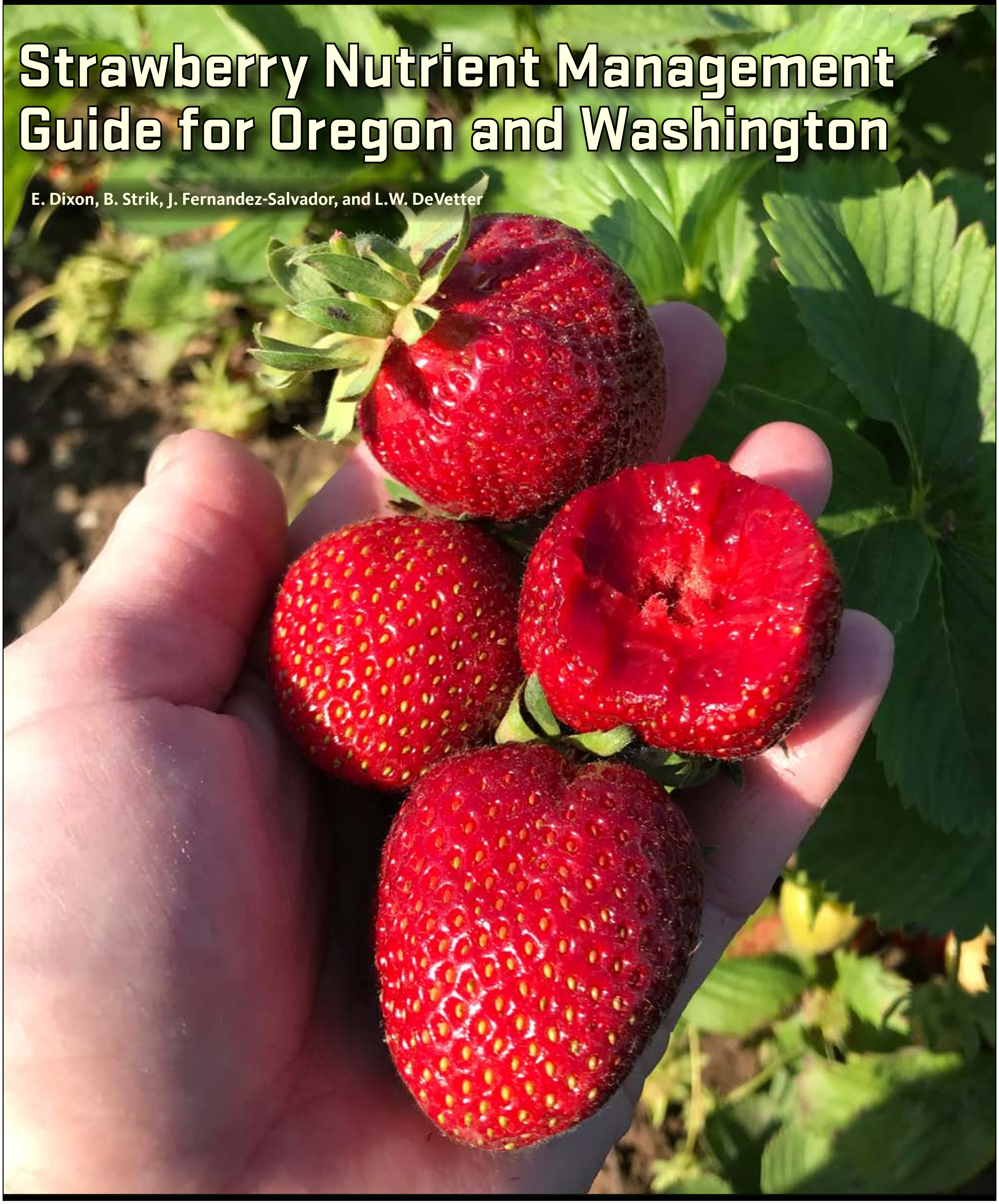
OREGON STATE UNIVERSITY EXTENSION SERVICE

Strawberry Nutrient Management Guide for Oregon and Washington

E. Dixon, B. Strik, J. Fernandez-Salvador, and L.W. DeVetter



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Introduction

Strawberry growers in Oregon and Washington raise fruit for both the processed and fresh markets, using both conventional and certified organic systems. This guide explains nutrient management for June-bearing and day-neutral cultivars — the two types of strawberries typically grown in the Pacific Northwest.

Farmers traditionally raise June-bearing (or short day) cultivars for the processed market. This type of strawberry is harvested over a three- to four-week season from mid- to late-May through June. We'll refer to this type of strawberry as "June-bearers."

Farmers in Oregon and Washington are increasingly planting day-neutral strawberries. Day-neutral strawberry plants flower and fruit throughout the growing season, providing a steady supply of berries that makes them ideal for the fresh market grower. In Oregon and Washington, day-neutral types are usually grown as semiperennials (two to three growing seasons), while farmers in California, Florida, and North Carolina usually grow them as annuals.

Preplant considerations are as important for day-neutral strawberries as they are in June-bearing types. Some organic growers may opt to grow day-neutral plants for one season to reduce the buildup of disease and pests and incorporate them into their annual rotations, usually with season-extension methods to increase profitability.

Our management recommendations for conventional or organic production in strawberry fields west of the Cascades assume:

- The use of well-adapted cultivars and disease-free plants.
- Selection of suitable soils.
- Control of various pests.
- Proper irrigation.

Optimum nutrient management will not compensate for poor management practices or fix problems unrelated to fertility. A good nutrient management program ensures sufficient nutrients are available when the plants need them. In Oregon and Washington, June-bearing strawberries (see Figures 1 and 2, page 3) are typically grown in a perennial, matted-row system with overhead sprinklers and granular fertilizers, while day-neutral cultivars (see Figure 3, page 4) are typically grown in a perennial, raised-bed, plasticulture system with drip irrigation and fertigation (application of fertilizers through the irrigation system). Since this publication focuses on production west of the Cascades, any recommendations for fertility management on the east side are based on research done in other locations with short growing seasons.

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Cover: Sweet Sunrise, June-bearing strawberries in Oregon. *Photo by Bernadine Strik, © Oregon State University.*

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Photo: Bernadine Strik, © Oregon State University

Figure 1. Matted-row field of June-bearing (short-day) strawberries grown on flat ground in Oregon.

Photo: Lisa DeVetter, © Oregon State University

Figure 2. Matted-row field of June-bearing (short-day) strawberries grown on raised beds in Washington.

Any nutrient management plan must address four key questions:

- How much nutrient should be applied?
- When should it be applied?
- What source or material is best to apply?
- Which application method is called for?

This publication explains how producers can prepare a site and lay the groundwork for optimum nutrient management during the life of the strawberry field. Using soil and tissue testing and basic fertility recommendations, it identifies how much of each nutrient should be applied. Finally, it explains each nutrient in detail for both June-bearing and day-neutral types of strawberries. The Oregon State University Extension Service agent or Washington State University Extension educator in your county can help with any further questions, including additional resources.

