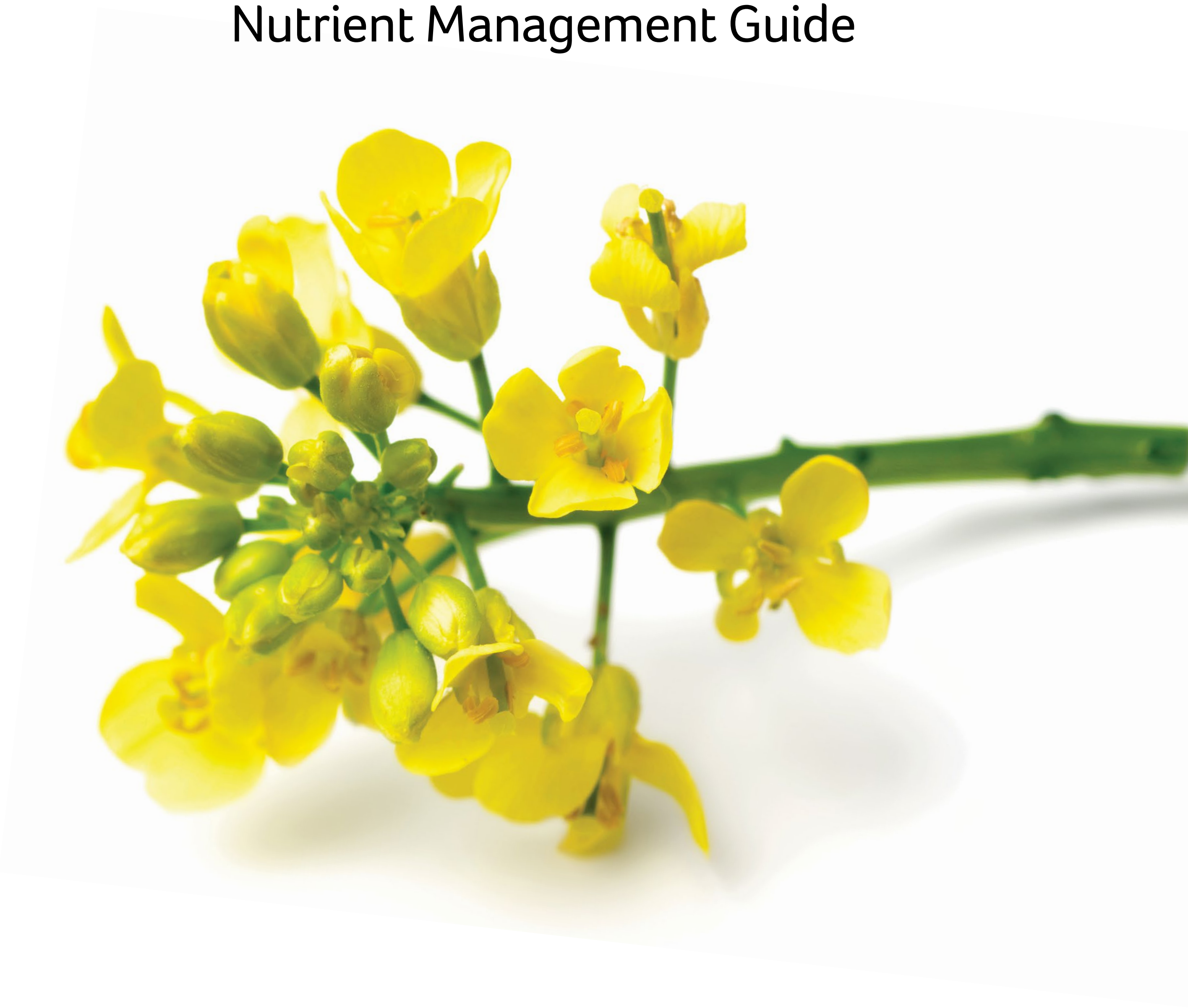
Canola

Nutrient Management Guide



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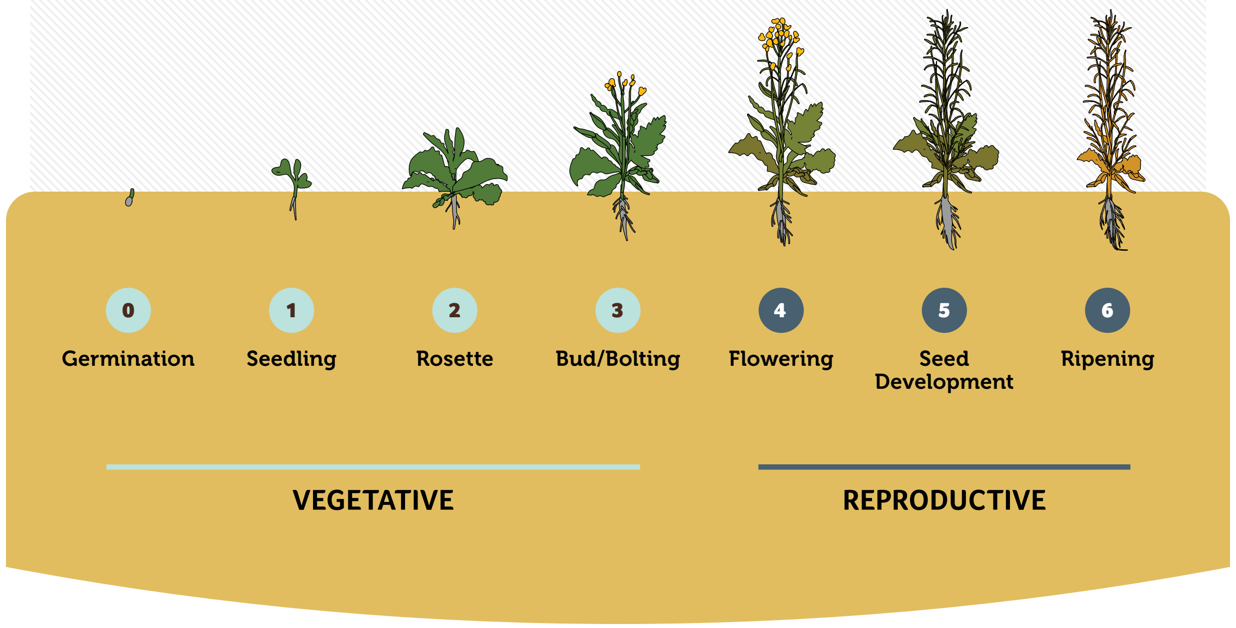
The production of high yielding, quality canola requires sound management, good soil, balanced nutrients, adequate moisture and heat, and a carefully selected variety. Although this publication focuses on nutrient management for maximum canola production, the importance of other yield-determining factors must not be overlooked.

Canola Development and Growth Staging



VEGETATIVE

0 Germination Stage

Seeds rapidly take on water and must be in contact with moist soil in the presence of oxygen. Canola is sensitive to soil salinity, and germination can be impaired in saline soils.

1 Seedling Stage

Seedling roots continue to develop, and leaf development begins. After emergence, the cotyledons open and supply the seedling with energy. The taproot system expands and secondary roots emerge from the taproot.

2 Rosette Stage

First true leaves begin to expand forming the "rosette" around the main stem with older leaves at the base and smaller leaves at the center. The stem continues to grow thicker. This stage can be characterized by an increase in leaf area index.

3 Bud/Bolting Stage

Bolting (stem elongation) and flower bud development are triggered by lengthening daylight and rising temperatures. The canola plant reaches maximum leaf area index during this stage. Most of the photosynthesis occurs in the leaves; loss of leaves means potential yield loss.

REPRODUCTIVE

4 Flowering Stage

