cultivars are either:

- F**loricane-fruiting** (early to midsummer season) and grown for processing or fresh markets,
- **Primocane-fruiting** (late summer through early fall) and grown mainly for the fresh market.

In Oregon and Washington, primocane-fruiting cultivars may be grown for two harvest periods, with early fruit harvested in summer on the floricanes and late-summer fruit harvested on the tip of current-season primocanes.

Some cultivars of floricane- and primocane-fruiting raspberry produce yellow or pink/rosé fruits.

Black raspberries (*Rubus occidentalis*), also called blackcaps, are grown almost exclusively for processing. They have a different growth habit, where the primocanes should be tipped in summer to induce branching and increase yield of the floricanes next season. See *Pruning and training of berries, kiwifruit and grapes.* (https://workspace.oregonstate.edu/course/pruning-series)

Caneberry plantings require adequate nutrition and well-developed nutrient management programs. Nutrient management strategies depend on the type of caneberry and whether the farm is conventional or organic.

Mineral nutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) magnesium (Mg) and boron (B) are added through fertilizers to supplement what is available in the soil. In certain cases, micronutrients can be applied, with caution, as a soil application or directly to the plant as a foliar spray to correct deficiencies.

Organic vs. conventional systems

For this publication**, organic production** refers to systems following U.S. Department of Agriculture National Organic Program standards, using only products for nutrient management that are approved by the Organic Materials Review Institute or other recognized organic material review programs.

Conventional production refers to systems that do not follow NOP standards and use synthetic fertilizers, but may include organic products as well.

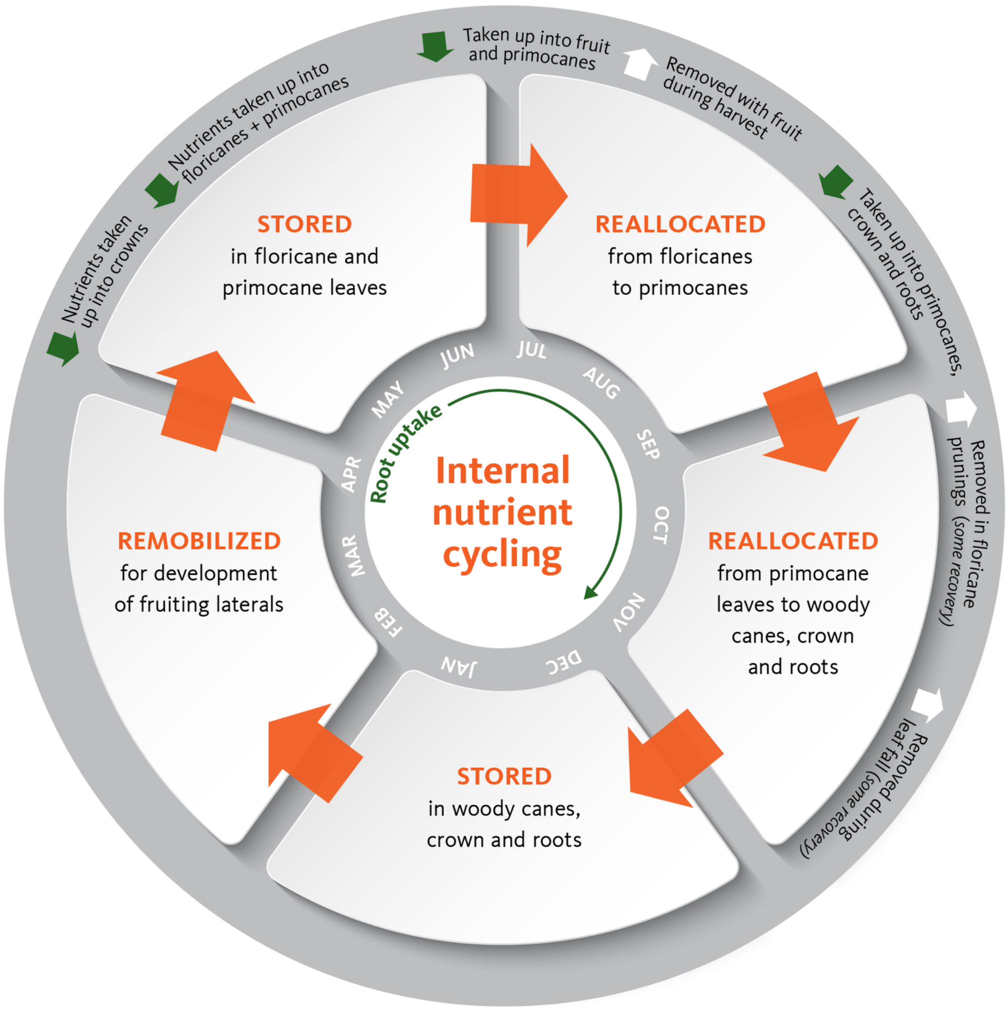

Figure 1. Nutrients are cycled internally, throughout the plants across the seasons. From April through November, nutrients flow from the roots to the canes and crowns.

Credit: Dave Bryla, © Oregon State University

Consider the unique growth habit of caneberries when developing and implementing a nutrient management plan. Nutrients accumulate in the primocanes, crown and roots and are lost during harvest, pruning and leaf fall. Research in Oregon shows that growth of fruiting laterals and fruit depends on nutrient reserves stored over winter in the canes, crown and roots, as well as additional nutrients available from the soil or new fertilizers. New primocane growth mostly depends on nutrients available in the soil or from fertilizers (Figure 1). Thus, good nutrient management programs are important for sustained growth and production of caneberries.

Our nutrient management recommendations for conventional or organic production are based on these assumptions:

- The use of well-adapted cultivars.
- Disease-free nursery plants.
- Soil suitable for good caneberry growth.

- Appropriate weed, disease and insect management programs.
- Proper irrigation (placement, uniformity, quantity, quality and scheduling).

Proper or excess fertilization will not compensate for poor management practices or fix problems unrelated to fertility. Soil properties such as low or high pH and poor drainage can limit plant growth and yield. In a survey of caneberry growers in Western Oregon, low pH, resulting in limited nutrient uptake (especially N), was the most common and impactful production issue.

Good nutrient management programs ensure sufficient nutrients are available when plants need them. The goal of fertilizing any high-value crop is to supply the plant with ample nutrition in advance of demand, thereby removing nutrient limitations to yield and fruit quality. Important considerations include economic return from investments in fertilizer, environmental stewardship and compliance with government regulations. Fertilizer application should produce obvious positive changes in plant growth or nutrient status, or otherwise benefit the crop in a measurable way, such as improved yield or fruit quality.

Soil and tissue sample analyses help determine appropriate nutrient applications. Keep records of weather, yield, disease and insect problems, and fertilizer nutrient application rates and timing. This will help in interpreting soil and tissue analysis results over time. Observations of annual growth (visual assessments of cane number, diameter, height and fruiting lateral length), leaf color and fruit quality (amount of rot, drupelet set and firmness) will also help in adjusting nutrient management programs as needed.

Any nutrient management plan must address four key questions for each nutrient, which are often known as the "4 R's":

- **Right source:** What source or material is best to apply?
- **Right rate:** How much is needed?
- **Right timing:** When should it be applied?
- **Right place:** Where and how to apply it?

This publication explains how producers can lay the groundwork for optimum nutrient management during the life of the caneberry field, including site preparation and establishment. By using soil and tissue testing and basic fertility recommendations, you will be able to identify how much of each nutrient to apply for the type of caneberry grown.

This publication is not intended as a production guide. Site-specific soil and climate conditions should be considered. Your Oregon State University, Washington State University or University of Idaho Extension Service can help with further questions. See "Resources."

Established plantings

Soil testing

Annual soil sampling or testing is not usually needed in established plantings unless you suspect a problem or are correcting a nutrient or soil pH issue. However, recent research has shown that growers in Oregon are overapplying certain nutrients, such as P and K, when they are sufficient in the soil. Regular soil sampling may help you reduce unneeded fertilizer nutrient applications. By looking at changes over time, you can make corrections before they cause a production issue.

Table 1 shows the recommended soil ranges for important nutrients. Soil N and some micronutrients are not included in this table because they are either highly mobile or unlikely to be problematic given the soil and climatic conditions in this region.

Collect soil samples at the same time of year and use the same laboratory so results from different fields and years are directly comparable. Be sure to send samples to an accredited laboratory to ensure proper analytical methods are being used. Often, soil test results vary less from year to year if samples are taken after consistent autumn rainfalls have begun (late October to early November). After planting, use a soil core to sample from within the plant row where fertilizer is applied. If your field is drip-irrigated or fertigated, sample at a similar distance from an emitter and a plant in each subsample location. Be aware that fertilization, the irrigation wetting front, fertigation and band fertilizer application all affect soil sample results. Do not collect soil samples right after fertilization. Use a soil core to collect only soil in your sample, removing surface mulch, leaves or other organic matter. Collect 15–30 subsamples from a grid or at random from each sample area or block, then mix subsamples from one block into a bucket and take an appropriate-sized sample for sending to the testing lab (required sample size may vary by lab). See *A guide to collecting soil samples for farms and gardens,* (https://extension.oregonstate.edu/catalog/pub/ec-628-guide-collecting-soil-samples-farms-gardens)EC 628.

Soil pH

It is crucial that you keep soil pH at 5.6 to 6.5, which is the ideal range for caneberry production (Table 1). Acidic soil conditions (with a pH less than 5.6) can develop over time due to ammonium (NH_4)-based fertilizer applications and heavy precipitation. In acidic soils, availability of nitrate-N (NO_3), P, Ca and Mg to caneberry plants decreases, while potentially causing aluminum (Al) and manganese (Mn) toxicity issues. Alkaline soil conditions (pH above 6.5) decrease the plant availability of P, iron (Fe), zinc (Zn), and Mn. Maintaining ideal soil pH conditions is one of the most important components for effective nutrient management in a caneberry production system, allowing plants to maximize their nutrient uptake potential.

For acidic soils (common in Western Oregon and Washington), lime (calcium carbonate) is the most effective amendment for raising soil pH. Calcium carbonate in lime slowly reacts with water to neutralize acidity and generally takes several months to fully react.