Photo: Bernadine Strik, © Oregon State University

Figure 3. Field of day-neutral strawberries grown on raised beds with plastic and drip irrigation in Oregon.

Preplant considerations

Sufficient strawberry plant growth and ideal nutrient uptake requires growers adjust soil properties, increase the level of organic matter, adjust soil pH if needed, and assess the potential for pest problems. Fertilizer programs do not correct for poor drainage, soilborne disease, nematodes, insect pests, and weed competition. Although some guidance is provided here, this publication is not an all-inclusive crop management guide. Refer to local publications or resources for a full strawberry production guide.

Soil preparation

Strawberries need well-drained soil and are often grown on raised beds to improve drainage. To evaluate your soil, dig pits to locate soil compaction or hardpan problems and evaluate soil quality and drainage needs. Break up hardpan by ripping or subsoiling from 12 to 24 inches

Typical planting systems in Oregon and Washington

Day-neutral

Summer planting: Overhead irrigate to soften the soil, amend the soil, shape beds, lay drip tape and plastic, and plant. Some fruit can be harvested that same year, but the field will produce a mature crop the following year.

Fall planting: Wait for the first rains in September or October, then follow the same steps as summer planting.

Winter/early spring planting:

- In open field production, the steps are the same as for fall planting, except bare-root plants are planted later in the winter or early spring. This is done by growers who grow multiple crops and find that winter or spring planting fits in better with the workload of their other crops. Bed preparation is still done during the fall before it becomes too wet to work the soil.
- In tunnels, you can prep soil anytime with a little overhead irrigation. Planting in late winter or early spring allows for an all spring, summer, and fall crop (similar to the California production season). Organic growers do this to get to market early.

June-bearing

Spring planting: As soon as you can work the soil in the spring, amend the soil and then shape the beds and plant. Very little fruit will be produced in the planting year, and it is not harvested commercially.

Organic vs. conventional systems

For this publication, **organic production** refers to systems following U.S. Department of Agriculture National Organic Program standards and using only nonsynthetic products for nutrient management approved by the Organic Materials Review Institute or other recognized organic material program. **Conventional production** refers to systems that use synthetic fertilizer products as well as organic products.

deep, depending on the soil type, followed by surface tillage and proper bed shaping (see Figure 2, page 3, and Figure 4). Effective soil preparation improves drainage, root growth, and nutrient uptake throughout the life of the planting. Preplant soil testing indicates nutrient status and soil pH (see "Soil testing" below) and what should be corrected before bed shaping and planting. Preplant nutrient applications enable better plant establishment. Refer to the results of your soil analysis (see below) for the required addition of other nutrients prior to planting.

Soil testing

Testing the soil and adjusting soil nutrient status prior to planting is a critical aspect of nutrient management in conventional and organic strawberry plantings. Soil testing can help you adjust soil nutrient deficiencies, which will help your planting get off to a good start. Nutrients such as phosphorus (P) or potassium (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. In June-bearing strawberries, you may not need to apply any nutrients other than nitrogen (N) after planting. Nutrient management of day-neutral strawberries grown on plastic with fertigation systems can be adjusted and applications monitored.

Collect soil samples from representative locations around the field or block. Collect samples 6–12 months before planting to allow time for soil modification. See *A Guide to Collecting Soil Samples for Farms and Gardens* (EC 628) for detailed information on sampling patterns and soil testing. Take soil samples from the top 6–12 inches of soil where strawberry roots will grow.

You may also divide your soil samples by depth (for example, taking some from 0–6 inches deep and others from 6–12 inches deep) to see if nutrients are distributed evenly throughout the soil profile or if there is

Photo: Javier Fernandez-Salvador, © Oregon State University

Figure 4. Raised beds topped with drip irrigation and plastic in preparation for planting day-neutral strawberries.

stratification of soil pH and nutrients. Soil from lower depths tends to have a lower pH and P and K concentration, and you would want to know that if you are turning the lower depths by subsoiling, plowing, or disking and bringing less-fertile soil to the surface where the strawberry roots will be. This is particularly important for day-neutral cultivars grown on raised beds. Raised beds generally use the top 6–8 inches of soil. Raised beds in Oregon and Washington are usually 4–10 inches high while those in California are 10–16 inches. Raised bed heights are determined by soil type, climate, precipitation, equipment availability, and production system.

Soil samples should be taken from the soil your plants will be grown in. Keep this principle of nutrient stratification in mind when interpreting soil analysis results and planning your nutrient management program. If you are growing conventionally and know the history of your site, you may not need to sample the soil again. Soil testing becomes more important in organic, diverse rotational systems, where strawberries are grown in an annual or biannual cycle under tunnels or in an open field where fertility is adjusted significantly depending on the rotation of other crops.

After you plant, annual soil sampling is not usually needed unless you suspect a problem or if strawberry is used in a crop rotation, annual production, organic systems, or with fertigation. Collect samples at the same time of year and use the same laboratory so results are directly comparable. Collect soil samples after planting 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—especially for preplant organic fertilizers, which take longer to break down in the soil and mineralize. Collect only soil in your sample, removing surface mulch or leaves. If solid organic amendments or fertilizers were applied on the surface, remove a 1-inch layer from your sample for more accurate results.

Soil nutrient status

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

Table 1. Suggested critical levels for soil nutrient status.

Nutrient	Deficient at less than (ppm):
Phosphorus (P; Bray 1)	45
Phosphorus (Olsen)	20
Potassium (K)[z]	75–175
Calcium (Ca)	1,000
Magnesium (Mg)	120
Boron (B)	0.3–1.0 [y]
Electrical conductivity (EC)*	No greater than 2 dS/m

[z] Rate of K fertilizer needed at each end of this range would vary; soil type impacts K availability

[y]Lower level for day-neutral; higher for June-bearers.

Adapted from *Strawberries: Western Oregon—West of Cascades Fertilizer Guide* (FG 14).

*Note that 1 dS/m = 1 mmho/cm = 1 mS/cm; tested using saturated paste

Soil pH

Although strawberries are tolerant of soil acidity, it may be necessary to apply lime to raise the soil pH. The ideal soil pH for strawberries is between 5.4 and 6.5.

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. Pelletized lime must be allowed time to break up through wet/dry and freeze/thaw events before incorporation.

The main difference between these products is application method, speed of action, and price. There is a second soil test called the lime requirement (or SMP buffer) test that can be used to estimate how much lime is needed to raise your soil pH. See Table 2 for interpreting SMP buffer test results. 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)* (EM 9057). Use the SMP soil test (Table 2) to adjust lime application rates. For example, depending on the SMP value, from 1–1.5 tons/acre of lime may be required if the soil pH is below 5.4. Consider lime or gypsum applications if soil calcium (Ca) or magnesium (Mg) are also required based on a soil test. Soil pH changes occur slowly, so apply and incorporate lime at least three months (and up to 12 months) prior to planting. Be aware that high application rates of the cations Ca and or Mg can decrease availability of K, thus requiring additional K fertilization. Discuss with Extension agents or fertilizer advisors. Organic strawberry 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 their certification status.

