

Nutrient Management for Blueberries in Oregon

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Commercial blueberry production in Oregon is dominated by the northern highbush type, although rabbiteye blueberries are produced on limited acreage. This publication addresses nutrient management of northern highbush blueberries in western Oregon. Where data are available to support management differences by blueberry type, this information is provided.

The following questions are addressed in this publication. These questions should be answered before any fertilizer is applied.

- How much fertilizer should be applied?
- When should the fertilizer be applied (timing)?
- What source (type) of nitrogen should be applied?
- What method of application should be used?

Growing condition assumptions

In western Oregon, blueberries typically are planted in Amity, Chehalis, Coloquato, Jory, Malabon, Nekia, Willamette and Woodburn soils. A typical yield for a well-managed, mature field is 8 to 9 ton/a.

Blueberries usually are planted at 3 ft x 10 ft spacing on either raised beds or flat ground. Douglas-fir sawdust generally is used as a preplant soil amendment. This guide assumes that 3.5 inches of sawdust are applied in 3-foot-wide strips on 10-foot centers and incorporated 10 inches deep before planting. Typically, container stock is planted in October, and a 2-inch surface sawdust mulch is applied.

Recommendations are based on research and experience with blueberry production in this setting and on research in other areas. Recommendations in this publication may not produce desired results in other production areas, especially in semiarid environments where soil pH is naturally above 6.0, water contains salts and carbonates, and warm winter temperatures limit the accumulation of chilling degrees.

Blueberry plants require chemical elements from air, water, and soil to ensure adequate vegetative growth and fruit production. When levels of these nutrients in the plant are inadequate, growth and yield may be affected. Severely reduced nutrient supply can lead to visible nutrient deficiency symptoms, such as leaf discoloration (Figure 1 and 2) and distortion.



Figure 1. Chlorosis caused by iron deficiency.



Figure 2. Nitrogen deficiency

The goal of fertilization for any high-value crop is to remove limitations to yield and quality by supplying the crop with ample nutrition in advance of demand. Nutrient application should be based on soil and plant analyses and grower experience. Consider the return on your fertilizer investment as well as environmental stewardship. A fertilizer application should be "bio"logically sound; in other words, it should produce a measurable change in plant growth or nutrient status. A fertilizer application is expected to increase fruit yield or quality, producing a return on your investment.

Results from a nutrient application will vary from field to field and from year to year. This guide does not address every circumstance encountered by growers. Growers, with the assistance of county Extension faculty and field representatives, should annually consider nutrient needs of each field. Routine analysis of soil and tissue samples is helpful in determining fertilizer requirements. Annual tissue testing can detect low nutrient concentration before visible symptoms or yield reduction occurs.

To assist with interpretation of soil and tissue analyses, keep records of weather, disease problems, and nutrient applications for each field. Observations of annual growth (whip number, diameter, and shoot length), yield, leaf color, and fruit quality (berry set and firmness) are also helpful.

The use of fertilizer should be part of a complete management package. Management practices from selection of certified plants to pre- and postharvest irrigation must be performed in an appropriate and timely manner so that plants can benefit from applied nutrients. Nutrient application is not a substitute for poorly timed irrigation, late harvest, or failure to control insects, diseases, rodents, or weeds. Soil properties such as high pH and/or poor drainage can be significant limiting factors to obtaining high berry yields. Increasing fertilizer rates or adding nutrients already in adequate supply will not correct these limiting factors.

Tissue testing

By analyzing plant tissue for nutrient content (tissue testing), you can evaluate the adequacy of nutrient levels. Plant tissue analyses indicate which elements are accumulated in adequate, deficient, or excessive amounts. This information will help you decide whether fertilizer is needed and, if so, how much and what kind.

Changes in tissue analyses for some nutrients, such as nitrogen (N) and boron (B), can occur within a few weeks of nutrient application. Typically, however, changes in nutrient concentration in a perennial crop such as blueberries require a longer time (sometimes as long as 2 years), especially when immobile materials (phosphorus and potassium) are applied to the soil surface.

Tissue testing can be used for any of the following:

- Predicting fertilizer needs of annual crops
- Diagnosing problems
- Evaluating a fertilizer program for perennial crops

Tissue testing can be used to monitor and adjust fertilizer use during early growth stages of annual crops such as potatoes, sugar beets, or lettuce. A tissue test can help growers anticipate fertilizer needs for these annual crops.

In contrast, tissue test results are not very useful for predicting current-season fertilizer needs of perennial crops such as blueberries. In part, this limitation is due to the minimal short-term effect of fertilizer on yield in perennial crops. In producing blueberries, tissue testing is best used for end-of-season evaluation of a fertilizer program.

If problems such as poor growth or discoloration of shoots or whips appear during the growing season, you can use a tissue test to check for nutrient deficiencies. When sampling outside the late July to mid-August time period (see “When to sample,” below), you must collect a companion sample from an unaffected area for comparison.

Tissue testing is based on sampling at the proper time, sampling the appropriate plant part, and using “standards” for comparison. The following sections discuss these topics.

When to sample

Tissue samples should be collected when nutrient concentration is stable. Samples collected just a few days apart during periods of rapidly changing nutrient concentration can give quite different results. For example, tissue N concentration changes rapidly early in the growing season but slowly after early July (Figure 3).

For evaluation of blueberry nutrient status, collect leaf tissue between late July and mid-August. Samples collected between these dates produce consistent analytical results.

