Nutrient Management

Soil Testing

Soil analysis is the most accurate guide to nutrient and lime requirements for most crops. It is especially useful before planting to determine soil fertility and pH levels. The necessary lime and fertilizer can then be added during the field preparation. Soil testing combined with tissue testing are useful tools for determining fertilizer requirements in established crops. However, sampling must be done accurately and carefully so the samples are representative of soil and crop conditions. Refer to the BCMAL Soil Note, "Soil Sampling" for more information on collecting and handling a soil sample.

The basic steps for soil sampling are:

- Use the same sampling method and pattern every year.
- Use clean tools (e.g. garden trowel) to collect the sample.
- Use a clean pail (e.g. ice-cream bucket) to hold all the samples for one combined analysis.
- Mark the locations on a field map where samples are to be collected. Avoid non-uniform areas.
- Record relevant information about the location and type of sample.
- Wear disposable gloves when sampling for micronutrients.
- Take 10 to 20 individual samples to a depth of 15 cm (6 in) for most nutrients. Sample to 30 cm (12 in) when sampling for nitrate-nitrogen (particularly in raspberries). Try to collect a uniform sample width through the entire 0-15 cm (or 30 cm) profile. Purposefully designed soil samplers remove a core about 2.5 cm (1 in) wide. Refer to the crop sections for sampling location in the row.
- Thoroughly mix the soil in the collecting pail.
- Put about 300 ml (1 cup) of the mixed soil into a clean plastic bag or box.
- Store the sample in a cooler until it is taken to the laboratory.

Soil testing is conducted by several private laboratories in the BC. Refer to the BCMAL factsheet, "Resources for Berry Growers" for a listing. Where possible, use local laboratories as they have knowledge of local conditions to conduct the appropriate analyses and give correct recommendations. Use the same laboratory each year for consistent interpretations and recommendations.

Tissue Testing

Specific plant tissue testing methods—including when and where to sample—and interpretation are limited for many plants. Tissue testing can be used to compare plants when a problem such as a nutrient deficiency is suspected. For a listing of laboratories conducting tissue testing, refer to the BCMAL factsheet, "Resources for Berry Growers."

Follow these guidelines when sampling for tissue analysis:

- Take sample for normal analysis at the same time of plant development each year. For example, blueberry leaf samples for normal analysis should be taken when the first fruits are turning blue.
- Sample for possible nutrient deficiencies (diagnostic sampling) at any time during the growing season.
- Use an X-pattern from corner to corner of the planting, if possible.

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- If possible, sample for each variety separately. On smaller plantings, a combined sample of mixed varieties should give a reasonable result, and may be more affordable.
- Sample the youngest, fully opened leaves of sample plants.
- Do not take samples from the outside edges of the planting.
- Avoid dirty leaves or leaves damaged by insects or mechanically.
- Sample using clean hands, or use plastic gloves.
- Put samples in a clean, paper bag.
- Take samples to the laboratory as soon as possible. If they must be held, keep in a cooler to avoid spoilage.
- Consult the laboratory that will conduct the analysis for more specific information, especially if samples must be mailed.

Record Keeping

For the most effective nutrient management program, it is essential to keep track of soil and tissue testing results along with all information about the rates, type and timing of fertilizer, manure or soil amendment applications. Other observations on crop growth, yield, quality and weather during the growing season are also useful.

Use test strips ("checks" or "control strips") to test changes in a nutrient management program. Then the old practice can be compared to the new practice to see if the crop is affected. This comparison can only be made when the old and the new practices are evaluated under the same field and management conditions.

Fertilizers

Recommendations

Fertilizer recommendations in this section of the guide are general guidelines only. Specific recommendations are given in most crop sections.

If a soil test is not available, appropriate rates should be based on information from previous fertilizer use, cropping history and basic nutrient requirements of the crop to be grown.

Berry crops in BC are known to respond to nitrogen, phosphorus, magnesium and boron fertilizers, and to lime amendments to adjust the pH of acidic soils. The rate will vary from soil to soil. The requirement of other fertilizer nutrient elements, such as sulfur (S), copper (Cu), zinc (Zn) and manganese (Mn) has not been determined to date. Applications of these nutrients should be done with caution—such as starting with test strips only—since additions in excess of plant requirements could result in damage to the crop and the environment.