Table 2. Preplant lime recommendations (tons/acre of 100-score lime needed to raise pH of surface 6 inches of soil. The higher lime rate is needed for the lower soil SMP buffer value).

If the SMP is:	Apply this amount of lime (ton/acre)
<5.2	5
5.2–5.6	4–3
5.7–5.9	3–2
6.0–6.2	2–1

It is crucial that you keep soil pH in the ideal range for strawberry production. Soil pH affects availability of soil nutrients. If the soil pH is too high or too low, nutrients can become deficient or toxic, depending on the nutrient. In this case, correcting the pH rather than the nutrient would solve the problem. Also, nitrification—the rate at which ammonium-N (NH_4-N) is nitrified to nitrate-N (NO_3-N) — is much slower at a low pH. Strawberries take up the nitrate form of N primarily, so rapid nitrification at pH 6.0 allows for the use of less-expensive, inorganic, and ammonium-based fertilizers and organic sources of nitrogen.

Organic amendments

Adequate levels of organic matter in soil aid in moisture retention, nutrient capacity, and soil structure. A soil test will indicate the level

Soil Electrical Conductivity

Electrical conductivity is a measure of the total concentration of ions dissolved in the soil solution (also called soluble salts). Strawberries are sensitive to salts in their root zones, so soil EC above 2 dS/m can lead to strawberry plant injury, including stunted growth and reduced yield. A soil EC value of closer to 1 dS/m is considered better for plant growth. Many conventional fertilizers have a high salt index and can increase soil EC, and composts and other organic amendments can also be high in salts. Excess salts can be leached out of the soil by rain or irrigation water. Because of this, plasticulture systems where the soil is sheltered from the rain are particularly susceptible to salt injury.

of organic matter in the soil, which may need amendments to bring it up to a suitable level. We recommend 3 percent of the soil be organic matter. For organic growers, organic amendments may also supply an important portion of the crop's nutrient needs. Organic amendments should be tested by an accredited lab prior to application for pH, nutrient concentrations, and salt concentration (electrical conductivity should be less than 1 deciSiemens per meter). Excess salts can be detrimental to strawberries, particularly in day-neutral plasticulture systems where the beds are sheltered from rain and drip irrigation concentrates the salts.

Manure

Manure applied before planting increases soil organic matter, improves soil structure, and enhances water and nutrient holding capacity. It can 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 uncomposted manure contains urea, which will volatilize and be lost into the air quickly, unless the manure is well incorporated into the soil. The N concentration in manure is low. It would require very high rates of application to meet crop demands for N, but manure may be used as a supplemental preplant nutrient source. Refer to *Estimating Plant-Available N from 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 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.

We don't recommend using manure as a nutrient source after planting strawberries. Berries in contact with fresh or raw manure can become contaminated and pose a serious food safety risk. The use of raw manure is regulated by both the Food Safety Modernization Act and the National Organic Standards. Refer to *Fertilizing with Manure and Other Organic Amendments* (PNW 533) for more information on manures and their risk of pathogens.

Compost

Compost is plant- or animal-based material that has decomposed and broken down over time into stable organic matter. Like fresh manure, compost builds soil health and water and nutrient holding capacity. Composts with high microbiological activity may contribute to soil health and disease suppression in strawberries. Some composts may introduce weed seeds to the strawberry planting. Organic growers must meet specific requirements for feedstock, carbon-to-nitrogen ratio (C:N), temperature, and manufacturing process for their compost to be considered compliant and allowed for use. Refer to the USDA National Organic Program standards for more details.

Composted manure or other compost contains much less inorganic N than fresh manure. Instead, the N is part of organic compounds that will break down into N 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 strawberries may lead to overapplication of other nutrients.

However, compost is a good source of P and K when amended prior to planting in organic production systems. Compost used as a supplemental nutrient source needs to be applied in advance of crop nutrient needs to give enough time for the nutrients to become available. For June-bearing strawberries, compost should be applied midsummer so that N is available when demand is high during flower bud development in late summer and early autumn. For day-neutral strawberries, compost should be applied and incorporated preplant only because it cannot be applied once beds are covered in plastic. See *Fertilizing with Manure and Other Organic Amendments* (PNW 533) and *Interpreting Compost Analyses* (EM 9217) for more information.

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 manure maintains porosity and structure, increases water infiltration, provides soil aggregate stability, adds organic matter to the soil, and is a source of nutrients for strawberry plants. 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 will reduce plant-available N. Time must elapse before this N is released into the soil again and is available for plant uptake. Therefore, strawberries 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 strawberries are planted. There are some good resources available to estimate N release from cover crops, including the OSU Extension Service'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* (PNW 636). See the "Resources" section on page 27.

Cover crops may also suppress weeds and pests and control soil erosion prior to planting strawberry.

Soil health

Strawberry is susceptible to several soilborne diseases, such as *Fusarium oxysporum* f. sp. *fragariae*, *Phytophthora cactorum*, *Rhizoctonia* spp., *Macrophomina phaseolina*, *Colletotrichum* spp., *Verticillium*, nematodes, and insect pests. Many of these diseases can be managed through good soil health practices that can be incorporated into preplant soil preparation and nutrient management activities. Weeds should be controlled as much as possible before planting to minimize the presence of weed seeds in the soil. Young strawberry plants in particular do not compete well with weeds for light, water, and nutrients.

Learning the field history and previous rotations will suggest which pests may already be present or may be potential problems for strawberry production. Refer to Extension's *PNW Insect Management Handbook* for more information. See the "Resources" section on page 27.

Tissue testing

Soil testing indicates whether the plant will have access to sufficient nutrients, but only tissue testing will reveal the nutrient status of the strawberry leaf itself. Nutrients may be adequate in the soil, but the plants may not be able to take them up — either because of environmental issues (for example, the soil pH is incorrect, the soil is dry or waterlogged, or the weather is too hot or too cold) or cultural issues, such as overcropping or irrigation.

Leaf nutrient concentrations change throughout the season, so collect your leaf tissue samples at the time recommended to ensure you can accurately compare your results with the published sufficiency standards (see Table 3, page 12). For example, leaf N concentration is always highest in spring and lowest in the fall. If the recommended sample time for June-bearing strawberries is after renovation in the summer, but you collect samples as soon as the plants leaf out in the spring, you will be comparing two very different seasonal stages, and your results will seem high compared to the standard.