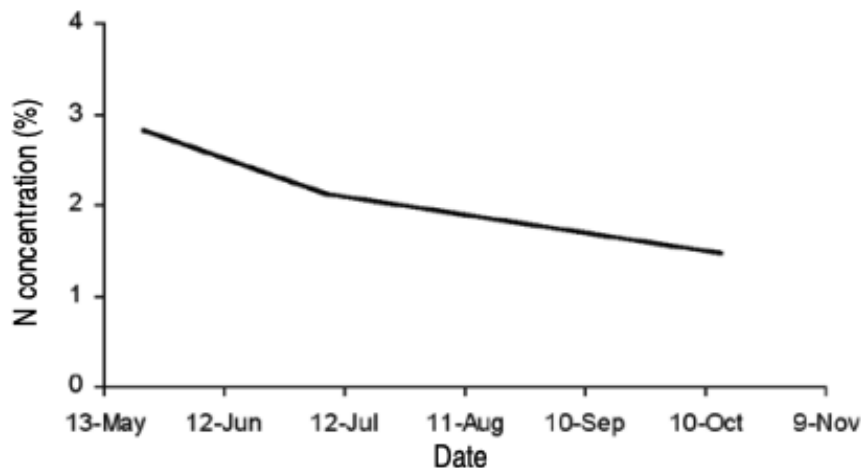


Figure 3. Seasonal change in 'Bluecrop' blueberry leaf tissue nitrogen concentration. Data are average leaf tissue concentrations from the whole plant.



Figure 4. Collect the most recent fully expanded leaves. Do not take leaves from whips.

How to sample

Collect samples of the most recent fully expanded leaves (Figure 4). Do not take leaves from whips. Collect leaves that are free of disease or other damage if possible. Pick leaves so that the petiole (stem) remains with the leaf.

Sample 5 leaves each from at least 10 plants distributed randomly throughout the field. A single sample should not represent more than 10 acres.

Do not mix cultivars in a tissue sample, as mixed samples have more variability. For example, cultivars might have different fruiting seasons and times of growth flushes; thus, they might differ in leaf nutrient concentration at any given time.

If the purpose of leaf sampling is to diagnose a suspected problem, collect one sample from affected plants and another from apparently healthy plants.

Do not wash samples. Put leaves in a paper (not plastic) bag. Air dry them or send them to a laboratory immediately. To avoid spoilage, ship fresh (moist) samples early in the week to ensure delivery before the weekend.

A list of laboratories performing tissue analyses is found in *Laboratories Serving Oregon: Soil, Water, Plant Tissue, and Feed Analysis (EM 8677)*.

Frequency of sampling

Annual sampling from all fields is recommended so that trends can be observed. This will allow adjustments in fertilizer application before a nutrient deficiency or excess occurs.

Other considerations

Tissue analysis results outside the normal range cannot always be attributed to the fertilizer program. Insufficient mineral nutrient concentration can be caused by unfavorable soil pH; saturated or dry soils; high temperatures; frost; shade; weed, insect, or disease pressure; herbicide injury; or overcropping. Insufficient pruning, resulting in a yield too high for the bush to support, will reduce overall bush vigor and root, shoot, and whip growth, and will result in tissue concentrations outside the normal range.

Several fungicides contain plant nutrients. Because tissue samples are not washed before analysis, high levels of copper (Cu), manganese (Mn), or zinc (Zn) might be the result of fungicide residue. High B and Zn also might occur after liquid or foliar fertilizer application.

Interpreting tissue test results

The sections on pages 6–11 discuss tissue concentrations and fertilizer application rates for specific nutrients. Compare the results from a laboratory analysis to the values in Tables 4–8 to determine whether sufficient nutrients were supplied by the soil and your fertilizer program.

Do not apply fertilizer based solely on lab results, however. Also review plant growth and yield from the previous season. Choose the combination of tissue analysis results and crop growth listed below that corresponds to your situation. Keep this information in mind as you use Tables 4–8.

- Low tissue analyses and abundant cane growth. A good target is 10 to 12 inches of shoot growth on 2-year-old canes by the end of the season. If growth is more luxurious, don't apply additional fertilizer even if tissue nutrient concentrations are low. Lower-than-normal tissue nutrient concentrations are common when growth is excessive because the tissue nutrient content is diluted by the intensive growth. This condition should correct itself when growth returns to normal. This situation usually is caused by oversupply of N; therefore, do not apply extra fertilizer, especially N. Belownormal N and high vigor also can occur on shoots with little or no crop. Note that rabbiteye types are more vigorous than highbush types and consequently require much less N than highbush types.
- Low tissue analyses and weak growth. If shoots or overall growth are weak, discolored, or stunted, and tissue nutrient concentrations are low, apply fertilizer at rates recommended in this publication.
- Normal tissue analyses and growth. If tissue analyses and growth are within the normal range, continue with your current fertilizer program.
- Above-normal tissue analyses and weak growth. If shoots are weak, discolored, or stunted, and tissue analyses are above normal, look for stress from pests, drainage, drought, frost, overcropping (not pruning hard enough), or other factors limiting growth.
- Above-normal tissue analyses and growth. If tissue analyses are above normal and growth is adequate or above normal, reduce the amount of fertilizer you apply, especially N.

Soil sampling

In contrast to use of annual tissue analyses to assess the adequacy of a fertilizer program, soil analysis is most useful before planting to determine what adjustments are needed. For example, soil pH might be too high for optimum blueberry production.

Obtain soil samples at least a year before planting so soil pH can be adjusted if necessary (see “Site preparation”). Applications of elements such as K and magnesium (Mg) also are more accessible to plant roots when mixed with the soil rather than broadcast over the surface after planting.

After planting, soil analyses can be helpful in diagnosing problems, such as high soil pH or excessive salts. Obtain samples from the area between the dripline and the crown.

Fertilizer is commonly applied in a wide band centered on the blueberry rows. This application method concentrates nutrients, complicating soil sampling after site establishment. For example, banding of N can decrease soil pH in the row more than between rows (Figure 5). In this example, the surface soil pH also was lower than the subsurface soil pH. A similar pattern can be found for nutrients such as K when fertilizer is placed in a band on the soil surface.