Lowest buds in the main stem begin to open. 40 to 55 percent of open flowers will develop pods. During this stage, heat and moisture stress and nutrient deficiencies can cause flowers to abort resulting in potential yield loss.

5 Seed Development Stage

Seed development occurs during mid-flowering. The location of the pod will determine the nutrient access, seed size, and number of seeds per pod.

6 Ripening Stage

Seeds start to fill about 35 to 45 days after flowering begins. When they are fully mature, seeds are yellow. The crop is considered ripe and is ready to be swathed when 30 to 40 percent of the seeds on the main stem have turned brown. If growers are using a contact herbicide to desiccate, the recommended application timing is when 60 to 70 percent of the seed has turned brown, more than the typical swathing stage.

Canola

MACRONUTRIENTS	
Nitrogen	N
Phosphorus	P
Potassium	K
Sulfur	S
Magnesium	Mg
Calcium	Ca

MICRONUTRIENTS	
Boron	B
Chloride	Cl
Copper	Cu
Iron	Fe
Manganese	Mn
Molybdenum	Mo
Zinc	Zn
Nickel	Ni

Essential Nutrients

Thirteen essential crop nutrients must be available for canola to grow and flourish. These nutrients are classified as macronutrients and micronutrients, based on the crop's level of requirement.

In western Canada most fields require additional nitrogen and phosphorus to maximize yield. While potassium and sulfur deficiencies are not universal, they are becoming more prevalent and should not be overlooked in any fertility program. Micronutrient deficiencies are far less common; however, boron, copper, and zinc deficiencies have been observed in canola.