The recommended sampling time after renovation is related to a period that has been found to have relatively stable leaf nutrient concentrations. Tissue nutrient concentrations depend on the age of the leaf as well, so collect the most recent fully expanded leaves. Tissue analyses and observations of plant growth are best used to adjust nutrient management programs the following year. Make sure you use tissue N concentrations in conjunction with recommended fertilizer application rates. You can adjust programs over time, but it is best to start at an established benchmark. Strawberry yield response to N application has been found to be extremely variable by numerous research studies, from no or even a negative response to N to a positive response to N. Use fertilizer wisely and observe your own plants on your own soil to adjust your nutrient management plan.

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 analysis results to determine the cause of the problem. Tissue nutrient problems may actually be soil problems. For instance, high tissue manganese (Mn) may mean soil pH is too low. Whether you are performing routine sampling or trying to correct a problem, keep excellent records on cultivars and blocks sampled, sampling date, associated yield or fruiting season information, and any fungicide or nutrient applications. These records can help you identify trends over time or spot problems more quickly.

Photo: Bernadine Strik, © Oregon State University

Figure 5. A June-bearing strawberry field in Oregon being renovated (mowed) a couple of weeks after the last fruit harvest.

Renovation is a practice in June-bearing strawberries where plantings are mowed about two weeks after the last fruit harvest (Figure 5). Matted rows are narrowed, weeds are managed, and fertilizer and irrigation are applied.

Photo: Bernadine Strik, © Oregon State University

Figure 6. June-bearing strawberries about three weeks after mowing (renovation) in early August.

Sampling time varies by type of strawberry. June-bearing strawberries should be sampled for tissue nutrient concentrations after renovation and when there has been sufficient time for regrowth to have recent, fully expanded leaves. A good time to take samples is mid- to late-August (Figure 6). Day-neutral strawberries should be sampled during the main fruit production season (June through frost in October).

For day-neutral strawberries, planting time influences the leaf sampling date since the strawberries will produce a crop in the planting year. For example, if planted early in the winter under a tunnel, sample in May and again in July or August. If planted in May or June, sample once in July or August. If planted in the fall for next year's crop, sample once the following year during the production season.

Collect the most recent fully expanded leaves. 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. Cultivars should be sampled separately. In some regions, petiole sap is used to test for nitrate and phosphate tissue levels throughout the season so that fertilizer applications can be adjusted in real time. These measurements were found to be highly variable by researchers in California and are not recommended as a standard for nutrient management. Try to collect samples at the same time of year (within types) so that you can compare tissue test results across years.

Table 3. Recommended tissue sufficiency levels for strawberries in Oregon.

			Sufficiency range by type of strawberry	
Nutrient	**Abbreviation**	**Unit of measurement**	**June-bearing**	**Day-neutral**
Nitrogen	N	%	2.5–3.0	2.4–3.0
Phosphorus	P	%	0.15–0.3	0.3–0.4
Potassium	K	%	1.0–2.0	1.3–1.8
Calcium	Ca	%	1.0–2.0	1.0–2.2
Magnesium	Mg	%	0.2– 0.5	0.28–0.42
Sulfur	S	%	0.11–0.4	0.15–0.21
Manganese	Mn	ppm	50–650	65–320
Boron	B	ppm	25–45	40–70
Iron	Fe	ppm	60–200	85–200
Zinc	Zn	ppm	20–50	11–20
Copper	Cu	ppm	6–20	2.6–4.9

Day-neutral standards are from California (Bolda, M., T. Bottoms, and T. Hartz. 2012. Strawberry Plant Nutrient Sufficiency Levels Revised. University of California Cooperative Extension. Crop Notes March/April 2012:1–3). Sufficiency levels given by the University of Florida are relatively similar to those given by California. Lower percent N may be sufficient for day-neutral strawberries as deficient fields were not used to develop the sufficiency levels.

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 nutrients from the roots to the leaves. 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, including sulfur (S), iron (Fe), Mn, copper (Cu), zinc (Zn), Ca, and boron (B), dissolved in the xylem fluid 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.

Nutrient fertility

A plant's fertilizer uptake efficiency is affected by the plant's age, the depth and width of the root zone, the presence of a surface mulch, the amount of coverage of the in-row area (plants that fill the row space have greater efficiency than those that don't), the application method (granular, liquid, or foliar), the nutrient source, and the amount and timing of fertilizer applied. "If enough is good, then more must be better" is not the best strategy for fertilizer applications! Overapplying fertilizer harms the plant's productivity, its fruit quality, and the environment. Use soil tests, tissue analysis, and visual observations to assess plant nutrient status and plan nutrient management programs.

Strawberry plants need N for fruiting and vegetative growth. For a field yielding 5–10 tons of fruit per acre, approximately 13–25 pounds per acre of N is removed in the harvested fruit. Additional N is also needed for plant growth. Day-neutral cultivars may yield twice as much fruit as June-bearing types, and this higher yield and prolonged growth means day-neutral cultivars have higher N requirements than June-bearing types. Fertilizer rates account for these differences and for the fact that plants cannot take up all the applied fertilizer.

Yields, fruit production patterns, and vigor differ, so the amount of nutrients you apply to your strawberry plants varies by plant age, type, and cultivar. Nutrients removed from the strawberry field, particularly in harvested fruit, need to be replaced, and additional nutrients must be made available for sustainable plant growth and production. These are important considerations when planning nutrient management programs. See Table 4 for nutrients removed in the harvested fruit by 'Hood' and 'Albion' strawberries in Oregon.

Table 4. Nutrients removed in fresh weight of fruit. All values are in pounds, except boron, which is in ounces.

	June-bearing			Day-neutral		
	Per ton	Per 5 tons	Per 10 tons	Per ton	Per 5 tons	Per 10 tons
Nitrogen	1.93	9.65	19.3	2.51	12.6	25.1
Phosphorus	0.45	2.25	4.5	0.39	1.97	3.9
Potassium	2.98	14.9	29.8	3.19	16.0	31.9
Calcium	0.21	1.05	2.1	0.37	1.86	3.7
Boron	0.04 oz.	0.2 oz.	0.4 oz.	0.04 oz.	0.21 oz.	0.4 oz.
All other nutrients	<0.25	<1.25	<2.5	<0.25	<1.25	<2.5

Unpublished data from Oregon, Bernadine Strik. June-bearing data from 'Hood' and day-neutral data from 'Albion.'

Sources of nutrients

Table 5 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 5. Percentage of nitrogen, phosphate, and potash concentration typical of commonly used manures and organic and inorganic fertilizers.