Nitrogen (N)

Recommendations are made in each berry crop section. A soil based nitrogen test has only been developed for raspberries grown in South Coastal BC. Therefore for all other crops, the recommendations are guidelines only.

In the South Coastal region, all mineral nitrogen (nitrate and ammonia) left in the soil in the fall is lost or not available to crops in the spring. Nitrogen applications can be based on soil or tissue testing but applications should not exceed the recommendations given for each crop. A "report card" soil test for nitrate-nitrogen (0-30 cm depth) in late-August gives an indication of the surplus amount applied. If the nitrate-nitrogen is more than 50 ppm (NO_3-N), then too much nitrogen was applied from all sources and less nitrogen should be added in the following season.

For areas outside of the South Coastal region, all soil nitrogen in the mineral form left at the end of the growing season is available to the crop in the next season. Soil testing for nitrogen in the fall or spring gives an indication of the amount available. This can be compared to the general nitrogen recommendation given in the individual crop sections.

Notes:

- The following recommendations are valid for the South Coastal and Southern Interior regions.
- Where two types of testing methods are listed in the tables, check with the laboratory conducting the analysis to find out the extraction method used and follow the appropriate recommendations.

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Phosphorus (P)

Table 7. Phosphorus fertilizer recommendations for cane and strawberry crops.

Rating	Comments	"Bray P1" method Soil Test-P ppm	"Kelowna" method Soil Test-P ppm	Recommended P_2O_5 application rate (kg/ha)
L	PG	0-15	0-20	70-90
M	PG	15-45	21-50	0-70
H	P2	45-100	51-100	0
VH	P3	100+	100+	0

PG Broadcast and incorporate the recommended phosphate rate into the rootzone before planting. If crop is established, phosphate can be applied in early spring as broadcast.

P2 Soil is well supplied with phosphorus, this rate is intended for maintaining soil fertility.

P3 No application of this nutrient is recommended as the soil already has an abundant supply.

Potassium (K)

Table 8. Potassium fertilizer recommendations for cane and strawberry crops.

Rating	Comments	"NH_4-Acetate" method Soil Test-K ppm	"Kelowna" method Soil Test-K ppm	Recommended K_2O application rate (kg/ha)
L	KG	0-100	0-80	90-115
M	KG	100-200	81-175	70-90
H	KG2	200-300	176-250	45-70
VH	KG3	300+	250+	0

KG Broadcast and incorporate the recommended potash rate into the rootzone before planting. If crop is established, potash can be applied in early spring as broadcast or in band.

KG2 Soil is well supplied with potassium, this rate is intended for maintaining soil fertility.

KG3 No application of this nutrient is recommended as the soil already has an abundant supply.

Boron (B)

Table 9. Boron fertilizer recommendations (kg B/ha) for cane and strawberry crops

Rating	"NH_4 - Acetate" Method		"Kelowna" Method	
	Soil Test-B ppm	Recommendation kg/ha (kg/acre)	Soil Test-B ug/mL	Recommendation kg/ha (kg/acre)
VL	< 0.20	2.2-3.4 (0.9-1.4)	< 0.20	3 (1.2)
L	0.21-0.50	1.1-2.2 (0.4-0.9)	0.21-0.40	2 (0.8)
M	0.51-1.00	1.1 (0.4)	0.41-0.80	1 (0.4)
H	> 1.00	0(0)	> 0.80	0 (0)

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Magnesium (Mg)

Table 10. Magnesium fertilizer recommendations (kg Mg/ha) for cane and strawberry crops

Rating	Soil Test - Mg ppm	Recommendation kg/ha (kg/acre)
VL	0-25	40 (16)
L	26-50	25 (10)
M	51-100	20 (8)
H	101-150	0 (0)

Calculating Fertilizer Rates

Fertilizers are labeled by percentage according to their guaranteed minimum analysis of nitrogen (N), phosphate (P_2O_5), potash (K_2O) and other nutrients that may be present. Five-20 kg bags (100 kg total) of 12-51-0 contain 12% nitrogen (12 kg N), 51% phosphate (51 kg P_2O_5), and no potash (0 kg K_2O). The rest of the material in the five bags is other elements that are part of the fertilizer compounds carrying the nitrogen, phosphate, and potash. Sample calculations for determining the amount of fertilizer and nutrients to apply are given below.