Deficiencies occur when nutrient supply is depleted below crop requirements. Although a soil may have supplied sufficient nutrients in the past, soil reserves can be depleted by crop removal, leaching, and erosion. Demand may also increase beyond the soil's ability to supply nutrients when higher yield targets are set or crop varieties change. The size of the soil nutrient reserve and nutrient demand will determine when deficiencies appear.

Soil erosion contributes to the depletion of soil nutrient reserves through the removal of nutrient rich topsoil and organic matter. In areas of severe soil and organic matter loss, nutrient deficiencies are frequently observed. Pay special attention to eroded areas when soil sampling. Sampling these areas separately from the rest of a field may be advisable.

Soil nutrients must be present in a balance that satisfies plant requirements. Excess quantities or deficiencies of a nutrient will lead to imbalances that limit yield and crop quality. Follow the principles of 4R Nutrient Stewardship – apply the Right source, at the Right rate, at the Right time, in the Right place.

In western Canada most fields require additional nitrogen and phosphorus to maximize yield.

Soil Nutrient Supply

Nutrients are managed using the concept of supply and demand. If a soil cannot supply sufficient nutrients to meet the crop's demand, fertilizer must be added to protect crop yield and quality.

This may sound straightforward, but determining the soil's ability to supply nutrients and the crop's requirement for nutrients is often complex.

To obtain an accurate estimate of the soil's nutrient-supplying capacity, a soil test must be taken. Although a soil test does not measure the amount of available soil nutrients present, it does provide an index of the soil's ability to supply nutrients. A soil test is likened to the oil dipstick in a car. It does not indicate how much is present, just that it is low or high.

The most accurate soil testing recommendations are made when each soil type is sampled and fertilized separately within a field. When only one sample is taken, the resulting analysis represents the average nutrient content for all soil types. An application made using this analysis provides surplus nutrients to some areas and insufficient nutrients in others.

Dividing a field into distinct soil types requires considerable knowledge of the field and its history. Each soil type will have a similar color, texture, cropping, and nutrient application history. Look for differences in slope, yield, crop growth, and the effects of soil erosion.

Be sure to sample to the appropriate depth for each nutrient. Samples must also be handled with care to prevent contamination and obtain the best results.

Soil testing should not be used in isolation. Cropping histories, scouting records, and field experience are valuable information sources that should be used when formulating nutrient recommendations. The soil test can indicate the probability of crop response to applied nutrients; other factors may also affect the probability of response and should be considered in relation to the soil test. In the hands of a qualified agronomist, this information provides a base for fine tuning and confirming soil test recommendations.

Isolating irregular areas will improve the quality of a soil test.

- Eroded knolls
- Old stack bottoms or manured areas
- Entrances and edges of fields
- Waterways, depressions, or wet areas
- Alkaline or saline areas
- Areas of different soil texture or drainage
- Areas of greater or lesser yield potential or history

Nutrient Demand

As canola yield increases, nutrient demand also increases to meet growth requirements. The amount of nutrients required to produce a target yield have been estimated for many soil and environmental conditions (figure below). However, requirements have not been determined for every crop, variety, soil, and climatic condition. In these cases, estimates must be made to establish the nutrient demand.

The first step in determining a crop's nutrient demand is projecting crop yield. Remember, crop production is no greater than that allowed by the most limiting growth factor. In many cases, moisture will determine the upper limit; however, factors such as pH, organic matter level, texture, aggregate stability, nutrients, insects, weeds, diseases, variety, or equipment may also affect yield.

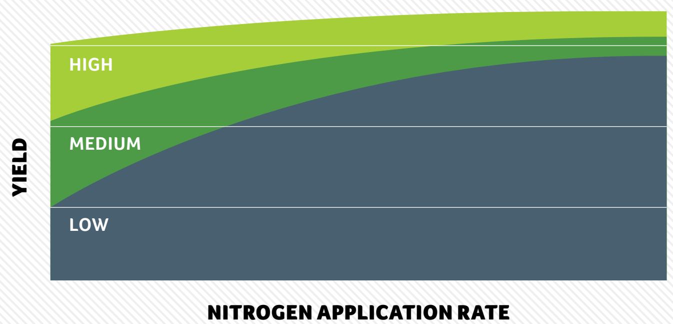
An estimate of the crop's yield potential is often made by establishing a realistic yield goal. The goal must reflect the yield potential of the variety, soil and climatic conditions, and management intensity. If increasing yield is the goal, production barriers must be removed.

Nutrient Uptake

Nutrient uptake is often restricted by soil, climatic, and plant physiological problems. For example, phosphorus uptake is reduced by cool spring temperatures. Low soil temperatures slow the movement of phosphorus to plant roots, creating a deficiency. This deficiency occurs even when soil phosphorus levels are considered sufficient. For this reason, many producers apply a small amount of phosphorus with the seed even when levels are considered adequate.