Fertilizer material	Percent			
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	2.0	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	
Bat guano	10	3	1	
Feather meal [b]	12–13	0	0	
Blood meal [b]	12–15	1	1	
Cottonseed	6–7	2	1	
Fish emulsion [b,e]	3–5	1	1	
Fish meal [b]	10	6	2	
Soybean meal	6	2	1	
Phosphate sources				
Bone meal	1–4	12–24	0	
Rock phosphate [c]	0	25–30	0	
Compost [d]	1–2	0.3–0.9	0.5–1.5	
Potassium sources				
Greensand	0	0	3–7	
Kelp meal	1	0.1	2–5	
Sul-Po-Mag (langbeinite)	0	0	22	22
Potassium sulfate	0	0	50	17
Compost [d]	1–2	0.3–0.9	0.5–1.5	

Table 5. (Continued)

Inorganic fertilizers	N	P_2O_5	K_2O	Sulfur
Nitrogen sources				
Ammonium sulfate	21	0	0	
Ammonium sulfate solution[e]	8	0	0	9
Ammonium thiosulfate[e]	12	0	0	26
Ammonium phosphate	11	5	20	
Ammonium polyphosphate[e]	10 or 11	34 or 37	0	
Ammonium phosphate-sulfate	16	20	0	15
Ammonium nitrate solution [e]	20	0	0	
Calcium ammonium nitrate[e]	27	0	0	
Calcium nitrate	15.5	0	0	
Urea	46	0	0	
Urea solution [e]	20 or 23	0	0	
Urea-sul	37–46	0	0	4–8
Urea ammonium nitrate solution[e]	28–32	0	0	
Phosphate sources				
Triple superphosphate	0	45	0	
Compost[d]	1–2	0.3–0.9	0.5–1.5	
Potassium sources				
Sulfate of potash-magnesia	0	0	21	11
Potassium chloride	0	0	60	
Potassium-magnesium sulfate	0	0	22	22
Potassium nitrate	14	0	45	
Potassium sulfate	0	0	52	18
Compost[d]	1–2	0.3–0.9	0.5–1.5	

[a] Perform lab nutrient analysis (and pH and EC) prior to consideration for use. See *Fertilizing with Manure and Other Organic Amendments* (PNW 533) and *Interpreting Compost Analyses* (EM 9217) for more information. Only use prior to planting. About 25 percent 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] Very low availability (only 2 to 3 percent of total P_2O_5). Useful only in acidic soils (pH 6.0 or below). Product has large effects on concentration: Phosphorite (usually 2 to 4 percent); soft rock phosphate (16 to 20 percent); rock phosphate (25 to 33 percent).

[d] Perform lab nutrient analysis (and pH and EC) prior to consideration for use. See *Interpreting Compost Analyses* (EM 9217) for more information.

[e] Suitable for fertigation

Adapted from *Growing Berries on the Oregon Coast: An Overview* (EM 9177), *Caneberry Nutrient Management Guide* (EM 8918), *Soil Fertility in Organic Systems: A Guide for Gardeners and 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.

Strawberry plants use primarily nitrate-N. Ammonium-N is changed into nitrate-N by bacteria in the soil during a process called nitrification, so it is OK to apply ammonium (NH_4) fertilizers. However, they will not be immediately available to the plants, and soil conditions such as pH and temperature have an effect on the speed of the nitrification process. Ammonium-N is rapidly converted to nitrate-N in warm, moist soil with a pH above 6.0. In addition, ammonium will acidify the soil more quickly over time than nitrate. For these reasons, amending the soil to the upper end of the suitable pH range (6.0–6.5) for strawberry prior to planting is a good idea. Nitrate-N is very mobile in the soil and readily leaches, so applying nitrate fertilizers during a time when the plants do not need fertilizer N or before heavy rainfall (in the late fall or winter, for example) will result in inefficient fertilizer use and nitrate leaching out of the soil. When plants do need the fertilizer, there may not be enough available within the root zone. In fertigated fields, nutrient application during the season is adjustable, and growers should aim to apply the annual amount needed based on their fertility plan through the entire production season and in as many applications as possible. For example, a grower with a six-month production season should divide the total N in 24 to 48 smaller applications for that year to avoid N loss and leaching, as well to maintain adequate growth.

Application methods

Powdered, granular or pelletized

Broadcasting fertilizer over the entire field will result in less fertilizer applied to the plants, since recommendations are for in-row applications. In this case, estimate the amount of fertilizer you are applying to between-row areas and increase the rate you are applying per acre accordingly. Applying the recommended amount in a broadcast band or where raised beds will be is an alternative application method and likely results in less fertilizer being leached to groundwater (Figure 7). See the “Nutrient Recommendations” section on page 19 for specific nutrient recommendations with granular products.

Photo: Bernadine Strik, © Oregon State University

Figure 7. Granular fertilizer applied to the in-row area of June-bearing strawberries in the planting year.

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 80 pounds per acre and we are applying a product with a fertilizer analysis of 16N-20P-0K. Remember that the product contains 16% N.

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

(80 lbs. N/acre ÷ 16) × 100 = 500 lbs. 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 in the fertilizer and divide by 100:

(500 lbs. product × 20) ÷ 100 = 100 lbs. P per acre

So to apply 80 pounds N per acre you will need to apply 500 pounds per acre of your fertilizer product and you will also be applying 100 pounds P per acre.

You will especially want to consider additional nutrients applied when you are working with organic products, such as feather meal, as you will be applying macro- and micronutrients in addition to N.

Fertigation

Fertigation is the practice of injecting liquid or water-soluble nutrients through the drip irrigation line using a fertilizer injector (Figure 8). In smaller plantings, a PTO-driven pump and tank may be used to apply organic fertilizers through the drip system (Figure 9). Fertigation is usually more common for day-neutral strawberries grown with plastic mulch. For day-neutral strawberry production in the Pacific Northwest, a single line of drip tubing is installed underneath the plastic mulch (with emitters spaced every 6 to 8 inches) and used to irrigate two rows of plants spaced 10–12 inches apart. Other emitter and plant spacings depend on raised bed dimensions and vary depending on target planting density and available equipment. Some growers use planting systems that more closely resemble the wider three- or four-row plantings with two or three drip lines used per bed in California (See Figure 10, page 18).

Photo: Javier Fernandez-Salvador, © Oregon State University

Figure 8. Fertigation system (application of liquid fertilizer through the drip irrigation system, day-neutral strawberries).

Photo: Javier Fernandez-Salvador, © Oregon State University

Figure 9. Fertigation of certified organic strawberries (day-neutral) using a PTO-driven pump and tank.

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 banded granular applications. Don't forget that 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 80 pounds N/acre of 23N–0P–0K urea solution, the calculation would therefore be the amount of amount of N recommended divided by the percentage of N in the fertilizer product multiplied by 100:

(80 lbs. N/acre ÷ 23) × 100 = 348 lbs. 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 pounds/gallon):

348 lbs. product ÷ 9.52 lbs./gallon = 36 gallons of urea solution per acre per 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 pounds/gallon at 70°F, your calculation to apply 80 pounds N/acre would look like this:

(80 lbs. N/acre ÷ 21) × 100= 381 lbs. 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):

381 lbs. ammonium sulfate ÷ 6.3 lbs./gallon of water = at least 61 gallons of water

Photo: Bernadine Strik, © Oregon State University

Figure 10. Strawberry field in California.