Table 1. Recommended soil nutrient ranges for all raspberry and blackberry types

Soil test	Recommendation
pH (tested in water)[a]	5.6–6.5
Electrical conductivity (EC)[b]	Below 2 dS/m
Available nutrients	
Phosphorus (P)[c], Bray 1 test	Over 20–40 ppm
Phosphorus (P)[c], Olsen test	Over 10 ppm
Potassium (K)[d]	150–350 ppm
Calcium (Ca)	Over 1,000 ppm
Magnesium (Mg)	Over 120 ppm
Manganese (Mn)	20–60 ppm
Boron (B)	0.5–1.0 ppm

[a]Tested in water (1:1).
[b]Tested using saturated paste (1 dS/m = 1 mmho/cm = 1 mS/cm).
[c]Bray 1 test is most reliable in neutral or acidic soils. The Olsen test is intended for high pH, calcareous soils. The tests differ in the extraction solutions used.
[d]Tested using ammonium acetate. Soil type impacts K availability.

There are various lime options for agricultural use: powdered or agricultural lime, pelletized or prilled lime and fluid or “liquid” lime. “Byproduct” lime is generally not recommended for caneberry production as it may be more difficult to apply and more variable in mineral content. Pelletized lime is usually applied prior to planting and needs time to break up through wet/dry and freeze/thaw events before incorporating into the soil. The main difference between these products is application method, speed of action and price.

Organic caneberry growers need to obtain approval from their certifier for the type of lime they intend to use prior to application, as some binding agents, dust suppressants, and manufacturing processes are not permitted and may risk organic certification status.

To determine how much lime to apply, request a buffer pH analysis for your soil sample. Most soil testing labs will use the SMP (Shoemaker-McLean-Pratt) or Sikora (modified SMP) buffer pH methods. Both of these buffer methods were determined to be effective for estimating lime requirement for Oregon soils. Use the buffer pH value to adjust lime application rates for new and existing fields (Table 2).

Incorporate lime into the soil for new caneberry fields prior to establishment, as it is very difficult to raise pH quickly with top-dress applications or through the irrigation system. When required, apply by top-dressing with no more than 2 tons lime per acre in the fall and retest again the following year to determine if more lime is needed. Top-dressed lime moves downward at a rate of ½ to 1 inch a year, up to 2 to 3 inches total, which is why adjusting soil pH before planting is critical. For a detailed explanation on types of lime and the SMP buffer test, see *Applying lime to raise soil pH for crop production (Western Oregon)* (https://extension.oregonstate.edu/catalog/pub/em-9057-applying-lime-raise-soil-ph-crop-production-western-oregon), EM 9057, and *Eastern Oregon liming guide,* *(https://extension.oregonstate.edu/catalog/pub/em-9060-eastern-oregon-liming-guide)* EM 9060.

Table 2. Lime recommendations for caneberries

SMP or Sikora buffer pH values	New crop, preplant application	Existing crop, top-dressed application
	Recommended lime application (ton/acre)[b]	Recommended lime application (ton/acre)[b]
Over 6.8	0	0
6.5–6.7	1–2	0
6.2–6.4	2–3	1
5.9–6.1	3–4	2
5.6–5.8	4–5	2
Below 5.5	5	2

[a]SMP and Sikora buffer values may be used interchangeably.
[b]Lime recommendations provided here are based on 100-score lime and 6-inch sampling depth.

For alkaline soils (pH above 6.5; common in Eastern Oregon and Washington), incorporate elemental sulfur (S) into new fields to acidify the soil (Table 3). Keep in mind that it may take several months to lower soil pH, as elemental S creates acidity through the slow conversion to sulfuric acid by microorganisms naturally present in soil. Lowering and/or maintaining low soil pH in calcareous soils through elemental S applications is challenging and may not be cost effective.

Berry growers cultivating their crop in calcareous soils usually amend soil pH using a combination of pre- and post-plant strategies including application of elemental sulfur and acidifying irrigation water through the use of sulfur burners. Excessive rates of S application increase soil electrical conductivity (EC) and can cause salt damage or kill plants. For more information, see *Acidifying soil in landscapes and gardens east of the Cascades,* (https://extension.oregonstate.edu/catalog/pub/ec-1585-acidifying-soil-landscapes-gardens-east-cascades) EC 1585.

Table 3. Elemental sulfur (S) requirement to acidify alkaline soils to a target pH of 6.5 for new fields going into raspberries and blackberries

Soil pH[a]	Sands, loamy sands and sandy loams	Loams and silt loams	Clay loams and clays
	Recommended elemental S application (pounds/acre)		
8.5	400	750	1,500
8.0	350	700	1,300
7.5	300	600	1,200
7.0	200	400	700

[a]For calcareous soil types, soil pH may respond less to elemental S applications.

Tissue testing

Soil testing indicates whether a plant will have access to sufficient nutrients, but only leaf tissue testing will reveal whether these nutrients are at adequate levels in the plant itself. Nutrients may be adequate in the soil, but the plants may not be able to take them up. This could be due to environmental issues, such as incorrect soil pH, dry or waterlogged soil, hot or cold weather, or cultural issues, such as pests, non-uniform irrigation or improper timing of nutrient applications.

Leaf nutrient concentrations change throughout the season, so collect leaf tissue samples at the time recommended to ensure you can accurately compare your results with published sufficiency standards (Table 4). For example, leaf N concentration is always highest in the spring and lowest in the fall. If the recommended sampling time for floricane-fruiting raspberries is in late July to early August, but you collect samples as soon as the plants leaf out in spring, you will be comparing two very different seasonal stages. Your results will seem high compared to the standard. The opposite is true for leaf Ca, which is lower in spring than at the recommended sampling time in late July to early August.

It is important to collect leaves from the proper canes, the correct location on the canes and at the correct time of year. If you collect the leaf samples improperly, the tissue test results will not be useful for informing your nutrient management programs.

Figure 2A. Location of primocane leaf sampling in floricane fruiting red raspberry.

Credit: Lisa Wasko DeVetter, © Washington State University

Figure 2B. Location of primocane leaf sampling in floricane fruiting trailing blackberry.

Credit: Amanda Davis, Oregon State University

- For all caneberry types, only collect leaves from the primocanes.
- Collect the most recent fully expanded primocane leaves (located about 12 inches from the tip). Sample only one leaf per primocane and include the petiole (leaf stem) (Figures 2A, 2B).
- Sampling time differs between raspberries and blackberries:
  - **All raspberries:** Sample from late July to early August. In primocane-fruiting raspberries, sample 3–4 nodes below the last obvious fruiting lateral.
  - **Floricane-fruiting blackberries (all types/cultivars):** Sample from mid- to late-August.
  - **Primocane-fruiting blackberries:** Sample during the green-fruit stage of the primocane fruit (approximately eight to 10 weeks after summer pruning or tipping). Sample leaves three to four nodes below the last obvious fruiting lateral.

- Sample each cultivar separately. Leaf nutrient concentrations often differ among cultivars.

The recommended sampling times are related to the periods in which caneberry leaf nutrient concentrations are relatively stable in Oregon. Nutrient concentrations also vary with leaf age, so collect only the most recent fully expanded leaves. Leaf nutrient concentrations can vary regionally, and sufficiency standards for raspberry systems in northwest Washington are in development. Growers are advised to use the published sufficiency standards (Table 4) as a guideline in the interim.

Use a combination of tissue analysis results (compared to nutrient sufficiency levels for the crop; Table 4) and observations of plant growth to adjust nutrient management programs the following year. This is particularly important in determining N fertilization rates. Plant sap also contains nutrients, and some retailers are promoting the use of sap tests for more rapid assessment of plant nutrient status. However, evaluation of sap testing in raspberry for N, Ca, and K shows the results to be highly variable with inconsistent and rarely significant relationships between tissue and sap tests. Tissue analyses are one of the best approaches to assess caneberry nutrient management, and sap testing is not recommended.

A single tissue sample should not represent an area of more than 5 acres or contain leaves from more than 50 primocanes. Avoid leaves that are diseased or damaged, if possible. Do not wash the leaves after sampling, as this can leach some nutrients. Foliar micronutrient applications, fungicide applications, dust or organic matter on the leaves will also affect results. If there is excessive dust on the leaves you may rinse them; let them dry before packaging them and sending to the lab.

Try to collect samples at the same time of year (within types) so that you can compare tissue test results across years. Ideally, fields are sampled annually. If annual testing is not feasible, rotate through sampling a subset of fields each year, so that you sample half to a third of your acreage each year.

Tissue sampling can also be used to diagnose problems in the field. At any time of the year, collect leaves from both affected and healthy-looking plants. Then compare the results to help determine the cause of the problem. Tissue nutrient problems may be related to soil issues. For instance, high tissue Mn may mean soil pH is too low. Whether you are performing routine sampling or trying to correct a problem, keep detailed records on cultivars and blocks sampled, sampling date, associated yield or fruiting season information, and any fungicide or nutrient applications. These records will help you identify trends over time and spot problems more quickly.

Table 4. Recommended tissue sufficiency levels by type of caneberry based on correct sampling time for each crop based on research in Oregon

Nutrient	Abbreviation and unit of measurement	Raspberry (floricane-fruiting)[a]	Blackberry (floricane-fruiting)[b]	Raspberry (primocane-fruiting)[a]	Blackberry (primocane-fruiting)[c]
Sampling time		**Late July to early August**	**Mid- to late August**	**Late July to early August**	**Green fruit stage, 8–10 weeks after summer tipping**
Nitrogen	N (%)	2.0–3.0	2.0–3.0	2.0–3.0	2.0–3.0
Phosphorus	P (%)	0.20–0.40	0.15–0.40	0.20–0.40	0.15–0.40
Potassium	K (%)	1.0–1.8	0.9–1.8	0.8–1.8	0.9–1.8
Calcium	Ca (%)	0.6–1.5	0.5–1.5	0.6–1.5	0.5–1.5
Magnesium	Mg (%)	0.25–0.50	0.25–0.60	0.25–0.50	0.25–0.60
Sulfur	S (%)	0.10–0.20	0.10–0.20	0.10–0.20	0.10–0.20
Manganese	Mn (ppm)	50–300	50–300	50–300	50–300

Nutrient	Abbreviation and unit of measurement	Raspberry (floricane-fruiting)[a]	Blackberry (floricane-fruiting)[b]	Raspberry (primocane-fruiting)[a]	Blackberry (primocane-fruiting)[c]
Boron	B (ppm)	30–80	30–70	30–80	30–70
Iron	Fe (ppm)	70–300	70–500	70–300	70–500
Zinc	Zn (ppm)	15–40	20–50	15–40	20–50
Copper	Cu (ppm)	3–10	5–15	3–10	5–15

[a]Changes to previous standards are based on Strik and Bryla (2015) and research by Bryla and Strik (unpublished).
[b]Changes to previous standards are based on Strik and Bryla (2015) and Strik and Vance (2016; 2017; 2018).
[c]Changes to previous standards are based on Strik (2015), and Strik and Bryla (2015).