Other examples of restricted uptake include soil hard-pans and compaction, gravel lenses, salinity, and waterlogged soil conditions. These conditions restrict nutrient uptake, causing a deficiency to occur even when nutrient levels are sufficient in the soil. When developing a nutrient recommendation, it is important to identify the potential for restricted uptake and develop plans for managing the problem.

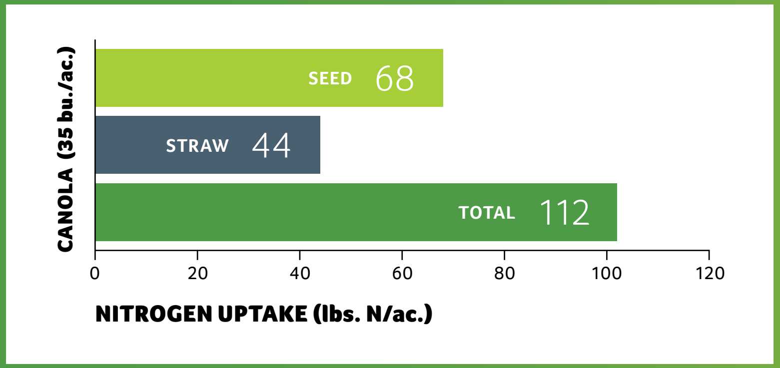
NITRATE TEST LEVEL



As canola yield increases, nutrient demand also increases to meet growth requirements.

Nitrogen

A typical canola crop requires 2.5 to 3.5 pounds of nitrogen (N) per bushel of yield produced.



Nitrogen Importance

Under severe nitrogen deficiency, canola may exhibit some or all of the following symptoms:

- Yellowing of older leaves first
- Purpling of leaves
- Reduced leaf and plant size
- Reduced flowering period
- Reduced pod formation and yield

Nitrogen deficiency is commonly confused with:

- Sulfur deficiency
- Water stress
- Soil salinity
- Restricted rooting
- Herbicide stress
- Root rot

Canola needs 2.5 to 3.5 pounds per acre of available nitrogen per bushel of seed yield. A canola crop yielding 50 bushels per acre takes up 125 to 175 pounds of nitrogen, and, of that, 88 to 105 pounds are removed with the seed.

As most soils cannot supply sufficient nitrogen to meet the high demand of canola, nitrogen is often recommended on stubble and summer-fallow fields. Optimum nitrogen application rates for canola usually exceed nitrogen rates for wheat by 30 to 40 percent.

Nitrogen is involved in protein formation and is a major component of chlorophyll. Canola crops with inadequate nitrogen will show symptoms of reduced growth, greenish-yellow leaves (older leaves first), decreased pod formation, and lower yields. Visual symptoms are often the first sign of a nitrogen deficiency. Although these symptoms are good indicators, they may not occur in marginally deficient soils and can be mistaken for symptoms caused by other problems – e.g., sulfur deficiency.

Suspicions can be confirmed by soil and tissue testing in combination with a review of field history and crop scouting information. Comparative sampling of good and poor growth areas is strongly recommended. This technique provides valuable information when making a diagnosis and recommendation.

Although adequate nitrogen is essential for a healthy, high-yielding crop, excessive nitrogen can cause lodging, delayed maturity, and reduced crop quality. Soil testing prior to seeding will help determine the soil nitrogen level and an appropriate application rate. Excess nitrogen can decrease seed oil content and increase the percentage of green seed resulting in poor quality and possible reduced crop value.

Most soils cannot supply sufficient nitrogen to meet the high demand of canola.

Canola crop with nitrogen deficiency.

Image by Canola Council of Canada

Nitrogen Placement and Timing

The efficiency of nitrogen fertilizer is affected by the method of placement and application timing. The best choice for a field depends upon the soil, climate, and management situation.

Seed Placement

Seed-placed nitrogen is one of the most effective ways of applying fertilizer. However, nitrogen fertilizers can reduce emergence and yields and lengthen the time to maturity if application rates are too high.