Many products, especially organic, can clog emitters, so use a filter with your drip system, run the irrigation system after fertigating to clear the end 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 iron bacteria or algae in the system. If this occurs or persists, install a chlorination system to treat irrigation water. Fertigation is usually more expensive than granular applications, but it can lead to increased yield through more efficient fertilizer uptake. See the "Nutrient recommendations" section on page 19 for nutrient recommendations with fertigation and Table 5 (pages 14–15) for products suitable for fertigation.

Foliar

Foliar applications of macronutrients are not an effective way of getting these nutrients into the plant.

Foliar Ca applications are often recommended as a way to increase fruit firmness and shelf life. However, field trials have shown that this isn't the case. Foliar Ca applications (conventional or organic products) at recommended product label rates do not increase fruit firmness or quality. Foliar applications at higher rates have resulted in phytotoxicity (damage to leaves or fruit).

Foliar applications of micronutrients, such as Zn or B, can be effective, however. Some nutrients can be toxic and burn leaves at high concentrations, so any nutrient should be applied 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.

Nutrient recommendations

Recommendations in this section are divided into June-bearing and day-neutral types where appropriate. *The Soil Test Interpretation Guide* (EC 1478) may be a useful additional resource, although the soil test values were not developed specifically for strawberries.

June-bearing recommendations assume production is with overhead irrigation and granular application of fertilizer. If you are using drip irrigation, refer to the day-neutral section but apply nutrients at the times and rates suggested for June-bearers.

Day-neutral recommendations are based on plants grown on raised beds with polyethylene or biodegradable plastic mulches and drip irrigation under the plastic. See *Biodegradable Plastic Mulch and Suitability for Sustainable and Organic Agriculture* (FS 103E) for more information about biodegradable plastic mulches. In this case, nutrients must be applied through the drip lines because the plastic mulch prevents topdressing. Since day-neutral strawberries have a long fruiting season, they require a constant supply of nutrients over the growing season, particularly N. It's important to note that the currently available biodegradable mulches are not allowed to be tilled into the soil at the end of the growing season in organic agriculture under the NOP standards and must be removed as with any other plastic mulch.

Nitrogen

Organic matter in the soil can release significant amounts of N, especially if the soil organic matter content has been built up over a number of years. Regardless of supplemental fertilizer, high organic matter soils (over 6 percent) increase plant growth over low organic matter soils (less than 2 percent). However, growers should still supplement N fertilizer during critical growth periods, because N is released slowly from organic matter and may not be able to supply the plant's demand during peak growth or while soil temperature is still cool. In organic systems where a cover crop has been incorporated in the rotation (prior to planting), refer to the OSU organic cover crop and fertilizer calculator for nutrient contributions from the cover crop (see "Resources" on page 27). Base the planting needs for N on the recommended rates, but adjust as needed based on your assessment of plant growth and tissue analysis. Nitrogen deficiency is characterized by small plants and reddish older leaves. Organic growers need to consider that most natural fertilizers are composed of organic N in the form of proteins or amino acids, and those need to be 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 the plant than solid products.

June-bearing cultivars

New plantings: The amount of N applied at planting will depend on the previous cropping history of your site. If it has been in a row crop, where more than 80 pounds N per acre was applied and little crop residue was incorporated (such as beans), then apply 30–40 pounds N per acre. However, if the site has been in sod or cereal and a large amount

Timing of fertilizer N application is important

Established, perennial June-bearing strawberry plants use predominantly stored N from fertilizer applied at renovation (See Figure 5, page 10) the prior year to support new growth and fruit production in the spring. This means that plants must have enough stored nutrients in the fall going into dormancy to support growth and fruiting the following year (Figure 11). Perennial day-neutral plantings also need stored nutrients to produce their first fruit in spring (Figure 12). While N should be applied during the growing and fruiting season (April to September in open field, March to October in tunnels) in day-neutral cultivars, N is best applied after fruiting and before flower bud development (at renovation) in June-bearing cultivars (Figure 5, page 10). Day-neutral cultivars grown as annuals (replanted every year) can have fertilization reduced at the end of the growing season in this region.

Photo: Bernadine Strik, © Oregon State University

Figure 11. Early growth in matted row production of June-bearing strawberries in Oregon in mid-March.

Photo: Bernadine Strik, © Oregon State University

Figure 12. Strawberry growth in late winter (early March here) depends on stored nutrient reserves in the roots and crown. These are 'Albion' strawberries in Oregon.

Photo: Bernadine Strik, © Oregon State University

Figure 13. Irrigating a June-bearing strawberry field after renovation to facilitate nitrogen fertilizer uptake and good growth prior to flower bud development.

of crop material was turned under, apply 50–60 pounds N per acre, to counteract the nitrogen-binding effects of residue breakdown.

Plant in the spring. In about mid-July of the planting year, apply 20–30 pounds N per acre to support continued growth (e.g. Figure 7, page 16). Assess growth and topdress with more N if needed. Calcium nitrate is a good choice, especially if fumigation occurred before planting. It does not volatilize, has a low salt index, and has quickly available N.

Organic solid fertilizers should be incorporated 1–2 months prior to planting to allow N to be mineralized for plant uptake. Most of the N release happens in the first four weeks, and the remainder of available N release has occurred at 10 weeks after application. Additional fertilizer can be added after planting, but since N release on organic products is so variable, special attention needs to be paid to factors of product, moisture, and soil temperature that will affect availability to the plant. If powdered, granular, or pelletized organic fertilizers are applied to a plastic-covered waiting bed in the fall (for spring planting) or on top of the bed after planting and not incorporated, allow 2– 6 months for the fertilizer to break down and N to be available to the plants. Availability rate will depend on physical breakdown of the product, soil moisture and irrigation, soil temperature, and microbial activity. Soybean, feather, blood, or fish meals are recommended options for their higher N concentration and relatively lower P and K, depending on the product.

Established plantings: Spring N applications are not recommended as they increase leaf growth and plant canopy density, increasing fruit disease problems and decreasing picking efficiency and possibly fruit firmness. However, an application of 15–20 pounds N per acre in the spring may be necessary if the field is weak because of reduced growth from winter cold injury, soil insects, or disease.

Additionally, apply 50 pounds N per acre about 1–2 weeks after renovation (Figure 5, page 10). The best timing for renovation or mowing off the old leaves is 2–3 weeks after last fruit harvest. Some cultivars such as 'Benton' produce too much foliage with excess N, so you may want to reduce the N rate for these cultivars by 25 percent. Irrigate the field with plenty of water after fertilizer application so that the N is quickly available (Figure 13). Additional research is needed, but a broadcast organic application right after harvest may work best to give additional time for

N mineralization prior to flower bud development. For quicker availability, some organic growers apply liquid fertilizer in one or two applications through their overhead irrigation system (injected) right after or two weeks after harvest.