To diagnose problems and apply nutrients correctly, it helps to know that plants have two "circulatory" systems — the xylem and the phloem. Xylem is dead tissue and is used to transfer water and dissolved nutrients from the roots to the leaves, with some water and nutrients also moving from the roots to developing fruits. However, nutrients that move in the xylem fluid cannot move from leaves to fruit, from old leaves to new leaves, or from leaves to root or crown tissues. Nutrients in the xylem fluid are therefore often considered immobile. Nutrients dissolved in the xylem fluid, including S, Fe, Mn, Cu, Zn, Ca and B, will follow the same pattern and move from roots to leaves.

Phloem is living tissue and moves sugars (the product of photosynthesis) throughout the plant. Nutrients in the phloem are mobile and can be redistributed from leaves to fruit or from leaves to root and crown tissues. Nutrients that are mobile in the phloem fluid include N, P, K and Mg. See "Nutrient recommendations" for symptoms associated with a nutrient deficiency or toxicity. Note that yield or quality can be reduced even when there are no obvious nutrient deficiency symptoms in the plants. Rely on proper plant tissue and soil analyses to adjust your nutrient management program.

Nutrient application rates and timing

Recommended nutrient application rates are a function of plant nutrient needs and fertilizer uptake efficiency (see "Relevant research papers"). Plant nutrient needs are affected by plant age, crop (fruit) load and plant canopy size. Fertilizer nutrient uptake efficiency is affected by the size and depth of the root system, as well as how you apply the nutrient (granular, liquid,or foliar), the nutrient source (such as a chemical formula), the amount and timing of the applied fertilizer, and whether a mulch is present. See "Nutrient recommendations."

Nutrient gains and losses

Caneberry plants require nutrients for plant growth and fruit production. Research in Oregon has documented nutrient losses (in harvested fruit, pruned floricanes when caning out and at leaf fall in autumn) and nutrient gains in the plant crown and roots over time. The greatest losses in nutrients from a caneberry field are for N, K and Ca (Tables 5 and 6).

Approximately 11–18 lb N/acre is removed in harvested fruit and 12–32 lb N/acre when caning out, depending on the type of caneberry, cultivar and production system (Tables 5 and 6). For example, in red raspberry, 3.5 lb N/ton of fruit (14 lb of N for a yield of 4 tons per acre) is removed at harvest along with 17.3 lb N/acre when caning out in

August and 9.5 lb N/acre in the senescing leaves. Based on this research, a floricane-fruiting raspberry field with an expected yield of 4 tons/acre would require about 41 lb N/acre for fruit and cane growth in the upcoming season, plus a small additional amount for crown and root growth. Since yield and vigor differ among caneberry types and cultivars and are affected by planting age, the recommended rate of nutrients to apply also varies (see "Nutrient recommendations").

Caneberries reallocate N from senescing or dying floricanes and primocane leaves into canes, crown and roots in late summer and fall. Waiting to cane out, or prune floricanes, until after they have fully senesced in autumn improves the plant's reallocation and recovery of nutrients when compared to caning out in August (Table 6). However, that decision is often driven by labor availability and presence of disease in the planting.

Table 5. Nutrients removed in each ton of harvested fruit (fresh weight)[a]

Nutrient	Unit	Red raspberry (per ton)[b]	Blackberry (per ton)[c]
Nitrogen	lb	3.5	2.9
Phosphorus	lb	0.5	0.6
Potassium	lb	3	3
Calcium	lb	0.3	0.6
Magnesium	lb	0.4	0.3
Sulfur	lb	0.2	0.2
Boron	oz	0.2	0.1
Copper	oz	0.03	0.03
Manganese	oz	0.1	0.2
Zinc	oz	0.1	0.1
Iron	oz	-	0.2

[a]From Strik and Bryla (2015).
[b]Floricane-fruiting red raspberry, 'Meeker'.
[c]Average of floricane-fruiting 'Black Diamond' and 'Marion' trailing blackberry.

Table 6. Nutrients removed per acre during pruning (caning out) and leaf fall in fall[a]

Nutrient	Unit	Red raspberry (per acre)[b]			Blackberry (per acre)[c]
		Floricane pruning (August)	Floricane pruning (September)	Leaves (fall)	Floricane pruning (August)
Nitrogen	lb	17.3	11.8	9.5	31.6
Phosphorus	lb	1.2	0.9	0.7	4.5
Potassium	lb	9.4	6.5	4.2	36.3
Calcium	lb	15.3	12.7	5	30.3
Magnesium	lb	3.1	2.4	2.1	6
Sulfur	lb	0.9	0.8	0.4	2.1
Boron	oz	1.7	1	0.8	0.2
Copper	oz	0.2	0.2	0.1	0.02
Manganese	oz	2.1	2.1	1.2	1.2
Zinc	oz	0.5	0.4	0.1	0.2
Iron	oz	-	-	-	0.8

[a]From Strik and Bryla (2015).
[b]Floricane-fruiting red raspberry, 'Meeker'.
[c]Average of floricane-fruiting 'Black Diamond' and 'Marion' trailing blackberry.

Most of the N present in senesced and fallen leaves and in prunings, chopped and left between the rows, is returned to the soil and taken up by the caneberry plants within 1.5 years. This is likely the case for other nutrients, too.

Timing of fertilizer N with plant uptake

Research has shown that when raspberry and blackberry primocanes begin growing in early spring, they rely on fertilizer N. Therefore, it is critical to time N fertilizer applications with new primocane growth. In contrast, spring floricane growth, including fruiting laterals, flowers and fruit, depends mainly on N stored in the canes, crown and roots. Thirty to 40% of stored N is allocated to new growth during floricane development in blackberry and raspberry. Applying too much N, particularly late in the season, can lead to excessive plant vigor, poor fruit quality and greater risk of developing bacterial or fungal diseases in the canopy. It also may delay cold acclimation and increase the risk of freeze injury.

Recommended fertilizer rates account for the differences in vigor and fruit production between caneberry types and fruiting category and for the fact that plants cannot take up all the applied fertilizer.

"If enough is good, then more must be better" is a poor strategy for fertilizer applications. Overapplying fertilizer harms plant productivity, fruit quality and the environment. Use soil tests, tissue analysis and visual observations to assess plant nutrient status and adjust nutrient management programs.

Nutrient recommendations

You can adjust nutrient programs over time, but it is best to start at an established benchmark. Use fertilizer wisely, watch the response of your plants and adjust your nutrient management plan as needed. In this section, we provide baseline recommendations for fertilizer applications based on planting age (establishment or mature) and caneberry type. Where appropriate, recommended fertilizer rates are also given if soil or tissue test results show deficiency. We provide the best timing for applying each nutrient to help maximize application efficiency. These recommendations are provided by nutrient.

Nutrient management plans should be developed based on these recommendations. However, each caneberry field is different. Growers should routinely collect and analyze soil and tissue samples, as described above, and keep meticulous records of weather, disease problems and nutrient application rates and timing. In addition, observations of annual growth (cane number, diameter, height, fruiting lateral length), yield, leaf color and fruit quality (amount of rot and drupelet set) are also helpful in determining and adjusting nutrient needs.

Typically, established caneberry plantings require annual applications of N, P, K and B fertilizer in the Pacific Northwest. Many growers also make annual applications of Ca fertilizer. Other nutrients should only be applied if visual deficiency symptoms are present in the field and have been confirmed by leaf tissue testing.

In plantings where a cover crop is being utilized between rows, refer to OSU's organic fertilizer and cover crop calculators (https://smallfarms.oregonstate.edu/calculator) and *OSU organic fertilizer & cover crop calculator: Predicting plant-available nitrogen, (https://extension.oregonstate.edu/catalog/pub/em-9235-osu-organic-fertilizer-cover-crop-calculator-predicting-plant-available)* EM 9235, to determine nutrient contributions from the cover crop.

Figure 3. Nitrogen deficiency in blackberry.

Credit: Bernadine Strik, © Oregon State University

Figure 4. Phosphorus deficiency in blackberry.

Credit: Bernadine Strik, © Oregon State University

Figure 5. Calcium deficiency in blackberry.

Credit: Bernadine Strik, © Oregon State University

Figure 6. Magnesium deficiency in red raspberry.

Credit: Bernadine Strik, © Oregon State University

Figure 7. Boron deficiency in red raspberry.

Credit: Bernadine Strik, © Oregon State University

Nutrient deficiency symptoms

Symptoms of nutrient deficiencies can appear similar to other biotic or abiotic problems. Use recordkeeping and testing procedures to support visual observations. Not all symptoms may be present at the same time.

Nitrogen: Pale green or yellow primocane leaves, particularly toward the base of the cane (Figure 3).

Phosphorus: Common symptoms include purplish older leaves and dark-green younger leaves (Figure 4). In early spring, when soils are cool, plant uptake of P may be delayed, leading to temporary P deficiency symptoms. These symptoms usually will go away once soil temperatures increase.

Potassium: Older leaves with marginal necrosis (leaf edges dying), followed by necrotic leaflet petioles and darkened leaflets.

Calcium: Soft fruit, distorted new leaf growth with wrinkles and reddish-brown leaf edges or tips (Figure 5).

Magnesium: Older leaves with interveinal chlorosis or leaf edge reddening (Figure 6).

Sulfur: Decreased plant vigor and reddish leaves.

Boron: Poor bud break on the floricanes, asymmetrical leaf growth and deformed berries (despite adequate pollination) (Figure 7).

Manganese: Poor overall plant growth, interveinal chlorosis.

Iron: Interveinal yellowing of younger leaves.

Zinc: Stunting and narrow leaves.

Copper: May not be easy to detect visually, but Cu deficiency has been shown to reduce fruit set in other crops.

Nitrogen

Growers should apply N fertilizer during critical growth periods, including peak primocane growth and while soil temperature is cool in early spring (Tables 7 and 8).