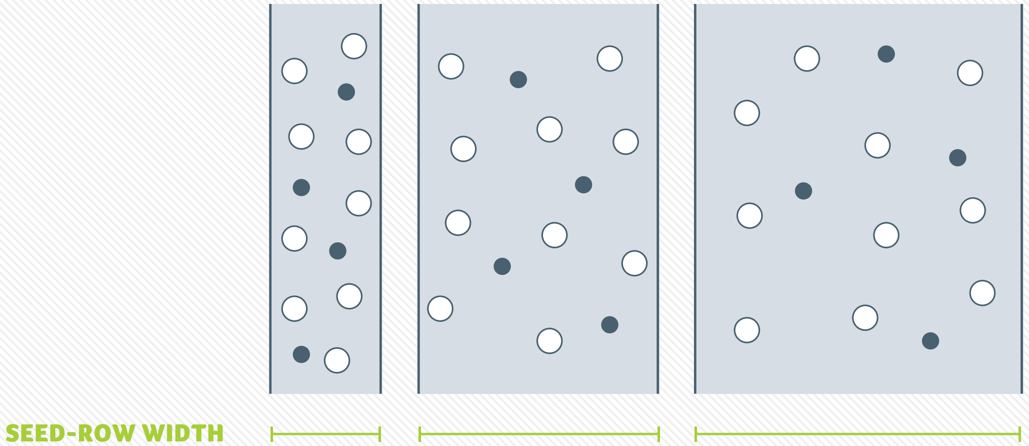
There are two primary causes of seedling damage. The first results because nitrogen fertilizers are salts and cause damage similar to that occurring when plants are seeded in saline soil. The second occurs when the seedling comes in contact with high concentrations of ammonia generated by the nitrogen fertilizer.

The amount of nitrogen that can safely be applied with canola depends upon the soil texture, organic matter levels, seedbed moisture, fertilizer type, and the percentage of seedbed used in the seeding operation. Each of these factors affects the concentration of salt or ammonia around the seedling. A controlled-release nitrogen fertilizer like Nutrien's ESN can be used to apply greater amounts of nitrogen in the seed row. ESN has been shown to be safe for seed placement at up to three times the safe rate of urea.

Recommendations for seed placement have been developed that consider many of these factors. These recommendations can be obtained from your Nutrien retailer.

With the increasing popularity of air seeders, some producers have increased seed placement rates. Air seeders can produce seed-rows that are wider than those produced by double disk press drills. This decreases the concentration of fertilizer material around the seed, allowing higher rates of application (figure below). Another way to decrease the concentration of fertilizer in the seed-row is to reduce the distance between seed-rows. A 6-inch row spacing contains 50 percent less fertilizer than a 9-inch spacing.

The amount of nitrogen that can be safely seed placed is generally far less than that required for optimum yield. As a result, there is little to gain from pushing nitrogen seed placement rates to their limit. Most agronomists recommend applying small amounts of nitrogen with the seed through the phosphorus application while the rest is placed away from the seed.



Increasing the seed-row width decreases the concentration of fertilizer material around the seeds.

Broadcast and Incorporating

Fall broadcast and incorporated nitrogen is not recommended in moist areas due to the high potential for denitrification and leaching losses. The greatest loss occurs when nitrates accumulate in the fall, and the soil becomes waterlogged in the spring. Under these conditions nitrate is converted to dinitrogen gas (N_2) by soil microbes and lost to the atmosphere. Losses are typically low in the Brown and Dark Brown soil zones due to typically low moisture levels.

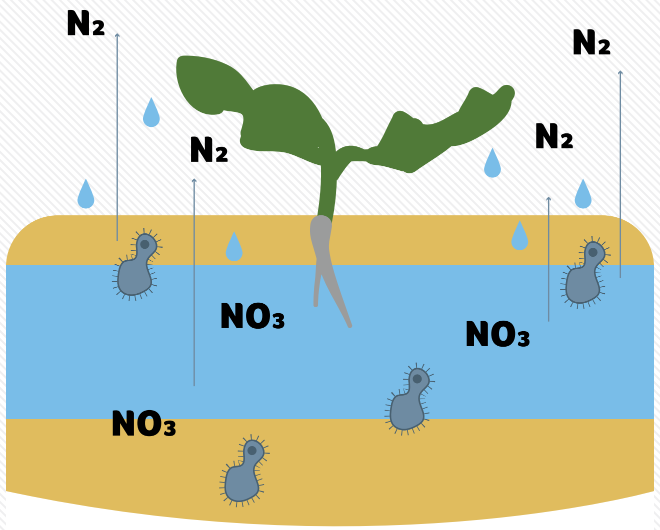
The efficiency of spring broadcast and incorporated nitrogen is greatest where there is sufficient rainfall to move the nitrogen into the rooting zone. In these areas, broadcast and incorporated nitrogen produces yields similar to banding.

Broadcast and incorporated nitrogen can be immobilized when large amounts of crop residue are added to the soil. A portion of the immobilized nitrogen will be released over time as soil microbes die and decompose. Immobilization can be managed by reducing residue contact through banding and increasing application rates to offset losses.

Under dry conditions, broadcast nitrogen is susceptible to surface stranding. This nitrogen is positionally unavailable as roots will not function in dry soil.