Calculating for fertilizer and nutrient applications

Calculating the amount of fertilizer to apply.

The amount of fertilizer required = recommended rate X 100 fertilizer analysis

Example:

Recommended rate potash: = 135 kg/ha

Fertilizer analysis: = 0-0-60

Amount of fertilizer required = $\frac{135 \text{ kg/ha X } 100}{60}$ = 225 kg/ha

Apply 225 kg/ha of 0-0-60

Calculating the amount of nutrients applied

The amount of nutrients applied by a fertilizer = $\frac{\text{amount of fertilizer applied X the fertilizer analysis}}{100}$

Example:

Amount of fertilizer applied: = 225 kg/ha

Fertilizer analysis: = 13-16-10

Amount of N supplied: = $\frac{225 \text{ kg/ha X } 13}{100}$ = 29 kg N/ha

Amount of P_2O_5 supplied = $\frac{225 \text{ kg/ha X } 16}{100}$ = 36 kg P_2O_5/ha

Amount of K_2O supplied = $\frac{225 \text{ kg/ha X } 10}{100}$ = 22.5 kg K_2O/ha

Methods of Fertilizer Application

Definition of Terms

Broadcasting and incorporating. Refers to spreading fertilizer on a soil surface before the crop has been planted, then incorporating the fertilizer into the soil by tillage.

Top-dressing. Refers to spreading fertilizer on a field when a crop is growing. It is not incorporated, but sprinkler irrigation will wash fertilizer off the leaves which prevents burning and moves the nutrients into the surface a few centimeters of soil.

Banding. Refers to the application of fertilizer at the time of planting in continuous bands 2.5 cm or more to the side of the plant and 5 cm or more deep, depending on the crop.

Side-dressing. Refers to the banding of fertilizer after plants are established. Care should be taken not to disturb the roots of the plants.

Fertigation. Refers to the application of fertilizer in irrigation water.

Deep-banding. Refers to banding fertilizer at a depth of 5 cm or more prior to planting. There is scientific evidence indicating that this results in greater fertilizer efficiency than surface broadcasting for deep-rooted row crops.

Soil pH

Soil pH refers to the acidity or alkalinity of the soil. pH is very important to berry production as it affects the availability of nutrients to the plant. Most crops do not respond to fertilization when the pH is very low (extremely acid soils, pH less than 4.5) or very high (extremely alkaline soils, pH above 8.0). Test the soil to determine pH before planting and every 3 to 4 years after planting to monitor changes. Soil pH can usually be modified to obtain a suitable pH for good berry production.

Raising Soil pH

Soils in South Coastal regions are typically acidic and, for most berry crops, usually require lime applications to raise the pH.

Dolomite limestone is generally recommended as it contains a significant quantity of magnesium— an essential and often deficient plant nutrient. For the Fraser Valley, the general application rate is 1 to 2 tonnes per hectare per year (400 to 800 kg/acre) for pH sensitive crops. Rates higher than 2 to 4 tonnes (800 to 1600 kg/acre) are not recommended due to soil reactivity and the difficulty in incorporation.

Strawberries, raspberries and blackberries will tolerate acid soils but do best in soils that are slightly acidic (pH = 6.0 to 6.5). Blueberries and cranberries prefer more acidic soils but do require calcium in the soil. Rather than using lime, gypsum may be used to supply calcium if levels are low.

Effects of Lime

- Corrects soil acidity.
- May improve the physical condition of the soil.
- Provides the nutrient calcium (and magnesium if dolomite limestone is used) and increases the availability of other plant foods.
- Favours bacterial action, thus hastening the decomposition of organic matter and releasing additional plant foods.
- Improves conditions for availability of other nutrients, notably phosphorus and some minor elements.
- High rates of lime may help digest organic matter and release nitrogen for a short period after application.
- Reduces the toxicity of some elements such as manganese and aluminum.
- Above 5 tonnes/ha may tie up some micro-nutrients such as boron. Magnesium deficiencies may be aggravated, especially in sandy soil. Where this is a problem, some dolomite lime should be used.
- Excessive use of lime may cause nutrient imbalances, so lime should be used in conjunction with a planned soil testing and fertilizer program.
- Increases rate of organic matter depletion.
- Encourages germination and growth of some weeds.