Soil tests taken in the fall can be used to measure nitrate-N and ammonium-N in the soil, with high levels being an indication of excessive or late applications of N fertilizer. However, fall nitrate- and ammonium-N tests are not useful for determining the amount of N fertilizer that will be needed the following season because ammonium-N is quickly converted to nitrate-N, which is leached from the root zone over the winter. For more information on in-season soil nitrate testing to measure N release from soil and supplemental organic matter as it applies to fertilizer application decision making, see *Soil nitrate testing for Willamette Valley vegetable production,* *(https://extension.oregonstate.edu/catalog/pub/em-9221-soil-nitrate-testing-willamette-valley-vegetable-production)* EM 9221.

Table 7. Recommended N fertilization rates for caneberries

Caneberry type	Planting year	Established plantings (per year)
Floricane-fruiting red raspberries	30-50 lb N/acre	50-80 lb N/acre
Primocane-fruiting red raspberries	30-50 lb N/acre	50-80 lb N + 20 lb N/acre at bloom
Floricane-fruiting black raspberries	20-40 lb N/acre	40-60 lb N/acre
Floricane-fruiting trailing and erect blackberries	30-50 lb N/acre	50-80 lb N/acre[a]
Floricane-fruiting semi-erect blackberries	30-50 lb N/acre	50-80 lb N + 20 lb N/acre at bloom
Primocane-fruiting blackberries	30-50 lb N/acre	50-80 lb N + 20 lb N/acre at bloom

[a]Alternate-year fields should be fertilized at the same rate of N, regardless of whether they are in an on- or off-year (Mohadjer et al., 2001).

Table 8. Recommended timing of N application for caneberries

Application method	Planting year	Established plantings
Granular[a]	Divide total N into three equal portions. Apply first portion two weeks after planting and the following two portions at monthly intervals.	Divide total N into two equal portions. Apply first portion one week before primocane emergence and the second portion one month before the first harvest[b]. For semi-erect blackberries and primocane-fruiting raspberries and blackberries, apply the additional 20 lb N/acre at the onset of bloom, typically six to eight weeks after the last spring application.
Fertigation	Apply 5 lb N/acre each week, beginning one week after planting and continuing through the end of July.	Apply 5-10 lb N/acre each week, beginning at primocane emergence and continuing through the end of harvest for floricane-fruiting raspberries and trailing blackberries. Continue fertigation through the first three to four weeks of bloom for primocane-fruiting raspberries and blackberries and through early August for erect and semi-erect blackberries.
Combination granular + fertigation	Two weeks after planting, apply 10–20 lb granular N/acre. Divide remaining N across fertigation applications starting six weeks after planting and continuing through late-July/early August.	Apply half the target N rate one week before primocane emergence as a granular fertilizer. One month later, begin fertigating 5–10 lb of N/acre/week through the recommended time period above depending on plant type.

[a]If applying dry/granular organic fertilizers, shift the application approximately one month earlier to give the fertilizer time to breakdown and release N and other nutrients.

[b]In Oregon's Willamette Valley, this is approximately late March to early April for the first application and late May to early June for the second application. In northwest Washington, this is approximately late March to mid-April for the first application and late May for the second application. Adjust timing for other growing regions.

How much fertilizer product to apply depends on the percentage of the desired nutrient in the source of fertilizer. See "Sources of nutrients" for the fertilizer calculation and fertigation calculation boxes.

On sandy soils, apply N fertilizer in smaller doses but more frequently, dividing the total rate into more split applications. If you are using organic fertilizer, apply it earlier, as described below and in Table 8. If you are using fertigation, apply liquid N fertilizer weekly (or more frequently) from primocane emergence in the spring through harvest (Table 8).

Base the planting's fertilizer N on the recommended rates (Table 7), but adjust as needed based on your assessment of plant growth and tissue analysis. A well-managed plant should have healthy, green leaves with good primocane growth (a good number per plant, a good diameter, and a normal length for the cultivar and the growing region). Pale green or yellow primocane leaves, particularly toward the base of the cane, could indicate N deficiency. Primocanes that are too tall (10 feet or more for raspberry), too thin (less than 3/8 inch in diameter) or with long internodes (the distance between leaves) indicate an excess of N fertilizer.

Nitrogen rates higher than recommended should only be applied if plant growth and tissue tests warrant it. Excessive N will not increase yield, and in fact it will decrease soil pH over time when an ammonium source of N is applied (see *Soil acidity in Oregon: Understanding and using concepts for crop production* (https://extension.oregonstate.edu/catalog/pub/em-9061-soil-acidity-oregon-understanding-using-concepts-crop-production), EM 9061, for more detail on the interactions of fertilizer with soil pH). Since many caneberries, especially blackberries, have a long lifespan, reductions in soil pH could be detrimental to the planting and difficult to correct. See "Established plantings, soil pH" for recommended ways to mitigate this decline in soil pH with applications of lime.

To ensure maximum availability of N to the plants, match the application method to the type or source of fertilizer you are using (see "Sources of nutrients" and "Application methods"). Inorganic granular fertilizers are often applied in equal, split portions from early spring (about a week before primocanes emerge) through early summer to maximize the efficiency of plant uptake and to minimize the risk of salt stress to the plants (Table 8). Granular organic fertilizers such as feather, soybean or cottonseed meals require longer periods of time for N to be available. Therefore, it is best to apply granular organic fertilizers about a month before inorganic fertilizers would be applied.

Broadcast granular fertilizer products over the soil surface, spreading it evenly in an area a little wider than the row width. If there is no rain in the forecast, irrigate after you apply inorganic or organic granular fertilizers. See "Preplant considerations" for suggested timing if you are using compost or manure as a nutrient source.

In general, liquid fertilizers applied through fertigation are available almost immediately to the plants but may also move out of the root zone quickly. So, for liquid fertilizers, divide the total amount of N into smaller, more frequent applications, such as every few days to weekly (Table 8).

If you are using drip irrigation but applying granular forms of fertilizer, you will be dependent on spring rainfall to dissolve the fertilizer and move the nutrients down to the roots. Some growers have found success by applying an early application of granular N in late March or April, when there is typically abundant rainfall in northwest Oregon and Washington, and then using fertigation to apply N once the plants are irrigated on a regular schedule (usually by May; see Table 8). That way, they can avoid turning on their irrigation system earlier than needed. In raspberry, this method was also found to result in better growth and production compared to fertigation only from April through July.

Adjust fertilizer timing and rates based on how well the plants are growing, anticipated yield and the results of the tissue tests (Table 4).

Phosphorus

A soil test may be useful for determining whether P fertilizer is needed prior to planting. However, use leaf tissue tests to determine if P fertilizer is needed in established fields (Table 9). Subsurface banding can be used when leaf P is below normal. Fall application is preferred so that winter rainfall can help break down the fertilizer in the rootzone for uptake in spring. Incorporate bands adjacent to each side of the row to a depth of 4 to 6 inches. See Table 12 for sources of nutrients and how to calculate the rate of product to apply.

Table 9. Phosphorous fertilizer recommendations for caneberries based on a Bray soil test (preplant) or a leaf tissue test

If the Bray I soil test for P (ppm) reads:	In raspberry[a], if leaf P (%) is:	In blackberry[a], if leaf P (%) is:	Apply this amount of phosphate (lb/acre P_2O_5):
Below 20	Below 0.20	Below 0.15	60-80
20-40	0.20-0.40	0.15-0.40	0-60
Over 40	Over 0.40	Over 0.40	0

[a]Recommendations apply to both floricane- and primocane-fruiting types.

Availability of P is affected by soil pH, soil moisture, soil type, organic matter content, and Ca and Al levels. Clay soils tend to fix more P than sandier soils, making it less available to plants. Incorporating residue from a green manure crop increases available P. In a survey of Oregon caneberry growers, P fertilization was common even when leaf tests showed sufficient levels, often resulting in excessive soil P, which increases the risk of runoff and environmental impacts, along with unnecessary fertilizer costs for the grower. Excess P can also be a problem because it reacts with micronutrients in the soil, making them insoluble and resulting in deficiencies, particularly for Zn.

Potassium

In established plantings, there is often a weak relationship between soil K and plant tissue K because cultural factors such as irrigation or soil water availability can influence plant uptake of K from the soil. Therefore, tissue testing becomes much more important than soil testing to determine K fertilizer needs (Table 10).

Table 10. Potassium (potash) fertilizer recommendations for caneberries based on a preplant soil test (ammonium acetate) or a leaf tissue test

If the soil test for K (ppm) reads:	In floricane raspberry, if leaf K (%) is:	In primocane raspberry, if leaf K (%) is:	In blackberry[a], if leaf K (%) is:	Apply this amount of potash (lb/acre K_2O):
Below 150	Below 1.0	Below 0.8	Below 0.9	60-100
150-350	1.0-1.8	0.8-1.8	0.9-1.8	40-60
Over 350	Over 1.8	Over 1.8	Over 1.8	0

[a]Recommendations apply to both floricane- and primocane-fruiting types.

Once plants are established, K can be banded, broadcast, or fertigated and applied alone or in combination with other nutrients. Potassium chloride, also known as muriate of potash, is a relatively inexpensive source of K, but salinity from chloride in the fertilizer can damage the plants (see “Sources of nutrients,” Table 12). To minimize risk of salt injury to plants, do not apply more than 75 lb K_2O/acre of potassium chloride. Salt injury is often expressed as necrosis or burning on the edge of the leaves. Foliar applications of K are not recommended, as products can result in residue on the leaves and fruit, and leaf burning may occur. If your soil K is high but leaf K is low, be sure to examine your irrigation practices closely to ensure the fertilizer you apply is available to the plants.

Calcium

Most soils have sufficient Ca for caneberry growth, especially if the pH is within the recommended range (5.6 to 6.5). Calcium deficiencies can occur in high Mg soils, such as the serpentine soils found in southwest Oregon. Make sure to adjust your soil pH prior to planting by incorporating dolomite lime (if Mg is insufficient also) or agricultural lime when soil pH is too low (see “Soil pH” (https://extension.oregonstate.edu/node/217361/latest#established-plantings)and “Preplant considerations”), especially in organic production where nutrient options are more limited.

Calcium is immobile in plants. Since Ca moves as a dissolved nutrient in the xylem as it flows from the soil to leaf or fruit tissue during transpiration, low soil moisture conditions or cool, wet or cloudy weather can all decrease Ca uptake. Lime is a reliable, low-cost and effective source of Ca, when applied at recommended rates shown in Table 2. Most sources of lime qualify as organic, although growers should confirm prior to purchase and obtain approval from their certifying agency prior to application. In both new and established plantings, apply lime if Ca levels are below 5 meq Ca/100 g soil or 1000 ppm (Table 1). If soil pH is too high, consider alternative sources of Ca.