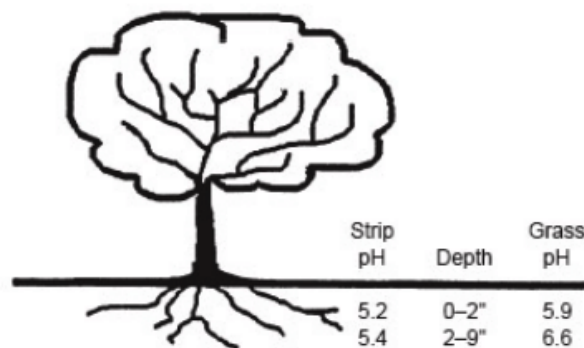


Figure 5. Soil pH differences from samples taken between rows and under the drip line. The figure also shows differences in soil pH with depth.

Additional information is found in Soil Sampling for Home Gardens and Small Acreages (EC 628) and Monitoring Soil Nutrients Using a Management Unit Approach (PNW 570-E).

Site preparation

Planting blueberries is an investment that can cost more than \$10,000 per acre (Blueberry Economics, EM 8526-E). A suitable site is necessary for growth, optimum production, and prompt recovery of the initial investment. Such a site has air and water drainage, good quality irrigation water, and adequate soil pH. Additional information is available in Proceedings for the 2004 Blueberry Production Course and in Highbush Blueberry Production (PNW 215).

Acidifying soil

High soil pH is one of the primary problems encountered with new blueberry fields. When blueberry plants are grown in high-pH soil, the leaves, especially new growth, are yellow with green veins or completely yellow. These leaves are small and often turn brown and fall from the plant before the end of the season. Little growth occurs, and some plants may die (Figures 6 and 7).

Plants stunted by high soil pH usually do not recover even when soil pH is reduced. Blueberries established in high-pH fields often require replanting to obtain a vigorous, uniform stand.



Figure 6. Rabbit-eye blueberry plant killed by high soil pH.



Figure 7. Highbush blueberry plant severely stunted by high soil pH.

The soil pH recommended for highbush blueberry production is 4.5 to 5.5; for rabbit-eye blueberries it is 4.2 to 5.0. Use the upper limit of soil pH as your target when planting, as soil pH will decline over time with application of N fertilizer. Plant highbush types in fields with soil pH about 5.5 and rabbit-eye blueberries at pH 5.0.

Measure soil pH well in advance of final site selection and planting. If soil pH is too high, acidify the soil a year before planting. Adjusting soil pH after planting is expensive, difficult, inefficient, and sometimes impossible.

Preplant acidification usually is achieved by applying and incorporating elemental sulfur (S). Elemental S can be supplied by a single application or by several smaller applications. Neither approach is superior. Splitting the elemental S application is a cautious approach compared to a more aggressive single application. Use finely ground S for acidification. Incorporation of elemental S is necessary for acidification to occur in a timely manner.

Acidification is a new management practice for western Oregon. See *Acidifying Soil for Crop Production West of the Cascade Mountains* (EM 8857-E) for more information.

Timing of acidification

IF PH NEEDS TO BE REDUCED BY MORE THAN 0.2 UNIT:

begin the acidification process a year before planting. Acidification using elemental S relies on microorganisms for conversion of S to sulfate. This process requires warm, moist conditions. Even an early fall application does not provide sufficient time or soil warmth for the elemental S to completely react by the following spring (Figure 8).

Data for Figure 8 were collected from a silty clay or silty clay loam soil in the Willamette Valley (Table 1). A single 3,500 lb/a elemental S application incorporated in September did not decrease soil pH for 6 months. The initial decrease was slight, 0.2 to 0.3 pH unit. When the soil warmed in the summer, soil pH declined from 5.3 to 4.8 in approximately 4 months. The acidification reaction seemed to be complete a year after application, as soil pH decreased only 0.1 unit during the second winter after application.

Table 1. Soil information and elemental S rate for sites represented in Figure 8 and 9.

	Figure 8	Figure 9
Soil series	Not available	Malabon
Clay %*	38.8	25
Soil textural class	Clay loam/clay	Loam/clay loam
Cation exchange capacity	34 meq/100 g soil	21 meq/100 g soil
Initial soil pH	5.6	6.4
Initial S application date	September 20, 2003	June 25, 2003
Initial S application rate	3,000 to 3,500 lb/a	600 lb of 0-0-95/a
Second S application date	None	October 3, 2003
Second S application rate	None	600 lb of 0-0-95/a
Table in Acidifying Soil for Crop Production West of the Cascade Mountains used to estimate S rate	Table 7	Table 5

*Determined by hydrometer method.

Figure 9 illustrates soil pH change from two elemental S applications, 3 months apart. Elemental S was initially applied in late June 2003 (Table 1). Three months later, soil pH had declined 0.5 pH unit, and the reaction was complete. A second application of elemental S was incorporated in October 2003. From October to March, soil pH declined only slightly. A sharp decline was measured after the summer of 2004. The reaction resulting from the second application was similar to that resulting from the fall application shown in Figure 8.

The data in Figures 8 and 9 highlight the need to acidify soil a year before planting. Be patient after a fall application, as the acidification process will begin slowly. Soil pH likely will decline only a few tenths of a unit until soils warm. In contrast, soil pH declines rapidly in the 3 to 4 months following a summer application.

The sites in Figures 8 and 9 were not irrigated. Winter and spring rainfall usually provides enough moisture for the acidification reaction.

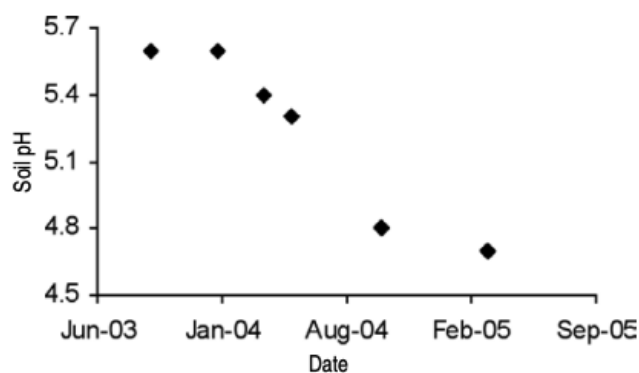


Figure 8. Soil pH change from a single incorporated elemental S application. Table 1 provides site and application details.