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Forms of Lime Used

Calcium oxide. Quicklime, caustic lime, burnt lime. Not recommended on agricultural land.

Calcium hydroxide. Hydrate or slaked lime. Should only be used as a spring application for rapid results. "Agricultural Lime" refers to this form but the use of this term is not recommended. It is the quicker acting form of agricultural lime. It will correct soil acidity quickly but is usually two or more times as expensive. Excessive rates above 1100 kg/ha (450 kg/acre) may be quite caustic and "burn out" organic matter.

Ground limestone. Calcium carbonate. The most convenient form to handle. May be applied at any time of the year. It dissolves slowly and lasts longer in the soil. (Usually gray lime material, sold in bulk in South Coastal BC.)

Ground dolomite. Calcium-magnesium carbonate. May be substituted for ordinary limestone. It contains magnesium.

Notes:

- Fineness of grind is very important. The finer grinds (100 mesh and above) react in soil much quicker than the coarser grind (10 to 100 mesh). Very coarse limestone (less than 10 mesh) is not recommended. Some coarse material is desirable to facilitate handling of the lime. Excessively fine material will not flow readily and is subject to wind drift during spreading.
- Lime does not move through the soil—it must be incorporated.

Lowering Soil pH

Sometimes it is advantageous to lower—or acidify—the soil. Some mineral soils in South Coastal areas may need to be acidified for growing blueberries. In Interior areas, alkaline mineral soils should generally be acidified for strawberry, blueberry or raspberry production. Incorporating sawdust before planting blueberries and mulching the bushes may sufficiently lower the pH of alkaline mineral soils.

The principle materials used to lower soil pH are elemental sulfur, sulphuric acid, aluminum sulfate and iron sulfate (ferrous sulfate). Ammonium sulfate, ammonium phosphate and other ammonium containing fertilizers are also quite effective in reducing pH when the soil receives sufficient water, though they are primarily sources of plant nutrients.

For large areas, elemental sulfur is probably the most economic product to use. The finer ground the sulfur, the more quickly it will react in the soil to lower the pH. Flower sulfur is very fine (powder) and reacts relatively quickly. Solid sulfur prills (granules) are less finely ground and therefore react more slowly—and they are more convenient to apply. Finely ground sulfur is sometimes available in prills that contain a mixture of flower sulfur and bentonite clay which improves the handling, stability and safety of the material.

Soil test laboratories can, by request, determine total soil acid and calculate the sulfur required to attain a desired pH. As a general recommendation apply the equivalent of 2 tonnes/ha (800 kg/acre) to a band where the planting beds will be formed. For example: sulfur applied to a blueberry planting with 3 meter row spacing and 120 cm wide beds, would require 800 kg/ha (325 kg/acre) spread only on the beds.

Starter Solutions

High analysis, readily soluble or liquid concentrate starter solution fertilizers are available for use with seedlings and transplants to help get them off to a quick start. Often, during warm, dry weather, only water is needed. However, starter solutions are particularly helpful in cool planting weather since the dissolved nutrients are immediately available to immature root systems. Most starter solutions are high in available phosphorus. Some typical fertilizers include: 0-52-0, 20-20-20, 10-50-10, 10-52-17, and 21-53-0. Fertilizers containing approximately 50% P_2O_5 should be dissolved at approximately 0.8 to 1.0 kilogram per 100 liters (22 gal) of water. If a highly soluble type fertilizer such as 20-20-20 is used, it should be dissolved at 0.2 to 0.3 kilograms per 100 liters (22 gal) of water.

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Manure Management

Code of Agricultural Practice for Waste Management

The use of livestock manure and agricultural vegetation wastes is covered by the “Code of Agricultural Practice for Waste Management”. This Code is part of the “Agriculture Waste Control Regulation” under the “Environmental Management Act.” The Code describes general practices for the use, storage and management of agricultural waste in an environmentally sound manner. Growers are encouraged to take advantage of the Canada-BC Environmental Farm Plan Program. Access to this program will provide more detailed information on a range of environmental issues including proper use of manure and woodwastes. See Environmental Farm Plans on page 47.