Other sources of Ca include calcium nitrate (conventional only), feather meal and gypsum, although they are generally not as cost-efficient as lime for meeting plant Ca requirements in caneberries. Calcium nitrate can provide a soluble source of Ca and N when applied in-season. In organic blueberries, feather meal was found to be an effective Ca source for increased leaf and fruit Ca after planting. Fine- or solution-grade gypsum (calcium sulfate) can be applied prior to planting, as well as injected as a suspension by fertigation through the drip irrigation system (may require specialized equipment), and will not change soil pH like lime. See “Sources of nutrients,” and check with local fertilizer representatives for product advice.

Research is ongoing to find an effective application timing, product and rate for foliar Ca (conventional or OMRI-approved organic products). Past studies have not been successful at increasing Ca levels in caneberry fruit or leaves in Oregon and Washington.

Magnesium

Dolomitic lime can be applied to acidic soils that are low in Mg (less than 1.0 meq/100 g of soil or 120 ppm, Table 1) at a rate of 1 ton per acre.

Magnesium may be banded using potassium magnesium sulfate (Sul-Po-Mag) or magnesium sulfate (Epsom salts) for organic or conventional production (see “Sources of nutrients”). Some products may be fertigated. Not all Mg products are approved for organic production, although the main ingredient may be allowed; check with your certifier prior to application. Foliar applications of Mg are not recommended, as products can leave a residue on the leaves and fruit.

Sulfur

Sulfur deficiency is uncommon in the Pacific Northwest, as soil S concentrations are usually adequate. Sulfur is also often added along with other materials, such as ammonium sulfate, potassium sulfate, or gypsum, and in fungicides. Sulfur is mobile in the soil, so soil tests are not particularly helpful indicators of sufficiency. When S application is needed, 30 to 40 lb S/acre is adequate. It can be added with N fertilizer or gypsum. See "Sources of nutrients" (Table 12) for N, P or K sources with significant S.

Sulfur and N are both key components of proteins and the N:S ratio in leaf tissue should be 15:1. Sulfur is likely deficient if the ratio is greater than 20:1.

Nutrient ratios

When tissue N is 3%, a 15:1 N:S ratio would represent 3% N and 0.2% S. For this tissue N concentration, a tissue S concentration of 0.1 percent would be low, creating an N:S ratio of 30:1. When using the ratio approach, be sure tissue N and S are not both low.

Manganese

High leaf tissue Mn concentrations (above 300 ppm) are an indication that soil pH is drifting downwards, as Mn availability increases at lower pH levels. Make sure that pH does not get too low, as many key nutrients become less available and micronutrients like Mn and Al can become toxic at soil pH levels lower than 5.5 (see "Soil pH").

Boron

Low soil B is typical in many fields in Western Oregon and Washington, including caneberries, because it is mobile in soil and winter rainfalls deplete soil levels. Boron deficiency may result in poor bud break, small fruit, cane dieback and reduced yield. Tissue testing is more effective at predicting crop B needs than soil testing (Table 11). Do not apply B without first testing to determine leaf nutrient status, as excessive use of B fertilizer was shown to reduce yield of raspberries in two of five years when it was applied to plants with adequate tissue B and overapplication can easily cause toxicity symptoms. High soil B levels may also reduce P uptake.

For established plants, broadcast B before budbreak in spring, based on measured soil and tissue levels (Table 11). Do not apply B as a band application, as this increases risk of toxicity. Granubor and Borax are good options for soil applied B in both organic and conventional production systems.

Boron is most effectively applied as a foliar spray in fall or spring prior to bloom, whereas soil-applied boron is more effective as a pre-plant amendment. Solubor (sodium pentaborate; 20% B) is a good foliar option for both organic and conventional production. Apply at a concentration of 2 lb sodium pentaborate (the equivalent of 0.4 lb of B) in 100 gal water. Solubor can also be applied by fertigation in spring through early summer (see "Application methods"), which has been shown to be as effective as foliar applications in blueberry and apple.

Table 11. Boron soil-applied fertilizer recommendations for caneberries based on soil (hot water extractable) or tissue tests

If the soil test for B (ppm) reads:	In raspberry[a], if tissue B (ppm) is:	In blackberry[a], if tissue B (ppm) is:	Apply this amount of B (lb/acre)[b]:
Below 0.5	Below 30	Below 30	2-2.5
0.5-1.5	30-80	30-70	1-2
Over 1.5	Over 80	Over 70	0

[a]Recommendations apply to both floricane- and primocane-fruiting types.
[b]Broadcast in the spring, prior to bud break; boron may also be applied as a foliar in spring or fall prior to bloom at label rates.

Iron

As soil pH declines, Fe becomes more available. Iron deficiency can be induced by high soil pH caused by excessive liming. Ideally, Fe deficiency in these situations would be corrected through modification of soil pH. Foliar applications may be used otherwise. Excessive leaf Fe may be a result of soil dust on the leaves. See Table 1, Table 4 and “Sources of nutrients.”

Zinc

Generally, soil tests are not good indicators of Zn availability to plants. Preplant-incorporated Zn applications are most effective, but foliar sprays or Zn fertigation may also be used when leaf Zn is deficient. See Table 1, Table 4 and “Sources of nutrients.” If tissue testing shows high levels of Zn (Table 4), this may be the result of fungicide residue remaining after application.

Copper

Copper is immobile in both soil and plants, but deficiency is uncommon unless you are planting into land that was previously unfarmed or was in pasture, sod or hay production. Copper can burn leaves and is toxic to roots at high levels. Copper is commonly used as a fungicide, especially in organic production, so you may already be applying Cu to your plants. If tissue testing shows high levels of Cu (Table 4), this may be the result of fungicide residue remaining after application.

Sources of nutrients

How much fertilizer product to apply depends on the percentage of the desired nutrient in the source of fertilizer you use. An example calculation is provided below. See the fertigation calculation box when applying product through a drip irrigation system.

Example fertilizer calculation

The amount of fertilizer to apply per acre equals the pounds of fertilizer recommended per acre divided by the percent nutrient in the product.

Let's say our target N rate is 50 lb/acre, and we are applying a product with a fertilizer analysis of 16N-20P-0K. Remember that this example product contains 16% N, 20% phosphate (P_2O_5) and 0% K.

The calculation would, therefore, be the amount of N recommended, divided by the percentage of N in the fertilizer product, multiplied by 100:

(50 lb N/acre ÷ 16) × 100 = 313 lb of product

In this case, you are also applying a substantial amount of phosphate. Multiply the total amount of product applied by the percentage of P_2O_5 in the fertilizer and divide by 100:

(313 lb product × 20) ÷ 100 = 63 lb P_2O_5 per acre

Apply the entire 313 lb of product to the in-row area only to achieve the recommended rate of 50 lb N/acre.

Caneberry plants use primarily nitrate-N. Ammonium-N is changed into nitrate-N by bacteria in the soil during a process called nitrification. Many growers use ammonium fertilizers such as urea because they are less expensive, but they may not be immediately available to the plants. Also, soil conditions such as pH and temperature affect the speed of nitrification. Ammonium-N is rapidly converted to nitrate-N in warm, moist soil with a pH above 6.0. In addition, ammonium-N will acidify the soil over time. For these reasons, amending the soil to the upper end of the suitable pH range (target of 6.0–6.5) prior to planting is a good idea. If ammonium-N is applied to caneberry fields with lower soil pH, nitrification will be greatly reduced and plants may be deficient in N, especially during critical early-season primocane growth, despite what appears to be adequate N being applied to the field.

Nitrate-N is very mobile in the soil and readily leaches. Applying nitrate fertilizers before heavy rainfall or during a time when the plants do not need fertilizer N will result in inefficient fertilizer use. Heavy rain will leach nitrate-N below the roots of the caneberry plants, making it unavailable later when needed, as well as increasing the risk of environmental pollution.

In fertigated fields, nutrient application during the season is adjustable. Dividing the plant's total N requirements into many applications minimizes the risk of nitrate-N leaching (see "Fertigation").

Organic growers need to consider that most OMRI-approved fertilizers are composed of organic N in the form of proteins or amino acids, and those need to be broken down or mineralized in the soil before the N is available to the plant. Liquid organic fertilizers derived from fish, soy or corn are more readily available to plants than solid products.

In organic blackberry research trials, there was no impact of several different OMRI-approved fertilizer sources (fertigated fish or corn solubles; pelletized soy; processed poultry litter) on yield or fruit quality of trailing and semi-erect cultivars. However, depending on the fertilizer source, the cost varies significantly per pound of N. Make sure to compare not just price per pound of the product, but also the price of the desired nutrient. Nutrient concentrations may vary considerably among fertilizer products. Use the fertilizer calculations to calculate price per pound of nutrient and how much of each product needs to be applied for the recommended level for each nutrient.

Compost used as a supplemental nutrient source needs to be applied in advance of crop nutrient demand to give enough time for the nutrients to become available. For floricane-fruiting caneberries, compost should be applied in late-winter or early spring. For primocane-fruiting caneberries, compost should be applied in early summer so that N is available when demand is high during primocane growth and flower bud development in late summer and early autumn. For information on the use of composts as a nutrient source, see "Preplant considerations."

If needed, organic P sources include compost, rock phosphate (soft and regular), bone and fish bone meal, bat guano and rock dust.

Many organic fertilizers, such as fish solubles, contain P and K in addition to N. Using this type of product may lead to excessive application of K if soil levels are sufficient. Monitor leaf nutrient levels (Table 4) to look for trends over time and adjust your nutrient management program as needed.

Table 12 shows common conventional and organic fertilizer sources. Organic fertilizers release nutrients more slowly and have a lower nutrient concentration than conventional fertilizers. Synthetic, conventional fertilizers tend to have a high salt index, which can burn plants if applied improperly. Some conventional fertilizers can easily leach out of the rooting zone, while nutrients in organic fertilizers tend to be integrated with organic matter, making them more stable and available to plants over a longer period.