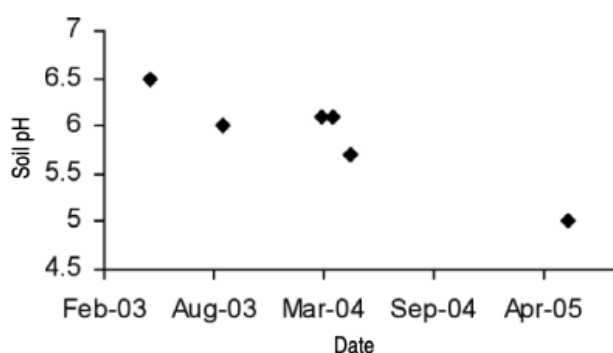


Figure 9. Soil pH change from two incorporated elemental S applications. Table 1 provides site and application information.

No “best” time exists for application of elemental S; choose a time that fits your situation. In western Oregon, the soil usually is dry in the fall, making tillage and incorporation of S easier. Delaying S application until spring risks wet conditions for incorporation, but should not disrupt planting a year after incorporation if the soil is kept moist throughout the summer.

IF INITIAL SOIL PH IS ONLY 0.1 OR 0.2 UNIT ABOVE THE DESIRED RANGE:

Acidification and planting can be within a few months of each other. One option is to incorporate elemental S in the fall and plant in the spring, 4 to 6 months after S application.

If the soil pH is below 6.0 and container stock is planted, another option is to plant a few days after a spring or fall application of elemental S. If elemental S is incorporated shortly before planting, it will react after establishment.

Soil also can be acidified after establishment by adding an acid through the drip irrigation system. The resulting reduction in soil pH usually is 0.2 to 0.3 unit.

How much elemental S to apply

Soil differs dramatically in the S rate needed for acidification. The two soils in Figures 8 and 9 are excellent examples. Even though the initial soil pH in Figure 8 was 1 unit lower than that of the soil in Figure 9, it required three times the amount of elemental S. Not only were the S rates markedly different, so was the amount of acidification. The higher S rate applied to the soil in Figure 8 reduced soil pH 1 unit, while the lower rate in Figure 9 reduced soil pH 1.5 unit.

Elemental S rates vary for each field. The tables in Acidifying Soil for Crop Production West of the Cascade Mountains should be used only to estimate S rate. The tables are based on soil buffering capacity, or how easily soil pH can be changed. The primary agent buffering soil is cation exchange capacity (CEC). Soil analysis for CEC is a better guide than soil series for selecting the S rate table. Experience with your soil and situation is necessary to select an elemental S rate that will achieve your pH target.

Before you plant!

Before making the investment to establish a blueberry planting, be sure to:

- Measure soil pH
- Allow sufficient time, possibly a year, for acidification
- Proceed cautiously with elemental S application
- Monitor or measure soil pH several times before planting.

Sawdust

Incorporation of Douglas-fir sawdust or compost prior to planting is a common industry practice. Recent research has shown that sawdust incorporated prior to planting may not improve plant growth in a good, well-drained sandy loam, loam, or silt loam. However, incorporation of an organic material such as sawdust can offer advantages in heavier soil.

To use sawdust preplant, apply 3.5 inches of sawdust in 3-foot-wide strips on 10-foot centers (19 units/acre). Add 5 lb N/unit of sawdust (95 lb N/acre) and incorporate to a depth of 10 inches. Sawdust contains little N. Soil microbes

require N for sawdust decomposition, and they are more efficient at using soil N than are plants. Fertilizer N must be added so that normal microbial decomposition can occur without taking N from newly planted blueberries. Incorporated sawdust immobilizes more N than does sawdust applied to the surface.

Use of cedar, oak, walnut, or any other sawdust often is associated with chlorotic (yellow) leaves and poor growth. In addition, growers have lost a year or more of blueberry plant growth by incorporating horse bedding prior to planting; some horse bedding contains added lime and has a pH over 6.5. This material is not recommended for use in blueberry production.

The pH of Douglas-fir sawdust is about 5.5. Before using other organic material, test its pH.

Nitrogen (N)

N source

Blueberry plants use ammonium-N (NH_4). Fertilizers that contain only nitrate (NO_3), such as calcium nitrate, may cause injury or reduced growth and should be avoided. Ammonium nitrate is no longer sold as a fertilizer material because it can be used to make explosives. Calcium ammonium nitrate is a replacement product.

If the soil pH is below 5, do not use only ammonium sulfate (urea-sul) or ammonium phosphate-sulfate (16-20-0-15), as these materials may reduce pH too much. Use urea or a blend of urea with a small amount of ammonium sulfate.

Controlled-release fertilizers may be used provided the N source and the release rate are appropriate for plant needs. Note, however, that a single application of a more expensive product may not be more economical than multiple applications of a less expensive product. Oregon State University has not tested controlled-release N sources in producing blueberries.

Common N fertilizers are listed in Table 2.

Table 2. Common nitrogen sources, chemical formula, and analysis.

Fertilizer material	Chemical formula	Analysis or grade
Ammonium sulfate	$(\text{NH}_4)_2\text{SO}_4$	21-0-0
Ammonium phosphate	$\text{NH}_4\text{H}_2\text{PO}_4$	11-5-20
Ammonium phosphate-sulfate	$\text{NH}_4\text{H}_2\text{PO}_4 (\text{NH}_4)_2\text{SO}_4$	16-20-0-15
Calcium ammonium nitrate	$\text{CaCO}_3 + \text{NH}_4\text{NO}_3$	27-0-0
Calcium nitrate*	$\text{Ca}(\text{NO}_3)_2$	15.5-0-0
Urea	$\text{CO}(\text{NH}_2)_2$	46-0-0
Urea-sul	$\text{CO}(\text{NH}_2)_2 + (\text{NH}_4)_2\text{SO}_4$	37 to 46% N + 4 to 8% S
Urea ammonium nitrate solution	$\text{CO}(\text{NH}_2)_2 + \text{NH}_4\text{NO}_3$	28 to 32% N

* Not recommended for blueberries

Establishment (years 1 and 2)

Note: Year 1 is considered the first growing season, regardless of October or spring planting. Prune any flower buds present on nursery plants to prevent fruiting the first year. Pruning to prevent cropping in year 2 also is recommended in most situations. Allow only plants with sufficient vigor to produce a light crop in the second year. Early cropping (fruiting in years 1 and 2) has been shown to reduce root growth and yield in years 3 and 4.