Calcium ammonium nitrate is a good choice for conventional growers because it has N available in the short and long term. However, established plantings can be fertilized successfully with a variety of N sources. Urea is inexpensive but can volatilize (N is lost to the air), and plant injury may occur. Foliar applications of urea are not recommended because research has shown that it is not effective at increasing plant N. The presentation and binding agents used in some organic fertilizer (powder, granular, and pelleted) affect the physical breaking down of the products and may affect the release of the nutrient and the immediate availability to the plant. Liquid products are considered the fastest release and most available form for organic fertilizers. See Table 6 for recommended N fertilizer rates for June-bearing strawberry.

Table 6. Nitrogen fertilizer rates for June-bearing strawberry.

	Spring (lb/a N)	Summer (lb/a N)	Comments
Preplant and planting year	Preplant apply 30–40 if following row crops, 50–60 if following sod or cereal	Apply 20–30 lbs. mid-July	Incorporate organic solid fertilizers 1–2 months preplant
Established plantings	Not recommended, but apply 15–20 if weak field	50 lbs. 1–2 weeks after renovation	Irrigate after application. Reduce N rate by 25% for 'Benton' and other cultivars with excess foliage

Day-neutral cultivars

New plantings: When planting in the early fall or early spring, apply 30–40 pounds or 60–80 pounds N per acre preplant, respectively, if you are applying granular or bulk/solid organic products when the raised beds are shaped and covered with plastic mulch. For spring planting, you can apply half the aforementioned rate prior to planting and half through fertigation, or all through fertigation once or twice weekly at a rate of 20 pounds N per acre per month from June through September. Either of these options work well for spring-planted organic strawberry fields also. Organic preplant fertilizer options are effective but should be applied well in advance of the strawberry plant's requirements for N so there is enough time for the N in the product to be mineralized. Combine preplant applications of N with N after planting to meet plant needs. Some studies in annual day-neutral production have shown that preplant N applications have no effect on yield.

Established plantings: For a six-month production season, apply fertilizer through a drip line at a rate of 2.5–3 pounds N per acre per week from mid-April when plants begin to grow vigorously through mid-September (a total of 60–80 pounds N per acre over 24 weeks). Annual plantings may need 120 pounds N per acre or more, but it is still unknown how much N perennial day-neutral plantings in the Pacific Northwest can utilize in conventional or organic production systems with our shorter production season in open fields, when compared to California. See Table 7 for recommended N fertilizer rates for day-neutral strawberry.

Table 7. Nitrogen fertilizer rates for day-neutral strawberry.

	Preplant (lb/a N)	Mature (lb/a N)	Comments
Day-neutral — fertigated	Apply no more than 60 preplant or up to 50% of the crop need, depending on organic matter.	2.5–3 per week from the onset of vigorous growth in April through mid-September.	Fertigation applications should be started the first growing season. Supplement K at a similar rate and Ca weekly based on growth and tissue analysis results.
Day-neutral — granular (no plastic mulch)	Apply no more than 60 preplant, depending on organic matter.	20 per month from May through September.	Add K in autumn or early spring depending on soil and tissue test results.

Phosphorus

Apply P on both sides of the row, 3–4 inches from the plants and 4–6 inches deep at planting or at the edge of the row after renovation. Phosphorus is not very mobile in the soil, so it should be incorporated, and will be used with greater efficiency if it is placed in the plant root zone. Because of this, P is not subject to leaching. Adjusting soil to provide all the needed P prior to planting is recommended (Table 8). See Table 5 (pages 14–15) for fertilizer sources.

Table 8. Phosphorus fertilization rates for strawberries.

If the soil test for P (Bray 1) is (ppm)	Apply this amount of phosphate (P_2O_5) (lb/a)
0–15	100–120
15–45	60–00
over 45	0–60[z]

[z]Leave plantings unfertilized with P_2O_5 at soil levels just over 45 ppm only if you are confident the soil test was very representative of the whole field to be planted. If you are concerned there may be areas in the field with slightly lower levels of P, apply nearer the high end of this range.

Phosphorus availability is affected by soil pH, soil moisture, soil type, organic matter content, and Ca and aluminum (Al) in the soil. Clay soils tend to fix more P than sandier soils, making it less available to plants. Incorporating green manure increases available P. Excess P can be a problem because it reacts with micronutrients to make them insoluble and can result in deficiencies. Apply P based on a soil test as shown in Table 8. If needed, organic P sources include compost, rock phosphate (soft and regular), bone and fish bone meal, bat guano, and rock dust. Also remember that most organic fertilizers contain P.

Phosphorus deficiency symptoms include purplish older leaves and dark-green younger leaves.

Potassium

Significant amounts of K are lost in strawberry fruit during harvest (see Table 4, page 13), so adequate K is important to support plant needs. Like P, K availability is dependent on a number of factors, such as soil texture, clay content, organic matter, and Ca and Mg. Certain clay soils and high soil availability of Ca and Mg can reduce K availability, while other clay soils and organic matter will increase K availability. Excess K can induce Mg deficiency. See Table 5 (pages 14–15) for fertilizer sources of K.

Potassium deficiency symptoms include older leaves with marginal necrosis (leaf edges dying), followed by necrotic leaflet petioles and darkened leaflets.

June-bearing cultivars:

In new plantings, K can be banded with N and P after planting at rates of less than 60 pounds K per acre. Potassium may be broadcast at higher rates before planting, based on soil test results. As K is not very mobile in the soil, pre-plant incorporation is the most effective method. See Table 9 for rates.

Table 9. K fertilization rates for strawberries.

If the soil test for K is (ppm)	Apply this amount of potash (K_2O) (lb/a)
Under 75	100–120
75–175	80–100
over 175	0–80

Day-neutral cultivars

Potassium should be applied at the same rate as N, both preplant in the fall or spring and through fertigation during the growing season. Both fish emulsion and liquid grain-based fertilizers supply K along with the N. Ensure products injected only for K application are compatible with fertigation.

Additional organically approved sources of K fertilizer include greensand and algae- or kelp-based products for preplant applications. Follow the same recommendations for rate when using conventional products.

Sulfur

Sulfur should be applied annually at rates of 15–20 pounds S per acre. Apply S with N after renovation for June-bearers and preplant or through the drip system during the growing season for day-neutrals. Be aware that you may be applying S along with other fertilizer materials and in fungicides. If so, reduce your rates accordingly. Sulfur fluctuates widely throughout the year, so soil tests are not a reliable indicator of sufficiency.

Sulfur deficiency symptoms include decreased plant vigor and reddish leaves.

Calcium

Most soils have sufficient Ca for strawberry growth, especially if the pH is within the recommended range. Calcium 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. For conventional growers, calcium nitrate can be an effective way of applying Ca along with the N fertilizer application. Foliar applications of Ca have not been found to be effective in Oregon and Washington. Calcium mobility in soil varies and depends on cation exchange capacity, but Ca is generally considered to have low soil mobility.