Table 12. Percentage of nitrogen, phosphate (P_2O_5), potash (K_2O) and sulfur (S) in commonly used manures and organic and inorganic fertilizers

Fertilizer material	Percentage			
Manures[a]	**N**	**P_2O_5**	**K_2O**	**Water content**
Dairy	0.5	0.16	0.44	87
Beef	0.65	0.43	0.53	82
Poultry	2.5–2.8	2	1.5–1.7	73
Hog	0.45	0.27	0.4	84
Sheep	1	0.36	1	73
Horse	0.7	0.25	0.6	60
Organic fertilizers	**N**	**P_2O_5**	**K_2O**	**Sulfur**
Nitrogen sources				
Alfalfa meal	2	0.5	2	0
Bat guano	10	3	1	0
Feather meal[b]	12–13	0	0	0
Blood meal[b]	12–15	1	1	0

Fertilizer material	Percentage			
Cottonseed	6–7	2	1	0
Fish emulsion[b, c, d]	3–5	1	1	0
Fish meal[b]	10	6	2	0
Soybean meal	6	2	1	0
Phosphate sources				
Bone meal	1–4	12–24	0	0
Rock phosphate[e]	0	25–30	0	0
Compost[a]	1–2	0.3–0.9	0.5–1.5	0
Potassium sources				
Greensand	0	0	3–7	0
Kelp meal	1	0.1	2–5	0
Sul-Po-Mag (langbeinite)	0	0	22	22
Potassium sulfate	0	0	50	17
Compost[a]	1–2	0.3–0.9	0.5–1.5	0
Inorganic fertilizers	**N**	**P_2O_5**	**K_2O**	**Sulfur**
Nitrogen sources				
Ammonium sulfate	21	0	0	24
Ammonium sulfate solution[d]	8	0	0	9
Ammonium thiosulfate[d]	12	0	0	26
Ammonium phosphate	11	5	20	0
Ammonium phosphate-sulfate	16	20	0	15
Ammonium nitrate solution[d]	20	0	0	0
Calcium ammonium nitrate (granular)	27	0	0	0
Calcium ammonium nitrate (liquid)[d]	17	0	0	0
Calcium nitrate	15.5	0	0	0
Urea	46	0	0	0
Urea solution[d]	20 or 23	0	0	0
Urea-sul	37–46	0	0	4–8

Fertilizer material	Percentage			
Urea ammonium nitrate solution[d]	28–32	0	0	0
Phosphate sources				
Ammonium polyphosphate[d]	10 or 11	34 or 37	0	0
Triple superphosphate	0	45	0	0
Potassium sources				
Sulfate of potash-magnesia	0	0	21	11
Potassium chloride	0	0	60	0
Potassium-magnesium sulfate	0	0	22	22
Potassium nitrate	14	0	45	0
Potassium sulfate	0	0	48–53	17–18
Potassium thiosulfate[d]	0	0	21	17

[a]Perform lab nutrient analysis (and pH and EC) prior to consideration for use. See *Fertilizing with manure and other organic amendments,* *(https://extension.oregonstate.edu/catalog/pub/pnw-533-fertilizing-manure-other-organic-amendments)* PNW 533, and *Interpreting compost* analyses, (https://extension.oregonstate.edu/catalog/pub/em-9217-interpreting-compost-analyses) EM 9217. Be advised of any food-safety regulations. About 25% of the N is available in the first year.
[b]These materials contain a substantial amount of quickly available nutrients that plants can use early in the season.
[c]Fish emulsion is salty and will injure plants unless the product is diluted 1:10 (1 part fish to 10 parts water) prior to using.
[d]Suitable for fertigation.
[e]Very low availability (only 2%–3% of total P_2O_5). Useful only in acidic soils (pH 6.0 or below). Product has large effects on content: Phosphorite (usually 2%–4%); soft rock phosphate (16%–20%); rock phosphate (25%–33%).

Adapted from *Growing berries on the Oregon Coast: An overview,* (https://extension.oregonstate.edu/catalog/pub/em-9177-growing-berries-oregon-coast-overview) EM 9177, *Soil fertility in organic systems: A guide for gardeners and small acreage farmers,* (https://extension.oregonstate.edu/catalog/pub/pnw-646-soil-fertility-organic-systems-guide-gardeners-small-acreage-farmers) PNW 646, and *Nutrient management of blueberry — assessing plant nutrient needs and designing good fertilizer programs,* a presentation from the Oregon State University Blueberry School proceedings, March 16-17, 2015, by Bernadine Strik and David Bryla.

Application methods

Powdered, granular or pelletized

Broadcasting fertilizer over the entire field will result in less fertilizer applied to the plants, since recommendations are based on in-row applications. Boron and lime are the exceptions, where rates are recommended for the entire field area. For granular fertilizer products, apply to the effective rooting width or raised bed area in the row. Most caneberry roots are located and take up nutrients in the plant row, especially in drip-irrigated fields. See the "Nutrient recommendations" for specifics on granular products.

Fertigation

Fertigation is the practice of injecting liquid or water-soluble nutrients (conventional or organic) through the drip irrigation line using a fertilizer injector. In smaller plantings, a PTO-driven pump and tank may be used to apply fertilizers through the drip system.

With fertigation, nutrient application during the season is adjustable, and growers should aim to apply the annual amount needed based on their fertility plan between primocane emergence and harvest. Typically, plants are fertigated once a week during this time period. Fertilization should stop after harvest, as the majority of the N and other nutrients are taken up by the plants in spring and early summer. Be sure to pressurize the system prior to injecting the fertilizer to obtain uniform distribution. Continue to run irrigation after injection to ensure the system is flushed.

Many products, especially organic fertilizers, can clog emitters. Use a filter with your drip system, run the irrigation system after fertigating to clear the lines (water flush) and regularly clean the system with approved products (citric acid or peroxide-based cleaners that are OMRI-approved for organic, for example). Even with conventional fertilizers, clogging can occur from the presence of algae or iron bacteria in the system. If this occurs or persists, install a chlorination system to treat irrigation water. Minerals in irrigation water, such as calcium carbonate, can also lead to emitters clogging if they precipitate out of solution. Incompatible products can also lead to precipitates. Make sure that no precipitates form by doing a "jar test" first. This entails mixing the desired products at the ratio you will use them in a container of water. This test will help determine fertilizer compatibility and unpredicted chemical reactions.

Fertigation is usually more expensive than granular applications, but it provides accurate control over fertilizer rates and rapid availability of nutrients, potentially increasing uptake efficiency over granular applications. See "Nutrient recommendations" for rate and timing recommendations and Table 12 for products suitable for fertigation.

Example fertigation calculation

When calculating the rates to apply, consider that the nutrients are delivered directly to the rows, so the same calculations can be used as with side dress granular applications. In this case, you will need to divide the amount of product to apply by the density (weight per volume) of the liquid fertilizer to get the number of gallons needed.

To apply a recommended 50 lb N/acre using 23N–0P–0K urea solution (liquid), the calculation would be the amount of amount of N recommended, divided by the percentage of N in the fertilizer product, multiplied by

100:

(50 lb N/acre ÷ 23) × 100 = 217 lb of urea solution

To calculate how many gallons of urea to apply, divide the weight of urea solution needed by the density, or weight per gallon, of the solution as stated on the label (in this case 9.52 lb/gallon):

217 lb product ÷ 9.52 lb/gallon = 23 gallons of urea solution per acre per season

Divide this amount by the number of fertigation applications you will make over the season.

If you are mixing your own solution using a soluble granular fertilizer, such as ammonium sulfate (21N–0P–0K), which dissolves in water at a maximum solubility of 6.3 lb/gallon at 70°F, your calculation to apply 50 lb N/ acre would look like this:

(50 lb N/acre ÷ 21) × 100 = 238 lb of ammonium sulfate

In order to use enough water to ensure that all of the fertilizer is dissolved before injecting, divide the amount of product applied by the maximum solubility of the fertilizer (per the label):

238 lb ammonium sulfate ÷ 6.3 lb/gallon of water = at least 38 gallons of water

Foliar

Foliar applications are generally ineffective for getting macronutrients such as N, P, K, Mg and S into the plants. However, new formulations, the use of surfactants, and applying early in the day to allow maximum contact with the targeted tissues at key periods of uptake may increase uptake of some macronutrients, such as Ca.

Foliar Ca applications are often recommended to increase fruit firmness and shelf life. However, field trials in Oregon and Washington have shown that this is not an effective method in caneberries, although research is ongoing. Foliar Ca applications of conventional or organic products at recommended product label rates did not increase fruit firmness, quality, shelf life or Ca concentration, nor did they increase leaf Ca. Foliar applications of calcium chloride at higher rates have resulted in phytotoxicity (damage to leaves or fruit).

Foliar applications of micronutrients, such as B or Zn, can be effective when needed based on tissue testing (Table 4) and may be more efficient than soil applications. However, foliar-applied nutrients can be toxic and burn the leaves at high concentrations. Any nutrient applied as a foliar spray should be used with caution and at the lowest concentration possible. Some micronutrient foliar products also contain N. These products should be avoided, as N can burn the plant, and foliar application is not an efficient method of N delivery.

Caneberries can be sensitive to surfactants. If applying foliar fertilizers with a surfactant, aim to use a nonionic surfactant and evaluate first within a small section of the field for phytotoxicity.

Preplant considerations

Raspberry plants can live for five to 15 years, depending on type, cultivar, pest and disease pressure, and environmental conditions. Blackberry plants can live for 25 to 40 years. Accordingly, it is important to make some careful considerations before planting.

Soil testing

Caneberry plants grow best in fertile, well-drained loam soils with moderate water-holding capacity. Good drainage helps improve root growth and plant nutrient uptake. Test the soil well before planting to determine soil properties such as pH, organic matter content and nutrient levels.

Testing the soil and making any necessary adjustments prior to planting is a critical aspect of nutrient management in conventional and organic caneberry plantings. Soil testing can help you adjust soil nutrient deficiencies, organic matter levels or pH for good planting establishment. Nutrients such as P and K are relatively immobile in the soil and are not readily available to plants from surface applications. Consequently, these should be incorporated before planting as needed, based on soil test results.

Collect soil samples from representative locations around the field or block to be planted. Collect the samples six to 12 months before planting to allow time for soil modification. See *A guide to collecting soil samples for farms and gardens,* *(https://extension.oregonstate.edu/catalog/pub/ec-628-guide-collecting-soil-samples-farms-gardens)* EC 628, for detailed information on sampling patterns and soil testing. Take soil samples from the top 12–18 inches of soil where the roots will grow. Use a soil core to collect only soil in your sample, removing surface mulch, leaves or other organic matter. Send samples to a laboratory you intend to use throughout the life of the planting. That way, results will be directly comparable across years. Compile subsamples from one block into a bucket and take an appropriate-sized sample for sending to the testing lab. Contact the lab prior to sampling to confirm specifics on sample size and shipment details.