Nitrogen application may not increase growth the first year. Most blueberry nursery stock contains sufficient N for the first year's growth. Recent research showed no increase in whip length or plant dry weight from N application in the planting year. Even so, a small N application is prudent to protect the substantial investment involved in establishing blueberries.

We recommend applying 0.6 oz N per plant in year 1 and 0.7 oz N per plant in year 2. These rates assume that sawdust and 95 lb N/a were incorporated prior to planting and that 2 inches of surface mulch are used.

These rates are per plant. Because the root system may not yet have covered the entire in-row area, per-acre rates depend on plant spacing. Per-plant rates can be converted to per-acre rates as follows:

$$(\text{oz/plant} \times \text{plants/acre}) \div 16 = \text{lb N/acre}$$

Remember to convert the N rate to the amount of product needed per acre (e.g., 100 lb N/a of ammonium sulfate [21-0-0] would be $100 \div 0.21 = 475$ lb product/a).

Rabbiteye blueberries need much less N than do highbush blueberries and will have poor growth and yield with overfertilization. Grower experience has indicated that N rates can be reduced by up to half for rabbiteye blueberries with good results.

Time of application

Young and mature plants take up fertilizer N at the same time of year. Very little fertilizer (less than 2 percent) is taken up before the end of April. N should be "split," with 0.2 oz (0.4 oz urea) applied in April, May, and June.

Controlled-release fertilizers may be used, provided the N source and the release rate are appropriate for plant needs. Note, however, that a single application of a more expensive product may not be more economical than multiple applications of a less expensive product. In experiments with a second-year planting, controlled release fertilizer provided no measurable advantage compared to ammonium sulfate. The only advantage was labor savings from a single application rather than several applications.

Application method

When plants are young and the canopy does not fill the row, we recommend applying fertilizer by hand. Spread the recommended rate in an area under the drip line of the bush (Figure 10). Apply fertilizer evenly.

Use caution when applying N to young blueberries, as over-application will cause leaf burn, and severe over-application will cause plant death. Young plants are much more sensitive to under- and over-fertilization because they do not have a lot of stored N reserves and because the young root system is very sensitive to fertilizer "burn."

Applying all of the N fertilizer in a concentrated area near the crown can cause plant death.

If fertilization must be done by machine, you will need to increase the rate because plants cannot take up fertilizer that is applied beyond the rooting area. You must calculate how much of the application is within the drip line of the bush and how much is “wasted” and adjust the application rate accordingly.



Figure 10. Application of N fertilizer for nonbearing blueberries or bearing plants with canopy closure.

Producing plants (starting in year 3)

Adequate tissue N levels are necessary for renewal growth, crop production, and flower bud development for next year's crop. Excess N early in the season may reduce fruit quality, increase risk of disease on fruit, and delay maturation. Excess N late in the season leads to excessive vegetative growth, a late flush of growth (which increases risk of winter injury), and reduced flower bud development.

In general, fertilizer rates should increase as the planting ages (Table 3). Rates for years 3 and 4 are per-plant, as the root system may not yet cover the entire in-row area, thus, per-acre rates would depend on plant spacing. Once plants "fill the row", or their canopies touch, per-acre rates no longer are affected by plant spacing.

Remember to convert the N rate to the amount of product needed per acre (e.g., 100 lb N/a of ammonium sulfate [21-0-0] would be $100 \div 0.21 = 475$ lb product/acre).

The rates in Table 3 assume that sawdust and 95 lb N/a were incorporated prior to planting. These rates are for fields with a surface Douglas-fir sawdust mulch (typical carbon-to-nitrogen ratio of 800:1) replenished every few years. Blueberries topdressed with other kinds of mulch with a higher C:N ratio, or to a greater depth, may need more fertilizer N. For example, if you apply an additional 11 units of sawdust (2 inches deep in 3-foot-wide bands on 10-foot centers), you will need to add 25 lb N/a to compensate for N immobilized by the fresh sawdust. In contrast, reduce the N fertilizer rate if no surface organic mulch is used.

Table 3. Blueberry N fertilizer rate (year 3 to maturity).

Year	N (oz/plant)	N (lb/a)*
3	0.8	-
4	0.9	-
5	-	100
6	-	125
7	-	145
8+	-	165

Table 4. Blueberry leaf N sufficiently, late July to mid-August sampling.

Leaf N (%)	Status
below 1.50	Deficient
1.50 - 1.75	Below Normal
1.76 - 2.00	Normal
2.01 - 2.05	Above Normal
above 2.50	Excess

Once the planting reaches maturity (year 7 or 8), apply 145 to 165 lb N/a. However, adjust N rates, if necessary, based on observations of growth, tissue N analysis (Table 4), and the amount and type of mulching.

Soil testing for N is not a reliable indicator of perennial crop N status. Leaf analysis alone (Table 4) does not indicate whether N fertilization is required, but it can be used in conjunction with an assessment of plant growth and productivity to determine N status (see “Interpreting tissue test results,” page 3).

Keep in mind that as sawdust ages and decomposes, it will release some N that is available to the plants. We do not know how quickly this process occurs. Thus, keep monitoring plant growth and N tissue concentrations. Before using any other organic material, test its pH.