Storage

The Code requires that agricultural waste, particularly manure, be kept in a storage facility or covered if not used immediately. The storage must prevent escape of manure to the environment that would cause pollution. Manure may be stored uncovered in the field for up to 2 weeks prior to use. Manure may be stored in the field for up to 9 months if it is kept in a temporary storage facility that prevents the escape of nutrients to the environment. For example: securely tarped on a dry site. In the Lower Fraser Valley and Vancouver Island regions, stored manure must be covered from October 1 to April 1. The field storage facility must be 30 meters from a water course or a water source used for domestic purposes.

Nutrient Value

Manures supply plant food over a period of time. Table 11 shows the typical amount of nutrients supplied in various types of livestock manure. ***Note*** the moisture and nutrient content varies as a result of storage method, litter content, and age of manure. Growers are encouraged to test manure for nutrient content prior to use.

The nitrogen values given in the table are for total nitrogen. For all types of manure, the amount of nitrogen that is available to the crop after it is applied on the field may vary from the total nitrogen listed in the table. Incorporate solid manures (e.g. poultry) within 12 to 24 hours of spreading, to achieve the most benefit. Nitrogen losses after spreading range from 20% if the manure is incorporated soon after spreading, to as much as 50% if the manure is left on the soil surface.

Have the manure tested for nutrient content after it is delivered to the farm. The nutrient content will not change significantly if the manure is kept covered by either a roof or a tarp. If a manure test is unavailable, the table values can be used but they may require adjustment of moisture content for the manure to be used.

Table 11. Typical Nutrient Content of Various Manures

Manure	Moisture %	Nutrient Content* kg/tonne (kg/m^3) Total N	P_2O_5	K_2O
Beef (solid)	68	4.2 (2.1)	4.8 (2.4)	8.2 (4.1)
Dairy (solid)	77	3.9 (2.0)	3.4 (1.7)	9.0 (4.5)
Dairy (liquid)	91	2.9 (1.5)	2.1 (1.1)	4.5 (2.3)
Swine (covered pit)	93	6.3 (3.2)	3.3 (1.6)	3.9 (2.0)
Swine (uncovered pit)	98	3.5 (1.8)	1.5 (0.8)	1.7 (0.8)
Horse (with shavings)	72	2.4 (1.2)	1.7 (0.8)	3.2 (1.6)
Spent mushroom compost	70	5.8 (2.9)	2.5 (1.2)	8.5 (4.2)
Poultry (broiler)	25	31.6 (15.8)	22.8 (11.4)	12.2 (6.1)
Poultry (layer)	50	22.8 (11.4)	29.2 (14.6)	11.2 (5.6)

** Nutrient values for manure assume proper storage, handling, and application to minimize losses.*

Conversions:

1 tonne of liquid manure = approximately 1000 litres = 1 m^3 = 220 Imp. gallons

1 m^3 = 1.25 yd^3 = 28 bushels

1 tonne of solid manure = approximately 2 m^3 = 2.5 yd^3

To convert kg/tonne to lb/ton, multiply by 2.0

To convert kg/m^3 to lb/yd^3, multiply by 1.7

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Nutrient applications from all sources—including manure and commercial fertilizer—should be balanced to meet the crop requirements for nutrients. The release of nutrients from manure is not consistent. Therefore, in any year manure should only be used to supply up to 75% of the crop's nitrogen requirement. About 50% of the phosphorus in manure is readily available in the year it is applied. Where manure has been used repeatedly, phosphorus is assumed to be 100% available. All potassium from manure is available in the year of application.

Compost

The nutrient content of composted manure is slightly higher than fresh manure. However the availability of the nutrients is lower as they are held in a more stable form by the organic matter of compost. Composted manure may be expensive for field application. The benefits of compost use include reduced nitrogen leaching in environmentally sensitive areas, and usefulness as a supplement or replacement for other organic matter in plant propagation. Composts should be checked for salt content prior to use as media for seedling or transplant production. Generally less than 50% of a growing media by volume should be made up from compost.

Soil Conditioner

Manure can be used as a soil conditioner if the amount of nutrients in the manure is determined and the application rate is no more than the crop requires for nutrients. Using manure together with cover crops can improve soil structure. The decomposition of the manure in the presence of cover crop roots stimulates biological activity, and increases aeration, permeability, and water holding capacity of the soil. Do not apply manure to bare ground in either the fall or winter (mid-September to March 1).

Applying Manure

Under the code, manure can only be applied to land as a fertilizer or soil conditioner.