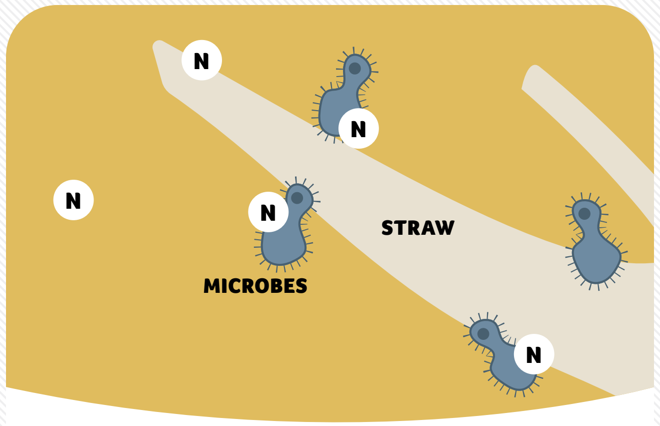
In recent years, producers have spread nitrogen with the canola seed, followed by a harrow or harrow-pack operation. This method is effective when soil moisture is adequate. However, germination and nitrogen availability are reduced under dry conditions.

DENITRIFICATION



1. **Denitrification occurs when soil is wet and oxygen deprived.**
2. **Microbes strip oxygen from nitrogen, producing gases that escape to the air.**

IMMOBILIZATION



1. **Immobilization occurs when soil microbes – consuming crop residues – utilize soil and fertilizer nitrogen.**
2. **This nitrogen is temporarily tied up in the microbes.**

Banding

Band applications tend to be more efficient than broadcast applications because the concentrated band reduces nitrogen losses from denitrification, immobilization, and leaching. In dry years, banded nitrogen is positionally more available to canola roots.

Fall banding is the preferred method of application with top producers. The reasons for this include time savings in the spring, reduced spring moisture losses, improved seedbed quality, greater equipment availability, and traditionally lower fertilizer costs. Fall applications are most efficient when the nitrogen is applied to cool soils (40°F or less) as anhydrous ammonia, urea, or ammonium sulfate. Spring banding is slightly more efficient than fall banding when moisture loss, seedbed quality, and time are not a concern.

Top Dressing

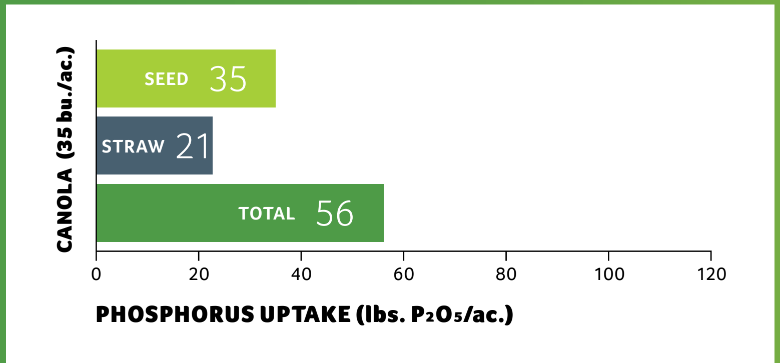
Top dressing large amounts of nitrogen after seeding canola is not recommended; however, lighter rates of nitrogen can be applied when initial rates fall short of the crop's requirement. Keep in mind effectiveness of top-dressed nitrogen will be dependent on sufficient precipitation to move the nitrogen into the root zone.