The N rates in this publication take into account “efficiency” of uptake. Plants cannot take up all of the fertilizer applied, regardless of the product or method of application. Efficiency of uptake is affected by plant age (depth and width of root zone), coverage of the in-row area (uptake efficiency increases as plants fill the row), method of application (granular, liquid, or foliar applications), and the amount and timing of application. Rabbiteye blueberries need much less N than do highbush blueberries and will have poor growth and yield with overfertilization. Grower experience has indicated that N rates can be reduced by up to half for rabbiteye blueberries with good results.

Time of application

Young and mature plants take up fertilizer N at the same time of year. Very little fertilizer (less than 2 percent) is taken up before the end of April and less than 10 percent after mid-July. The blueberry plant relies on stored N reserves early in the season. A relatively clear “application window” for efficient N fertilizer uptake exists between late April and mid-June.

The total N fertilizer rate should be split into thirds, with the first application in late April, the second in mid-May, and the third in mid-June. Blueberries are shallow rooted and inefficient at using fertilizer N. Multiple applications provide the N fertilizer when plants need it and allow plants more time to absorb N before it is moved below the root zone.

Application method

When plants are young and the canopy does not fill the row, we recommend fertilization by hand. Spread the recommended rate in an area under the drip line of the bush. If fertilization must be done by machine, increase the rate, as any fertilizer not above the roots will be unavailable to the plants. Once the canopy is full and plants “touch,” fertilizer uptake efficiency is much greater.

The least expensive method of fertilizer application is to apply a granular product as a broadcast band in the row. Recommended per-acre rates in this publication are based on this method of application.

Little lateral nutrient movement occurs within the plant. Thus, fertilizer (whether applied as a granular material or via drip irrigation) should be as evenly distributed under the plant canopy as possible to ensure even growth. Any N fertilizer application should be followed by rain or irrigation as soon as possible.

Foliar application is an inefficient method of applying N fertilizer to blueberry plants. No more than 5 percent urea (in water), the equivalent of about 14 lb N/a, can be applied to plants without burning leaves. However, not all of this N is taken up by plants. In research with other crops, no more than 50 percent (or 7 lb N/a) of foliarapplied N

was taken up. Because of their waxy cuticle, blueberry leaves are not very effective at taking up N. Most foliar-applied N that is taken up by plants is taken up through the roots (runoff).

Phosphorus (P)

Symptoms of P deficiency—stunted plants with dark, purplish-green, small leaves—rarely are seen in Oregon. Pears planted in Parkdale soil in the Hood River area are the only documented case of P deficiency in deciduous fruit in western Oregon. Leaves sometimes have a purple color in early spring when temperatures are cool and soils are wet—a sign of temporary P deficiency. This condition will be corrected when soils warm. Effects from excessive P also are rare.

P application might be justified if tissue P and soil P levels are low. Soil test P alone is a poor indicator of P sufficiency for blueberries.

No universal tissue concentration is used to define blueberry P deficiency. Michigan Extension publications define P deficiency as below 0.07 percent P, Massachusetts below 0.05 percent, and Wisconsin and Minnesota below 0.08 percent. Pennsylvania, Massachusetts, Wisconsin, and Minnesota define optimum P as above 0.1 percent, the value used in this publication.

Apply P according to Table 5, based on tissue concentration. These rates are appropriate for any plant spacing. Keep in mind that P is not mobile in the soil; thus, changes in tissue P occur a year or two after application.

Apply P in late fall or spring prior to budbreak. When N is included with P and K, apply in spring. Irrigate after application if rain does not fall within 1 or 2 days.

Various fertilizers can be used: triple superphosphate (0-45-0), ammonium phosphate (11-52-0), or ammonium phosphate sulfate (16-20-0-15).

Table 5. P fertilization rates based on soil and late July to mid-August tissue sampling.

Soil test P (Bray) (ppm)	Leaf P (%)	Apply this amount of P ₂ O ₅ (lb/a)
0 - 25	below 0.07	40 - 60
26 - 50	0.08 - 0.10	0 - 40
above 50	above 0.10	0

Table 6. K fertilization rates based on soil and late July to mid-August tissue sampling.

Soil test K (ppm)	Tissue K (%)	Apply this amount of K ₂ O (lb/a)
0 - 100	below 0.20	75 - 100
101 - 150	0.21 - 0.40	0 - 75
above 150	above 0.40	0

Potassium (K)

Potassium deficiency is relatively rare in Oregon. Leaves of K-deficient plants may develop several symptoms, including scorching along the margin, cupping, curling, and necrotic spots. Low leaf K values may be caused by poor

drainage, drought, or very acid soils.

Yield also has a strong influence on leaf K levels. Potassium concentration in the berry increases dramatically as fruit matures, averaging more than 60 mg per berry when ripe. Thus, deficiency levels in leaves may occur in a heavy yield year, with normal levels returning after harvest.

Normal August leaf K levels are 0.41 to 0.70 percent. Blueberry yields have been shown to increase with K fertilization on various soil types if K is deficient. If a below-normal leaf value occurs, band trial applications of 150 lb/a potassium sulfate (0-0-52) [K₂SO₄]. Use Table 6 as a guide, keeping in mind that application rates for established plantings should be based on tissue concentration. Use these rates regardless of plant density.

Avoid muriate of potash (potassium chloride), because chloride may cause reduced growth or injury to blueberries. If both K and Mg are needed, use 400 lb/a sulfate of potash-magnesia (0-0-21, 11% S, 10% Mg) [K₂SO₄, MgSO₄]. Excess K can interfere with uptake of other elements, especially Mg. Therefore, do not apply K unless foliar analysis indicates a deficiency.

Apply K in late fall or in spring prior to budbreak. When N is included with P and K, apply in spring. Irrigate afterward if rain does not fall within 1 or 2 days.

Potassium is immobile in soil. Thus, changes in blueberry tissue K occur a year or two after application.

pH and manganese (Mn)

pH and manganese (Mn) The critical soil pH range for blueberries is 4.5–5.5. If the soil pH is above this range, use elemental sulfur to reduce soil pH before planting. (See “Site preparation,” page 4, and Acidifying Soil for Crop Production West of the Cascade Mountains). Soil pH will begin to decrease within 4 to 5 months if soil moisture and temperature are adequate for growth. Before and after planting, sample again to determine whether further acidification is necessary.