South Coastal B.C. Apply manure to berry crops between mid-Feb and mid-April. Manure application rates should match the nutrient requirements of the crop and be based on soil tests. No manure should be applied to berry land between September 1 and February 15.

Interior B.C. Spread manure only when the risk of runoff is near zero. Manure should not be applied to frozen or snow-covered ground. No manure should be applied to berry land between mid-September and mid-February. Manure application should match the nutrient requirements of the crop and be based on soil tests.

Additional Precautions

Recently concerns have increased over potential contamination of watercourses with constituents of manure. Berry growers are encouraged to use beneficial management practices to avoid direct discharge or runoff losses of manure into watercourses. This concern applies not only to the nutrient and solid fractions, but also to the potential pathogens that may exist in animal manure.

Water in ditches is often used for irrigation, so water quality is important. Refer to "Water Management", page 31 for water quality criteria and "Food Safety" page 49 for additional information.

Determining the Amount of Manure to Spread on the Field

To spread manure as a fertilizer the following must be known:

- the nitrogen content of the manure,
- the amount of nitrogen supplied by the manure to the crop,
- the amount of manure the spreader can hold (its capacity),
- the nitrogen needs of the crop, and
- the number of spreader loads of manure per area in the field.

The following steps show how to calculate the amount of manure to spread.

Step 1. Determine the nitrogen content of manure.

Refer to Table 11 for typical total nitrogen contents of various types of livestock manure. Use these values if a laboratory or quick test value is not available. Nitrogen comes in several forms in manure. The amount of nitrogen in manure also varies and is subject to many management and environmental conditions that can result in nitrogen losses.

Step 2. Calculate the approximate amount of nitrogen supplied by the manure (kg N/yd^3).

Losses of nitrogen upon application of manure can range from a low of 20% if manure is incorporated within 24 hours, to as much as 50% by volatilization if the manure is left on the soil surface. A detailed discussion of loss factors is available in the "Environmental Guidelines" for various commodities.

$$= \frac{\text{N supplied by manure (kg N/m}^3\text{) (from Table 11) X initial application loss factor}}{1.31 \text{ (m}^3\text{/ yd}^3\text{)}}$$

Step 3. Determine the capacity of the manure spreader (yd^3).

$$= \frac{\text{box length (ft) x width (ft) x average height of manure in spreader (ft)}}{27 \text{ ft}^3\text{/yd}^3}$$

Step 4. Determine the nitrogen needs of the crop (kg/ha).

Refer to specific crop recommendations in the appropriate crop sections or the results of a soil test.

Step 5. Calculate number of spreader loads of manure per area in the field (loads/ha).

$$= \frac{\text{crop N requirements (kg N/ha)} \div \text{spreader capacity (yd}^3\text{/load)}}{\text{N supplied by the manure (kg N/yd}^{3)}}$$

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Example:

A spreader has a box that is 7.5 feet long and 4 feet wide. It is filled with a solid poultry (broiler) manure to an average depth of 2.25 feet. The manure will be spread on an established raspberry crop that, based on soil testing, requires about 80 kg/ha (32 kg/acre) of nitrogen. The manure is to be broadcast over the entire interrow area using a conventional spreader. How many loads are needed to supply the crop's nitrogen requirements?

Step 1. Determine the nitrogen content of manure.

From Table 11, poultry manure contains 15.8 kg N/ m^3

Step 2. Calculate the approximate amount of nitrogen supplied by the manure (kg N yd^3).

$$= \frac{15.8 \text{ kg N/m}^3 \text{ (from Table 11) X } 0.80}{1.31 \text{ (m}^3\text{/yd}^3\text{)}} = 9.6 \text{ kg N/yd}^3$$

Step 3. Determine the capacity of the manure spreader (yd^3).

$$= \frac{7.5 \text{ ft long X } 4 \text{ ft wide X } 2.25 \text{ ft deep}}{27 \text{ ft}^3\text{/yd}^3} = 2.5 \text{ yd}^3\text{/load}$$

Step 4. Determine the nitrogen needs of the crop (kg/ha).