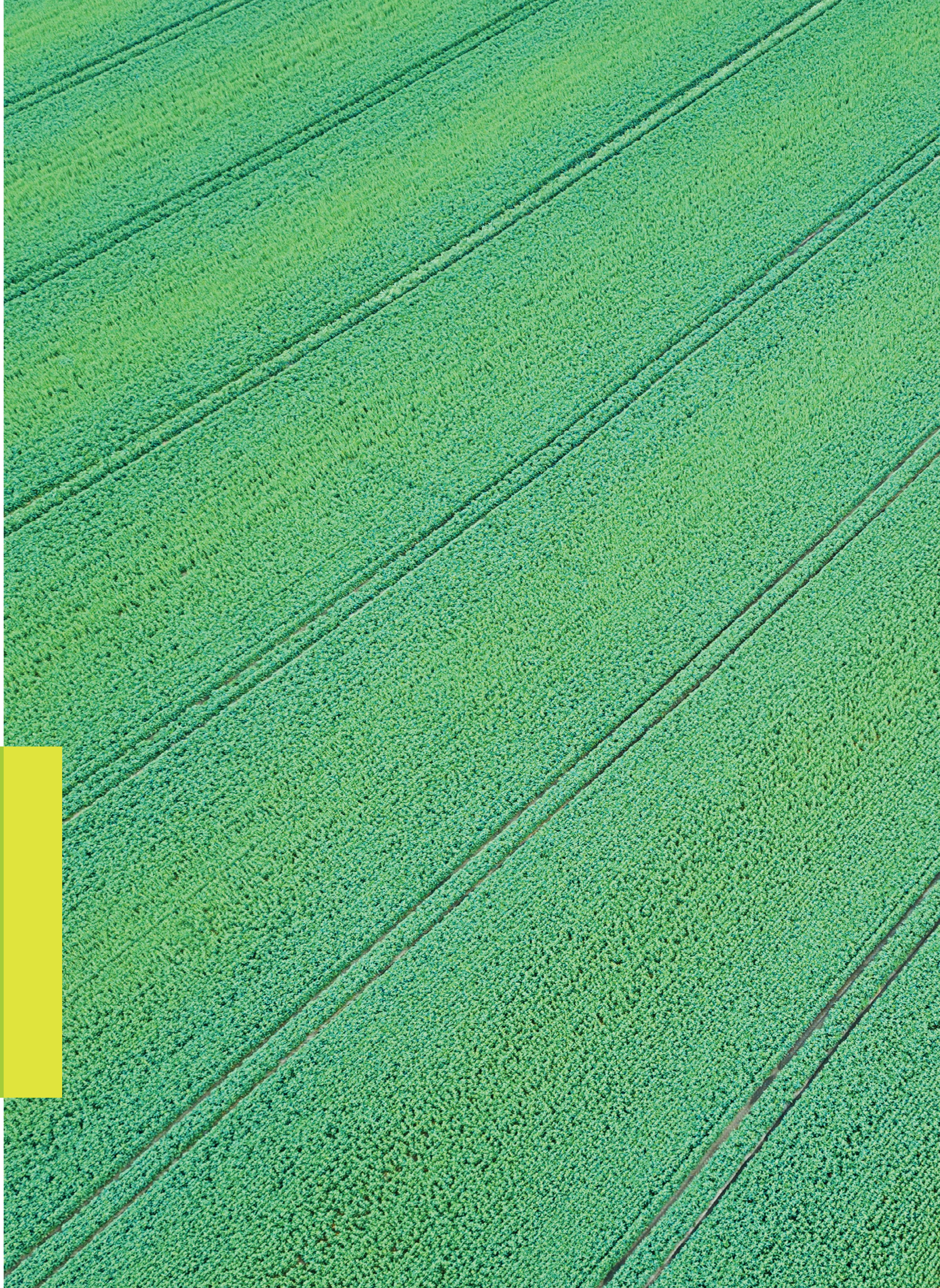
The greatest yield benefit occurs when applications are made prior to bolting (before or when the canola is in the rosette stage with four true leaves). Applications made after the bolting stage usually increase protein content with less effect on yield. Careful crop scouting is essential to ensure that nitrogen is top dressed at the correct stage.

Fall banding is the preferred method of application with top producers.

Phosphorus

A typical canola crop
requires about 1.6 pounds of phosphate (P_2O_5) per bushel of yield produced.





Phosphorus Importance

Under severe phosphorus deficiency, canola may exhibit some or all of the following symptoms:

- Reduced growth
- Purpling leaves and stems
- Delayed maturity
- Increased disease level
- Reduced yield and quality

Phosphorus deficiency is commonly confused with:

- Restricted rooting
- Root rot
- Herbicide injury
- Sulfur deficiency

Phosphorus plays a vital role in energy transfer, photosynthesis, nutrient transport, plant genetics, and as a structural component of the plant. A typical canola crop requires about 1.6 pounds of phosphate (P_2O_5) per bushel of yield produced.

When phosphorus supply does not meet crop requirements, growth, yield, and quality are reduced. Additionally, maturity is often delayed, increasing the chances of frost damage. Canola grown on severely phosphorus-deficient soil develops a purple coloration on the leaves and stem. Phosphorus is mobile within the plant, causing deficiency symptoms to appear on the older, lower leaves first. As the deficiency progresses, leaves and stems can take on a purplish color or the leaves may become a dark bluish-green.