Keep in mind that use of ammonium sulfate fertilizer as a source of N will lower soil pH. If soil pH declines in the surface 6 inches or top foot of soil, increasing pH is extremely difficult and often impossible since lime is not mobile in soil. Thus, application of a small amount of lime when soil pH drops below 5.0 is prudent. To maintain soil pH above 4.5, apply 200 to 300 lb lime/a annually in the fall. If the soil pH is below 4.0, apply 1 to 2 ton lime/a. Sample and test soil pH in the surface 3 inches of soil 8 months after lime application. Do not apply lime in spring before N fertilizer is used.

Foliar manganese concentration normally is between 30 and 350 ppm. Tissue Mn increases as soil pH decreases; thus, tissue Mn can serve as a guide to soil pH changes. Blueberry tissue Mn above 450 ppm is considered excessive and an indicator of decreasing soil pH and the need for lime application. Blueberry plants grow normally with Mn concentration as high as 650 ppm. Vaccinium plants (blueberries and relatives) are thought to have a mechanism for Mn tolerance, since Mn levels can be as high as 4,000 ppm in lowbush blueberries without affecting plant growth. Even so, sustained tissue Mn concentration of 500 ppm or above is not recommended.

In addition to low soil pH, fungicide and foliar micronutrient application can cause high (above 450 ppm) tissue Mn results. These materials are “coatings” on leaves and not a measure of Mn in leaf tissue. Before beginning a liming program based on high tissue Mn, confirm that no foliar Mn application has been made and check soil pH.

When soil sampling an established blueberry planting, keep in mind that soil pH differences will occur throughout the field. Close to the plants, where N fertilizers are applied, the pH will be lower than between rows (Figure 5, page 4).

Calcium (Ca)

Normal blueberry tissue Ca concentration is from 0.41 to 0.8 percent. Although blueberries seldom are deficient in Ca, variations in leaf Ca occur. High leaf Ca concentration might indicate high soil Ca or a high crop load. Low leaf Ca concentration can be present in heavily fertilized, vigorously growing plants, or it might be a result of low soil pH. If low soil pH is suspected, check the tissue Mn concentration. Abnormally high Mn (above 450 ppm) is an indication of low soil pH and low soil Ca.

If Ca is required and pH is below 4.0, topdress 0.5 to 1 ton/a agricultural limestone (Ca). If Mg is needed as well, substitute dolomitic limestone (Ca + Mg). If Ca is needed and the pH is above 5.0, apply 0.5 to 1 ton gypsum/a. Apply these materials in the fall to permit time for reaction with soil before the growing season.

Sulfur (S)

Sulfur is an essential element. However, it is more commonly applied to blueberries to reduce soil pH than to correct a nutrient deficiency. Normal leaf levels for S range from 0.11 to 0.16 percent.

Boron (B)

Boron deficiency, which is relatively common in Oregon, causes tip dieback. Leaves close to aborted shoot tips develop a mottled chlorosis and cupped shape. Leaf and fruit buds fail to develop in severely deficient plants. Winter injury also may be greater on B-deficient plants.

Use Table 7 as a guide to fertilization. If B is deficient, apply either Solubor (20% B) at 2 to 6 lb product/100 gal water/a, or 10 to 20 lb/a borax (11% B).

Apply Solubor or an equivalent material as a foliar spray before bloom or after harvest and before leaf senescence. Apply borox in the fall or early spring prior to rain.

Many blueberry growers in Oregon follow an annual B application program of 0.5 lb B/a. Monitor leaf B levels carefully. Excess B is toxic to plants.

Zinc (Zn)

Zn deficiencies are less common than B deficiencies in Oregon. Symptoms of Zn deficiency include short internodes and small leaves. The youngest leaves are somewhat yellow and folded upward along the midrib. Excessive use of P sometimes results in Zn deficiency symptoms. Zn deficiency is less common when pH is below 6.0.

Table 7. Blueberry leaf B sufficiency, late July to mid-August sampling.

Leaf B (ppm)	Status
below 20	Deficient
21 - 30	Below normal
31 - 80	Normal
81 - 150	Above normal
above 150	Excess

Normal leaf concentrations are from 8 to 30 ppm. If plants are deficient, apply one of the following:

- Zn chelate (14% Zn) as a foliar spray at 1 lb/100 gal water/a after harvest
- 10 to 30 lb/a Zn chelate or 10 to 30 lb/a Zn sulfate (36% Zn) to the soil

Copper (Cu)

Copper deficiency is rare in Oregon blueberries. Symptoms of Cu deficiency include yellowing between veins of young leaves and, in severe cases, young shoot dieback. Cu deficiency may be more severe on soils with more than 25 percent organic matter.

Normal leaf levels for Cu are from 5 to 15 ppm. If tissue concentration is below 3 ppm, use a trial application of copper sulfate (25% Cu). Broadcast at 30 to 50 lb/a or apply 1 lb/100 gal water/a as a foliar spray anytime leaves are present. Cu is very toxic at an excessive rate, so use caution and experiment on a few plants before applying to the entire field.

Iron (Fe)

Iron deficiency in leaves often is the result of high soil pH rather than Fe deficiency in the soil. Symptoms of Fe deficiency include yellowing between leaf veins, appearing first on the younger leaves. Shoot growth and leaf size sometimes are reduced.

Normal Fe leaf values are 61 to 200 ppm. If leaf levels are deficient, apply iron chelate (10% Fe) at 2 lb/100 gal water/a twice as a foliar spray when leaves are present (see label) or 15 to 30 lb/a to the soil. A soil application of 10 to 20 lb/a ferrous sulfate (34% Fe) also is suitable.

Do foliar applications work?

Foliar applications are sometimes an effective way to correct micronutrient deficiencies. However, foliar applications are expensive and usually must be repeated several times to be effective for an entire season.

Foliar applications are not an effective way to apply nitrogen.