80 kg N/ha (32 kg N/ac) (established raspberry crop, based on soil testing)

Step 5. Calculate the number of spreader loads of manure per area in the field (loads/ha).

$$= \frac{80 \text{ kg N/ha} \div 2.5 \text{ yd}^3 \text{/load)}}{9.6 \text{ (kg N/ yd}^3\text{)}} = 3.3 \text{ loads/ha } (\div 2.47 = 1.3 \text{ loads/acre})$$

Nutrient Reactions in Soil

Nutrients added to the soil may become more or less available depending on the type of fertilizer, the soil moisture, the pH conditions, the nature of the soil and the amount of organic matter, rainfall, and temperature. Some nutrient elements may be completely lost; others may be "tied-up". This section gives information on nutrients from conventional fertilizer sources (i.e. not organic sources such as manure).

Nitrogen

The most common forms of fertilizer nitrogen are nitrate (NO_3), ammonium (NH_4) and urea ($CO[NH_2]_2$). All three forms are highly water soluble. Urea is converted to the ammonium form by enzymes in the soil. Ammonium nitrogen is adsorbed (chemically bound) to clay minerals and organic matter, and is retained by the soil. Some ammonium and urea nitrogen may be converted to ammonia gas which escapes into the atmosphere. This usually occurs in dry soil with surface-applied fertilizer. Ammonia losses are reduced or eliminated by making sure that the fertilizer is well covered with moist soil. Losses are minimized by banding, immediate incorporation after broadcasting, irrigation following application or broadcasting on to moist soil in cool weather.

Slow release forms of fertilizer have the same reactions in the soil as non-slow release forms, once the nitrogen is released. The slow release mechanism, whether it is a capsule like sulfur coating or a blend like a polymer, is designed to overcome problems with nitrogen losses and availability.

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Nitrate-nitrogen is not held by the soil and can be leached by water. Leaching losses of nitrate-nitrogen are most severe in sandy soils, in areas with high rainfall, and under intense irrigation. Some nitrate-nitrogen may be converted to gases which escape into the atmosphere. This frequently occurs in wet soils during fall, winter and spring.

Phosphorus

All phosphorus fertilizers are phosphate salts. They are water soluble but tend to form insoluble compounds when incorporated into the soil. Unlike nitrogen and potassium, phosphorus does not readily move in the soil. Very little phosphorus leaches out of the soil. It tends to remain where it is placed. Therefore, it is important to place phosphorus fertilizer in the rooting zone of the crop before the crop is established, or to band it next to the roots in the established crop. Surface applied phosphorus without incorporation is the least efficient way of utilizing phosphorus fertilizer. In some soils, phosphorus becomes "tied-up" at a pH below 6.0 or above 7.5.

Potassium

Potassium fertilizers are all simple potassium salts, such as potassium chloride, potassium sulfate, potassium-magnesium sulfate, or potassium nitrate. All are readily water soluble. Potassium is adsorbed to some extent to organic matter and clay minerals. However, it is subject to leaching, especially in sandy soils.

Nutrient Deficiencies

A nutrient deficiency may be the problem when parts of berry plants that are not yet mature become yellow or purple, or show unusual growth or stunting, or a combination of these symptoms. The nutrient required may be present in the soil but unavailable to the plants because of weather or soil conditions.

Some nutrients will slow down the uptake of other nutrients unless they are present in the correct proportion. All nutrients have a pH range at which they are most available to the plants, providing other factors are favourable.

Too much of a nutrient may cause growth problems as well. Excess fertilizer may cause leaf "burn" or stunted growth.

Calcium (Ca) is applied as lime and is, therefore, rarely deficient in soils. Many common fertilizers contain calcium.

Magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn) and boron (B) are sometimes deficient in the soil for optimum crop production.

Boron deficiency may cause a wide variety of abnormalities in berry crops. However, even in soils with adequate boron levels, it can be tied up and unavailable to plants when soils are warm and/or dry or heavily manured. Many of the fertilizers used on berry crops have some boron added to the blend. **Caution:** Do not exceed the recommended amount of boron per hectare as it may cause plant injury. If boron-deficiency symptoms occur during the growing season, boron can be applied as a foliar spray. In the Interior, boron should be applied in the fall. At the Coast, it should be applied in the spring where a need for it has been shown.