Recommended soil nutrient levels are presented in Table 1. Preplant nutrient incorporations should be based on these recommendations. Predicting N fertilizer application rates using soil tests is not recommended. Plant-available nitrate-N is very mobile in the soil, so large fluctuations are normal.

Soil pH

Caneberry plants require soils with a pH range of 5.6 to 6.5 for optimal growth and yield. In many growing areas in the Pacific Northwest, soil pH is too acidic for caneberries and needs to be increased by applying and incorporating lime before planting. Try to raise soil pH to the upper end of the ideal range, as ammonium-N fertilization will lower the soil pH over time. You can use either the Sikora or Shoemaker-McLean-Pratt buffer test to estimate how much lime is needed to raise your soil pH (Table 2). See the soil pH section under “Established plantings” for information on various forms of lime that can be used. Soil pH changes occur slowly, so apply and incorporate lime at least three months (and up to 12 months) prior to planting.

Consider lime or gypsum applications if soil Ca or Mg are also required based on the soil test results (Table 1). Sandy soils sometimes have a low pH and a high SMP buffer value. Typically, light lime applications of 1–2 tons per acre will neutralize soil acidity. Discuss your conditions with Extension agents or fertilizer advisors.

Organic caneberry growers need to obtain approval from their certifier for the type of lime they intend to use prior to application, as some binding agents, dust suppressants and manufacturing processes are not permitted and may risk organic certification status.

Top-dressed lime moves downward at a rate of ½ to 1 inch a year, up to 2 to 3 inches total, which is why adjusting soil pH before planting by incorporating lime is so critical.

If soil pH is too high (above 6.5 — more common in Eastern Oregon and Washington), add elemental sulfur (S) to acidify the soil (Table 3). For more information see *Acidifying soil for blueberries and ornamental plants in the yard and garden,* (https://extension.oregonstate.edu/catalog/pub/ec-1560-acidifying-soil-blueberries-ornamental-plants-yard-garden-west-cascade-mountain) EC 1560, and *Acidifying soil in landscapes and gardens east of the Cascades,* (https://extension.oregonstate.edu/catalog/pub/ec-1585-acidifying-soil-landscapes-gardens-east-cascades) EC 1585.

Nitrification — the rate at which ammonium-N is converted by soil bacteria into nitrate-N — is much slower at a low pH. Because caneberry plants primarily take up the nitrate form of N, rapid nitrification at pH 6.0 allows for the use of urea and other less-expensive inorganic ammonium-based fertilizers. It also allows for the use of organic N sources, which after mineralization (breakdown) predominantly contain the ammonium form of N.

Phosphorus

Phosphorus is highly immobile in soil. If soil levels are insufficient (Table 1), broadcast and incorporate fertilizer P before planting, such that P is placed in the rooting zone area. If a preplant soil test is deficient in P, apply double or triple the rate of phosphate recommended in Table 9, based on soil P level. See Table 12 for fertilizer sources.

Potassium

Preplant K fertilization rates should be determined using a soil test (Table 1). Potassium is not very mobile in the soil, so incorporation into the rooting zone area is the most effective application method. Prior to planting, broadcast and incorporate one-half to two-thirds of the required potash (K_2O) based on the soil test result (Table 10). Apply the remaining one-half to one-third of the recommended rate of potash with N and any P fertilizer applied a couple of weeks after planting (see "Nitrogen"). Do not apply more than 40 to 60 lb K_2O/acre by banding after planting, as it may burn new roots, especially in sandy soils.

Calcium

Most soils have sufficient Ca for caneberry growth, especially if the pH is within the recommended range. However, as indicated, Ca deficiencies can also occur in high Mg soils, such as the serpentine soils found in Southwest Oregon. Make sure to adjust your soil pH prior to planting by incorporating dolomite lime (if Mg is insufficient also) or agricultural lime when soil pH is too low (see "Soil pH"). In new plantings, apply lime if Ca levels are below 5 meq Ca/100 g soil or 1000 ppm (Table 1). Fine- or solution-grade gypsum (calcium sulfate) is commonly used in organic production, which can be applied prior to planting, as well as injected as a suspension through fertigation (may require specialized equipment). See "Sources of nutrients" and check with local fertilizer representatives for advice on available products.

Boron

Prior to planting, broadcast B and incorporate based on soil test results (Table 11). Granubor and Borax are good options for establishing either conventional or organic caneberry fields.

Organic amendments

A soil test will indicate the level of organic matter in the soil. Adequate levels of soil organic matter aid in moisture retention, nutrient holding/exchange capacity and soil structure. We recommend at least 3% of the soil be organic matter. You can increase soil organic matter content by amending the soil with fine, aged woodchips or sawdust, bark, well-composted manures or plant-based composts. It is important that whatever material you apply is free of arthropod pests and weed seeds. Apply organic matter down the row prior to planting, at a rate of 2–3 inches deep, depending on soil organic matter level, and incorporate it. Organic materials differ in nutrient content, pH, salt concentration (measured as EC or electrical conductivity) and the carbon to nitrogen ratio (C:N), each of which affects the rate of decomposition. Therefore, prior to application, they should be tested by an accredited lab for pH, nutrients and EC (should be less than 1 dS/m). For more information on use of organic matter in crop production, see *Improving garden soils with organic matter,* (https://extension.oregonstate.edu/catalog/pub/ec-1561-improving-garden-soils-organic-matter) EC 1561. For organic growers, organic amendments may also supply an important portion of the crop's nutrient needs.

Incorporate the organic material into the soil by tilling. Mixing in the amendment well ensures uniformity of soil properties. If you apply large amounts of fresh sawdust or other organic materials with high C:N, you can aid their decomposition by applying approximately 10 lb N/acre (see fertilizer calculation example). In areas with little summer rain, irrigate the intended planting area to ensure amendments, such as lime, elemental S or organic materials react thoroughly with the soil prior to planting.

Manure

Manure is an amendment derived from animal feces. Although there are green manures, which are defined as crops grown and cultivated into the soil when still green for provision of organic matter and other nutrients (see "Cover crops"), this section focuses on un-composted animal-based manures. Manure applied before planting increases soil organic matter, improves soil structure and enhances water and nutrient-holding capacity. It can also be a supplemental nutrient source for plants. Manure incorporated prior to planting provides a slow-release source of N and other nutrients for organic plantings and can reduce synthetic fertilizer costs for conventional growers. Fresh or noncomposted manure contains urea, which will volatilize and be lost into the air quickly, unless the manure is well incorporated into the soil. The use of raw manure is regulated by both the Food Safety Modernization Act and the USDA National Organic Program standards. See *Fertilizing with manure and other organic amendments,* (https://extension.oregonstate.edu/catalog/pub/pnw-533-fertilizing-manure-other-organic-amendments)PNW 533, for more information on manures and their risk of pathogens.

The N concentration in manure is low (see "Sources of nutrients"). It would require very high rates of manure application to meet crop demands for N, but manure may be used as a supplemental preplant nutrient source, as mentioned above. See *Estimating plant-available N from manure,* (https://extension.oregonstate.edu/catalog/pub/em-8954-estimating-plant-available-nitrogen-manure) EM 8954, for more information on the percentage of nutrients available to plants in dairy-sourced manure. If you apply manure in the fall prior to planting, spread it over a cover crop (see below) to capture the N that might otherwise be leached out during the rainy season, or incorporate it into the soil prior to seeding the cover crop.

Compost

Compost is plant- or animal-based material that has decomposed and broken down over time into stable organic matter. Like fresh manure, compost increases the water- and nutrient-holding capacity of the soil. Composts with high microbiological activity may contribute to soil health and disease suppression in caneberry. Some composts may introduce weed seeds to the caneberry planting, so careful selection of well-composted material is required. Organic growers must meet specific requirements for feedstock, the C:N ratio, temperature and manufacturing process for their compost to be considered compliant and allowed for use. Refer to the NOP standards for more details and work with a certifier to confirm an approved compost.

Composted manure or other composts contain much less inorganic N than fresh manure. Instead, the N is part of organic compounds that will break down into a form that is accessible to the plants over a long period. Applications of fertilizer N may still be necessary during the growing season to sustain plant growth, since using compost as the sole N source for caneberries may lead to overapplication of other nutrients such as P and K, depending on the source material. However, compost is a good source of P and K when it is applied prior to planting in organic production systems. See *Fertilizing with manure and other organic amendments,* (https://extension.oregonstate.edu/catalog/pub/pnw-533-fertilizing-manure-other-organic-amendments) PNW 533, and *Interpreting compost analyses,* (https://extension.oregonstate.edu/catalog/pub/em-9217-interpreting-compost-analyses) EM 9217.

Inoculants

Commercial microbial inoculants are often promoted at planting to increase root colonization by beneficial bacteria and fungi with the aim of improving plant nutrient uptake and subsequent growth. However, raspberry roots naturally form these associations with microorganisms already present in field soil, and these microbial associations do not consistently increase plant growth. Furthermore, there are some ecological concerns regarding the introduction of non-native microorganisms to soils through commercial inoculant use.

Humic and fulvic acids

Humic and fulvic acids (sometimes called “organic” acids or humic substances) are molecules that are extracted from materials such as coal, lignite, soil, peat, compost or animal sources and applied to crops as biostimulants. These substances are becoming a common addition to fertility programs, as they are known to promote plant growth and root development in many crops. In red raspberry grown in Washington, application of humic and fulvic acids improved plant growth in the first two years after planting but had no effect on growth or yield in mature plants.

Cover crops

Cover crops can be beneficial for a number of reasons. A cover crop that is grown to be incorporated into the soil is called a green manure crop. Green manures help maintain soil porosity and structure, increase water infiltration, improve soil aggregate stability, add organic matter to the soil and are a source of nutrients for caneberry plants.

Cover crops may also suppress weeds and pests and control soil erosion prior to planting caneberries. If cover crops are planted after manure, or if there are other sources of N in the soil, they can capture the nutrients and hold onto them until the cover crop is incorporated.

Some cover crops with a high N concentration, such as legumes, will decompose and release N quickly back into the soil. Others, such as cereal crops, will decompose slowly and hold N for a longer period of time. Initially, microbial decomposition of cover crops with a higher C:N ratio will reduce plant-available N. Time must elapse before this N is released into the soil again and is available for plant uptake. Therefore, caneberries should not be planted immediately after cover crop incorporation.