In contrast, calcium is immobile in plants. Since Ca moves only in the xylem, cool, wet, or cloudy weather or low soil moisture can decrease Ca uptake. Calcium may be supplemented weekly through fertigation in day-neutral production, although it tends to clog emitters, especially with high pH irrigation water and high application rates. A commonly used Ca source in organic production is fine- or solution-grade gypsum (calcium sulfate), which can be applied prior to planting, as well as injected as a suspension (may require specialized equipment). Check with local fertilizer representatives for advice regarding products available. The best approach to ensuring adequate plant Ca in organic production is to modify soil pH and thus soil Ca prior to planting.

Calcium deficiency symptoms include soft fruit, distorted new leaf growth with wrinkles and brown leaf edges or tips, and brown daughter plants with new leaves with interveinal necrosis (Figure 14). Symptoms can also show up as a syrupy exudate on leaves and dense seed cover on unexpanded fruit. Calcium deficiency symptoms are sometimes seen in strawberry because there can be very rapid spring growth in the planting year when we typically have cool, wet, and cloudy weather. Often these symptoms will stop once Ca is more available to the new growth or growth is less rapid.

Magnesium

Magnesium should be applied if soil test values are below 300 parts per million of Mg. Magnesium may be banded as described above at 0–60 pounds Mg per acre if soil test results are between 60 and 300 ppm or from 10–100 pounds Mg per acre if soil test results are less than 60 ppm using potassium magnesium sulfate (Sul-Po-Mag) or magnesium sulfate (Epsom salts) for organic or conventional production.

Photo: Javier Fernandez-Salvador

Figure 14. Symptoms of calcium deficiency (leaf tip wrinkling and burning) in a strawberry plant.

You can also supply Mg with dolomitic lime if soil pH needs to be increased prior to planting. Foliar applications of Mg are not recommended. 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.

Magnesium deficiency symptoms include older leaves with interveinal chlorosis or leaf edge reddening (Figure 15).

Photo: Javier Fernandez-Salvador

Figure 15. Magnesium deficiency symptoms in strawberry leaves.

Iron

As soil pH drops, 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.

Iron deficiency symptoms include yellowing of younger leaves.

Manganese

Manganese availability depends on soil pH, and levels in leaves are higher at low soil pH than at high soil pH. Despite this, strawberries are relatively tolerant to high or low Mn. Soil test values between 1 and 5 ppm using the DTPA extraction method are usually sufficient.

Manganese deficiency symptoms include poor plant growth in general.

Boron

There is a very fine line between B deficiency and toxicity in strawberries. Never band B or borated fertilizer. Prior to planting, B should be broadcast and worked into the soil at low rates, if needed, based on soil test results. Granubor or Borax are good options for both organic and conventional production. After planting, if plant B is deficient based on tissue testing, apply foliar B sprays at early bloom or in late summer at a rate of 2–6 pounds of Solubor (20% B) per acre.

Day-neutral strawberries are more susceptible to B toxicity than June-bearing types. In an Oregon study, B applications did not affect day-neutral yield the first year and decreased yield the second year, so the researchers concluded that 0.27 ppm soil B was sufficient, rather than 1 ppm, which is recommended in June-bearing types (Table 1, page 6).

Boron deficiency symptoms include asymmetrical leaf growth and deformed berries (despite adequate pollination).

Zinc

Zinc is an important micronutrient that is often deficient. The DTPA extraction method can serve as an indicator of Zn availability in both alkaline and acidic soils, but high levels of organic matter and negatively charged ions can limit the accuracy of the results. 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. Applying zinc sulfate at a rate of 5–15 pounds Zn per acre is usually sufficient.

Zinc deficiency symptoms include stunting and narrow leaves.

Copper

Copper is extremely immobile in both soil and plants, but deficiency is uncommon, unless you are planting into land that was previously unfarmed, or in pasture, sod, or hay production. Copper soil test results above 0.6 ppm using the DTPA extraction method are sufficient. Copper can burn leaves and is also 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.

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

Containerized transplants

In some day-neutral systems, particularly under tunnels for early organic production in our region, containerized transplants may be used to decrease plant mortality and produce an earlier harvest. Bare-root plants are potted in cells on growing media (usually peat moss or forest byproducts mixed with perlite). Some products may have organic fertilizers incorporated at very low rates. Depending on the time the plants will remain in the greenhouse prior to transplanting, additional fertilizer can be added to the mix or fertigation can be supplied through the mist/sprinkler system at very low N rates.

Resources

Other Extension publications

A Guide to Collecting Soil Samples for Farms and Gardens (EC 628) (https://catalog.extension.oregonstate.edu/ec628)

Applying Lime to Raise Soil pH for Crop Production (Western Oregon) (EM 9057) (https://catalog.extension.oregonstate.edu/em9057)

Biodegradable Plastic Mulch and Suitability for Sustainable and Organic Agriculture (FS 103E) (http://cru.cahe.wsu.edu/CEPublications/FS103E/FS103E.pdf)

Estimating Plant-Available N from Manure (EM 8954) (https://catalog.extension.oregonstate.edu/em8954)

Estimating Plant Available Nitrogen Release from Cover Crops (PNW 636) (https://catalog.extension.oregonstate.edu/pnw636)

Fertilizing with Manure and Other Organic Amendments (PNW 533) (https://catalog.extension.oregonstate.edu/pnw533)

Interpreting Compost Analyses (EM 9217) (https://catalog.extension.oregonstate.edu/em9217)

Pacific Northwest Insect Management Handbook (https://catalog.extension.oregonstate.edu/insect)

Pacific Northwest Plant Disease Management Handbook (https://catalog.extension.oregonstate.edu/plant)

Soil Test Interpretation Guide (EC 1478) (https://catalog.extension.oregonstate.edu/ec1478)

Strawberry Cultivars for Western Oregon and Washington (EC 1618) (https://catalog.extension.oregonstate.edu/ec1618)

FDA Food Safety Modernization Act (https://www.fda.gov/food/guidanceregulation/fsma/)

Hoashi-Erhardt, W. and T. Walters. 2014. *Growing Day-Neutral Strawberries in Western Washington*. Washington State University Extension Service. FS132E.

Lantz, W., H. Swartz, K. Demchak, and S. Frick. (date unknown). *Season-Long Strawberry Production with Everbearers for Northeastern Producers*. University of Maryland Extension. EB 401.

USDA NOP Standards https://www.ams.usda.gov/rules-regulations/organic/handbook

Additional information

Bolda, M., T. Bottoms, and T. Hartz. 2012. Strawberry Plant Nutrient Sufficiency Levels Revised. University of California Cooperative Extension. Crop Notes March/April 2012:1–3.

Oregon State University Small Farms Program Organic Fertilizer and Cover Crop Calculator (http://smallfarms.oregonstate.edu/calculator)

University of California Santa Cruz Alternatives to Soil Fumigation (https://shennanlab.sites.ucsc.edu/home/page-builder/alternatives-to-soil-fumigation/)

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