Micronutrients are required only in very small amounts and it is important to ensure that micronutrient fertilizers are applied at the correct rate. High levels of micronutrients, especially boron and manganese, are toxic to plants. Soil and/or tissue testing are the only accurate ways to determine if these elements are lacking. If they are needed, micronutrients can be added to blended fertilizers and applied along with the routine fertilizer program. If necessary, micronutrients can be applied in irrigation water (drip) or with a crop sprayer (foliar feeding).

Characteristic symptoms of nutrient imbalances are listed in Table 12.

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Table 12. Foliar symptoms of nutrient deficiencies and corrective treatments

The following nutrients may be deficient at certain times in BC soils. Foliar sprays should not be applied at higher than recommended concentrations or crop damage may result. Use enough water to wet the foliage. Apply under slow drying conditions. Other prepared fertilizer formulations are also available. Follow manufacturers recommendations.

Nutrients	Nutrient deficiency symptoms	Materials	Application rate	Comments
Nitrogen	Slow growth. Pale green to yellow colours.	15.5-0-0	15 kg/ha (6 kg/acre)	Apply in 1000 L/ha (400 L/acre) of water.
		46-0-0	10 kg/ha (4 kg/acre)	
		20-20-20	3 kg/ha (1.2 kg/acre)	
Phosphorus	Slow growth. Reddish, purple colours.	20-20-20	3 kg/ha (1.2 kg/acre)	Apply in 1000 L/ha (400 L /acre) of water.
Potassium	Slow growth. Purple band around margin of older leaves of strawberry, especially after harvest. Cupping and curling, and necrotic spots on leaves.	20-20-20	3 kg/ha (1.2 kg/acre)	Apply in 1000 L/ha (400 L /acre) of water.
Calcium	Slow growth. Die-back of terminal growth. Leaf margins chlorotic and scorched. Spotting of leaves.	Calcium nitrate or Calcium chloride	5 to 10 kg/ha (2 to 4 kg/acre)	Apply at full leaf, in 1000 L/ha (400 gal/acre) of water.
Magnesium	Area between veins turns yellow to red beginning with the older or lower leaves. The veins remain green. Yellow areas eventually die and turn brown as deficiency increases. Raspberries: shows at base of fruiting laterals during rapid growth.	Dolomite lime or Sul-po-mag	250 to 300 kg/ha (100 to 120 kg/acre)	Apply and incorporate into soil in spring.
		Epsom salts or Magnesium sulfate	10 to 15 kg/ha (4 to 6 kg/acre)	Apply at full leaf and under cool, slow drying conditions in 1000 L/ha (400 L/acre) of water. Add 0.5 kg urea (46-0-0) in 1000 L of water.
Boron	Raspberries: uneven bud break in spring, downward cupped leaves, death of terminal bud on new canes leads to side branching, crumbly fruit. Strawberries: leaf tip turn on new leaves, monkey faced fruit, hollow fruit with green tips, crowns may be dark inside. Poor pollination and seed set in all berries.	Solubor	1.0 kg/ha (0.4 kg/acre)	Apply at full leaf in 1000 L/ha (400 L/acre) of water. Avoid high rates of lime, manure or irrigation.
Iron	Strong yellowing and sometimes whitening of the young or new leaves at the tips of the plants, especially when soil pH is too high for the crop.	Ferrous sulfate	2 to 3 kg/ha (0.8 to 1.2 kg/acre)	Apply in 1000 L /ha (400 L/acre) of water.
		Chelated iron	1 kg/ha (0.4 kg/acre)	
Manganese	Stunting of plants. Smaller than normal leaves with yellowing between the veins.	Manganese sulfate	3 kg/ha (1.2 kg/acre)	Apply in 1000 L/ha (400 L/acre) of water.
Molybdenum	Growing points die, leaf blades distorted and narrow.	Sodium molybdate or Molybdic acid	500 g/ha (200 g/acre)	Apply in 1000 L/ha (400 L/acre) of water.
Zinc	Yellowing between veins of new leaves, especially following heavy manuring or where the soil pH is too high.	Zinc chelate	1 kg/ha (0.4 kg/acre)	Apply in 1000 L/ha (400 L/acre) of water.
		Zinc sulfate	2 to 4 kg/ha (0.8 to 1.6 kg/acre)	
Copper	Severe stunting. Yellowing of new leaves.	Copper sulfate or Copper oxide	2 to 5 kg/ha (0.8 to 2 kg/acre)	Apply in 1000 L/ha (400 L/acre) of water.

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