Management points

- Maintain soil pH between 4.5 and 5.5 to maximize highbush blueberry production.
- Blueberry plants prefer the ammonium (NH_4) form of nitrogen to nitrate (NO_3).
 - Use ammonium sulfate and urea fertilizers.
 - Do not use ammonium nitrate fertilizer or calcium nitrate fertilizer. High rates of nitrate will burn plants and be "wasted."
- Do not use fertilizer blends containing ammonium sulfate if the soil pH is below 5.0. Use urea or blends of urea with a small amount of ammonium sulfate (urea-sul) to minimize changes in pH.
- Applications of more than 100 lb of urea (24 lb N/a) at one time may cause temporary iron deficiency (yellow leaves with green veins).

- Do not apply more than 50 to 60 lb N/a (total) on first-year fields without sawdust mulch. Overapplication of N will burn plant leaves and roots.
- Do not use fresh horse manure and/or shavings as a nitrogen sources, as the pH of these materials often is too high.
- Apply granular nitrogen fertilizers in a triple split in spring/early summer (one-third per application).
- Do not apply nitrogen fertilizer of any kind after harvest.
- Monitor soil pH regularly.
- If pH needs to be reduced after planting and use of ammonium sulfate fertilizer will not reduce it fast enough, use elemental sulfur. Do not use more than 200 to 300 lb elemental S/a per application on established planting to avoid harming plants.
- If pH is too low, apply lime in the fall. Do not apply surface lime to the field in the spring.
- Note that surface applications of lime take a long time to change pH in the root zone. Monitor pH to avoid problems.
- Soil pH in a blueberry field will bevel increase if no lime or other alkaline material is applied.
- Rabbit-eye blueberries grow best at a lower soil pH than do highbush blueberries and are more sensitive to overapplication of N fertilizer. They require less N than highbush types.

Western Oregon highbush blueberry nutrient management calendar

Year before planting

- Soil test
 - Acidify with elemental S if needed (see "Site preparation".)
 - Apply P and K if needed.
-

Year 1

- Test pH and nutrient content of sawdust or other organic material to be used.
- Add 5 lb N/a per unit of sawdust incorporated.
- Incorporate sawdust and fertilizer.
- Form raised beds
- Plant blueberries (spring or previous fall).
- Test pH of surface mulch.
- Apply surface mulch.
- Prune to remove fruit buds.

Spring. Apply a total of 0.6 oz N (1.3 oz urea) to individual plants. N should be "split". Apply 0.2 oz N (0.4 oz urea) in April, May and June, or use a single application of controlled-release material. Test soil pH and add amendments as needed.

Summer. Collect the most recent fully expanded leaves from current-season shoots between late July and mid-August. Sample 5 leaves each from at least 10 plants distributed randomly throughout the field. Request laboratory analyses for nutrients listed in Table 8.

Winter. Prune to remove fruit buds.

Year 2

Spring. Increase N rate to 0.7 oz/plant. Follow other recommendations for first year.

Winter. Prune to shape bush and limit crop.

Years 3 and 4

Spring. Apply 0.8 to 0.9 oz N/plant. Follow other recommendations for Year 1.

Summer. Harvest crop.

Winter. Prune

Older than 4 years or at canopy closure

Table 8. Blueberry tissue nutrient concentration guidelines.

Nutrient	Normal concentration (%)
Nitrogen (N)	1.76 - 2.00
Phosphorus (P)	0.10 - 0.40
Potassium (K)	0.41 - 0.70
Calcium (Ca)	0.41 - 0.80
Magnesium (Mg)	0.13 - 0.25
Sulfur (S)	0.11 - 0.16
Boron (B)	31 - 80
Copper (Cu)	5 - 15
Iron (Fe)	61 - 200
Manganese (Mn)	30 - 350
Zinc (Zn)	8 - 30

Spring. Add surface mulch and nutrients other than N as needed.

To plants more than 6 years old, apply a total of 110 to 165 lb N/a (240 to 360 lb urea/a). N should be split into thirds and applied in April, May, and June (see page 8).

Summer. Collect tissue samples as described in year 1. Request laboratory analyses for nutrients listed in Table 8. Harvest crop.

Winter. Prune.

For more information

OSU Extension publications

- [Acidifying Soil for Crop Production West of the Cascade Mountains \(Western Oregon and Washington\)](https://catalog.extension.oregonstate.edu/em8857) (<https://catalog.extension.oregonstate.edu/em8857>), EM 8857-E, by D. Horneck, J. Hart, R. Stevens, S. Petrie, and J. Altland (2004).
- [Blueberry Economics: The Costs of Establishing and Producing Blueberries in the Willamette Valley](https://catalog.extension.oregonstate.edu/em8526) (<https://catalog.extension.oregonstate.edu/em8526>), EM 8526-E, by B. Eleveld, B. Strik, K. DeVries, and W. Yang (2005).
- [Fertilizer and Lime Materials](https://catalog.extension.oregonstate.edu/fg52) (<https://catalog.extension.oregonstate.edu/fg52>), FG 52, by J. Hart (1992). Highbush Blueberry Production, PNW 215, by B. Strik et al. (1993).
- [Laboratories Serving Oregon: Soil, Water, Plant Tissue, and Feed Analysis](https://catalog.extension.oregonstate.edu/em8677) (<https://catalog.extension.oregonstate.edu/em8677>), EM 8677, by J. Hart (2006).
- [Monitoring Soil Nutrients Using a Management Unit Approach](https://catalog.extension.oregonstate.edu/pnw570) (<https://catalog.extension.oregonstate.edu/pnw570>), PNW 570-E, by M. Staben, J. Ellsworth, D. Sullivan, D. Horneck, B. Brown, and R. Stevens (2003).
- [Soil Sampling for Home Gardens and Small Acreages](https://catalog.extension.oregonstate.edu/ec628) (<https://catalog.extension.oregonstate.edu/ec628>), EC 628, by M. Robotham and J. Hart (2003).

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Berry Crops

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