Cover crops should decompose for a minimum of one month in the spring or summer before caneberries are planted. There are several good resources available to estimate N release from cover crops, including OSU Extension’s organic fertilizer and cover crop calculators, (https://extension.oregonstate.edu/organic-fertilizer-cover-crop-calculators)and *Estimating plant-available nitrogen release from cover crops,* (https://extension.oregonstate.edu/catalog/pub/pnw-636-estimating-plant-available-nitrogen-release-cover-crops) PNW 636.

Relevant research papers

- Bryla, D.R. 2016. A comparison between fertigation and granular fertilizer applications on yield and leaf nitrogen in red raspberry. Acta Horticulturae 1133:527-531.
- Bryla, D.R. and O.L. Vargas. 2023. Beneficial use of biostimulants in northern highbush blueberry. Acta Horticulturae 1357:43-50.
- Calvo, P., L. Nelson and J.W. Kloepper. 2014. Agricultural uses of plant biostimulants. Plant Soil 383:3–41.
- Chaplin, M.H. and L.W. Martin. 1980. The effect of nitrogen and boron fertilizer applications on leaf levels, yield and fruit size of the red raspberry. Communications in Soil Science and Plant Analysis 11:547–556.
- Dixon, E.K., B.C. Strik, and D.R. Bryla. 2016a. Weed management, training and irrigation practices for organic production of trailing blackberry: III. Accumulation and removal of aboveground biomass, carbon and nutrients. HortScience 51:51-66.
- Dixon, E.K., B.C. Strik and D.R. Bryla. 2016b. Weed management, training, and irrigation practices for organic production of trailing blackberry: II. Soil and aboveground plant nutrient concentrations. HortScience 51:36-50.
- Fernandez-Salvador, J., B.C. Strik and D.R. Bryla. 2015a. Liquid corn and fish fertilizers are good options for fertigation in blackberry cultivars grown in an organic production system. HortScience 50:225-233.
- Fernandez-Salvador, J., B.C. Strik and D.R. Bryla. 2015b. Response of blackberry cultivars to fertilizer source during establishment in an organic fresh market production system. HortTechnology 25:277-292.
- Harkins, R.H., B.C. Strik and D.R. Bryla. 2014. Weed management practices for organic production of trailing blackberry: II. Accumulation and loss of biomass and nutrients. HortScience 49:35–43.
- Jones, P.A., A.J. Davis and B.C. Strik. 2021. Alignment between university nutrient guidelines and grower practices for blackberry and red and black raspberry in Oregon. Journal of The American Pomological Society 75:17-30.
- Leon-Chang, D.P., and D.R. Bryla. 2024. Applying boron by fertigation or as a foliar fertilizer is more effective than soil applications in northern highbush blueberry. HortScience (in press).
- Lu, Q., C. Miles, H. Tao and L.W. DeVetter. 2022. Evaluation of real-time nutrient analysis of fertilized raspberry using petiole sap. Frontiers in Plant Science. 2729.
- Lu, Q., R. Bunn, E. Whitney, Y. Feng, L.W. DeVetter and H. Tao. 2023. Arbuscular mycorrhizae influence raspberry growth and soil fertility under conventional and organic fertilization. Frontiers in Microbiology 14.
- Makepeace, C., A. Moore, D. Sullivan and D. Huggins. 2022. Evaluation of nonhazardous lime requirement estimation methods for Oregon. Soil Science Society of America Journal. 86:1354-1367.
- Mohadjer, P., B.C. Strik, B.J. Zebarth and T.L. Righetti. 2001. Nitrogen uptake, partitioning and remobilization in `Kotata' blackberries in alternate year production. Journal of Horticultural Science and Biotechnology 76:700-708.
- Muscolo, A., M. Sidari and S. Nardi. 2013. Humic substance: relationship between structure and activity. Deeper information suggests univocal findings. Journal of Geochemical Exploration. 129:57-63.
- Neilsen, G.H., D. Neilsen, E.J. Hogue and L.C. Herbert. 2004. Zinc and boron nutrition management in fertigated high density apple orchards. Canadian Journal of Plant Science 84:823-828.
- Rempel, H., B. Strik, and T. Righetti. 2004. Uptake, partitioning and storage of fertilizer nitrogen in red raspberry as affected by rate and timing of application. Journal of the American For Society Horticultural Science. 129:439-448.

- Strik, B.C. 2015. Seasonal variation in mineral nutrient content of primocane-fruiting blackberry leaves. HortScience 50:540-545.
- Strik, B.C. and D.R. Bryla. 2015. Uptake and partitioning of nutrients in blackberry and raspberry and evaluating plant nutrient status for accurate assessment of fertilizer requirements. HortTechnology 25:452-459.
- Strik, B., T. Righetti and H. Rempel. 2006. Black plastic mulch improved the uptake of ^{15}N from inorganic fertilizer and organic prunings in summer-bearing red raspberry. HortScience 41:272-274.
- Strik, B.C., and A.J. Vance. 2016. Leaf nutrient concentration in blackberry – recommended standards and sampling time should differ among blackberry types. Acta Horticulturae 1133:311-317.
- Strik, B.C., and A.J. Vance. 2017. Seasonal variation in mineral nutrient concentration of primocane and floricane leaves in trailing, erect, and semi-erect blackberry cultivars. HortScience 52:836-843.
- Strik, B.C., and A.J. Vance. 2018. Seasonal variation in mineral nutrient concentration of primocane and floricane leaves in trailing blackberry cultivars produced in an organic system. Journal of the American Pomological Society 72:181-193.
- Strik, B.C., A.J. Vance, D.R. Bryla and D.M. Sullivan. 2019. Organic production systems in northern highbush blueberry: II. Impact of planting method, cultivar, fertilizer, and mulch on leaf and soil nutrient concentrations and relationships with yield from planting through maturity. HortScience 54:1777-1794.
- Vance, A.J., P. Jones and B.C. Strik. 2017. Foliar calcium applications do not improve quality or shelf-life of strawberry, raspberry, blackberry, or blueberry fruit. HortScience 52:382-387.

Resources

Other Extension publications

- *A guide to collecting soil samples for farms and gardens,* (https://extension.oregonstate.edu/catalog/pub/ec-628-guide-collecting-soil-samples-farms-gardens) EC 628
- *Acidifying soil for blueberries and ornamental plants in the yard and garden* (https://extension.oregonstate.edu/catalog/pub/ec-1560-acidifying-soil-blueberries-ornamental-plants-yard-garden-west-cascade-mountain), EC 1560
- *Acidifying soil in landscapes and gardens east of the Cascades* (https://extension.oregonstate.edu/catalog/pub/ec-1585-acidifying-soil-landscapes-gardens-east-cascades), EC 1585
- *Applying lime to raise soil pH for crop production (Western Oregon)* (https://extension.oregonstate.edu/catalog/pub/em-9057-applying-lime-raise-soil-ph-crop-production-western-oregon), EM 9057
- *Commercial red raspberry production in the Pacific Northwest,* *(https://extension.oregonstate.edu/catalog/pub/pnw-598-commercial-red-raspberry-production-pacific-northwest)* PNW 598
- *Eastern Oregon liming guide,* (https://extension.oregonstate.edu/catalog/pub/em-9060-eastern-oregon-liming-guide)EM 9060
- *Estimating plant-available N from manure,* *(https://extension.oregonstate.edu/catalog/pub/em-8954-estimating-plant-available-nitrogen-manure)* EM 8954
- *Estimating plant-available nitrogen release from cover* crops, (https://extension.oregonstate.edu/catalog/pub/pnw-636-estimating-plant-available-nitrogen-release-cover-crops)PNW 636
- *Fertilizing with manure and other organic amendments* (https://extension.oregonstate.edu/catalog/pub/pnw-533-fertilizing-manure-other-organic-amendments), (https://extension.oregonstate.edu/catalog/pub/pnw-533-fertilizing-manure-other-organic-amendments) PNW 533
- *Growing berries on the Oregon Coast: An overview,* (https://extension.oregonstate.edu/collection/growing-berries-oregon-coast) EM 9177

- *Growing berries on the Oregon Coast: Raspberries and blackberries,* (https://extension.oregonstate.edu/catalog/pub/em-9180-growing-berries-oregon-coast-raspberries-blackberries) EM 9180
- *Growing blackberries in your home garden,* *(https://extension.oregonstate.edu/catalog/pub/ec-1303-growing-blackberries-your-home-garden)* EC 1303
- *Growing raspberries in your home garden,* *(https://extension.oregonstate.edu/catalog/pub/ec-1306-growing-raspberries-your-home-garden)* EC 1306
- *Growing small fruits in the home garden,* *(https://pubs.extension.wsu.edu/growing-small-fruits-in-the-home-garden-home-garden-series)* EM 103E
- *Improving garden soils with organic matter,* (https://extension.oregonstate.edu/catalog/pub/ec-1561-improving-garden-soils-organic-matter) EC 1561
- *Interpreting compost analyses* (https://extension.oregonstate.edu/catalog/pub/em-9217-interpreting-compost-analyses), EM 9217
- *Organic fertilizer and cover crop calculators* (https://smallfarms.oregonstate.edu/calculator)
- *OSU organic fertilizer and cover crop calculator: Predicting plant-available nitrogen,* *(https://extension.oregonstate.edu/catalog/pub/em-9235-osu-organic-fertilizer-cover-crop-calculator-predicting-plant-available)* EM 9235
- *Soil acidity in Oregon: Understanding and using concepts for crop production,* (https://extension.oregonstate.edu/catalog/pub/em-9061-soil-acidity-oregon-understanding-using-concepts-crop-production)EM 9061
- *Soil Fertility in Organic Systems: A Guide For Gardeners And Small-acreage Farmers,* *(https://pubs.extension.wsu.edu/soil-fertility-in-organic-systems-a-guide-for-gardeners-and-small-acreage-farmers)* PNW 646
- *Soil nitrate testing for Willamette Valley vegetable production,* *(https://extension.oregonstate.edu/catalog/pub/em-9221-soil-nitrate-testing-willamette-valley-vegetable-production)* EM 9221
- *Soil test interpretation guide,* (https://extension.oregonstate.edu/catalog/pub/ec-1478-soil-test-interpretation-guide) EC 1478

Additional information

- FDA Food Safety Modernization Act (https://www.fda.gov/food/guidanceregulation/fsma/)
- OSU Extension organic fertilizer and cover crop calculators (https://smallfarms.oregonstate.edu/calculator)
- USDA NOP standards (https://www.ams.usda.gov/rules-regulations/organic/handbook)

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