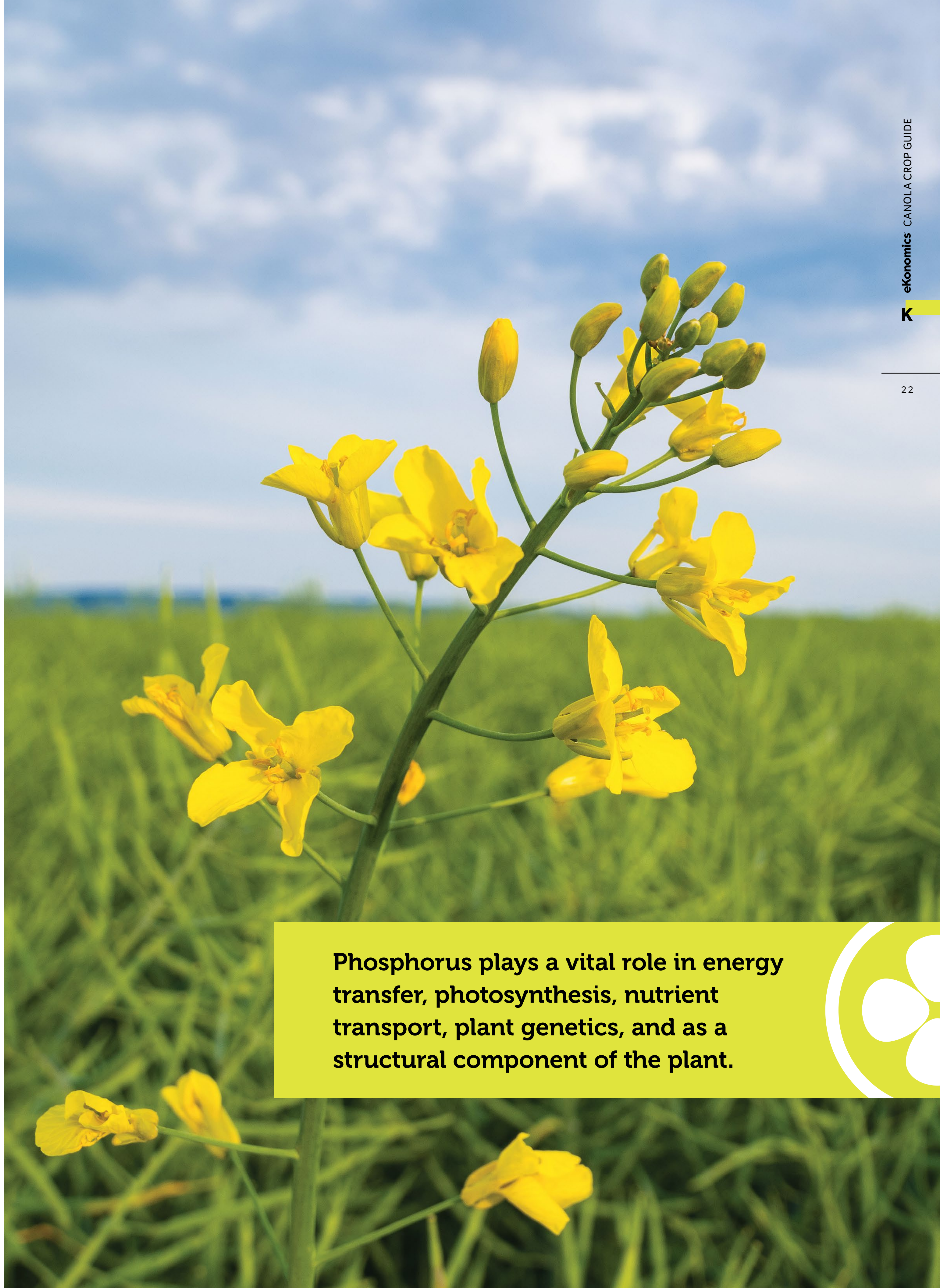
Although these symptoms are good indicators, they may not occur in marginally deficient soils and can easily be mistaken for symptoms caused by sulfur deficiency, etc.

To confirm suspicions, agronomists recommend soil and tissue testing in combination with a review of field history and crop scouting information. Comparative sampling is strongly recommended.

Soil phosphorus availability is highly weather dependent; therefore, deficiencies may occur one year and not the next. When they occur, yields are substantially reduced.

Phosphorus deficiency.

Image by Canola Council of Canada



Phosphorus plays a vital role in energy transfer, photosynthesis, nutrient transport, plant genetics, and as a structural component of the plant.

Phosphorus Placement and Timing

The method of placement and timing have a major effect on the availability of fertilizer phosphorus and its accessibility to plant roots.

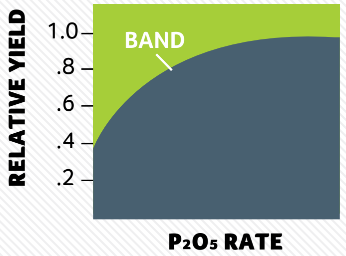
Canola roots have an exceptional capacity to absorb soil and fertilizer phosphorus. This is attributed to the numerous root hairs and their ability to reduce soil pH.

When phosphorus fertilizer is applied to moist soil, water immediately moves to the fertilizer granule. The granule begins to dissolve, forming a concentrated fertilizer solution around it. If using monoammonium phosphate (MAP), this generally acidic solution moves slowly through the soil, dissolving compounds and releasing ions such as calcium, magnesium, aluminium, and iron. These ions react with the phosphorus fertilizer to form precipitates with a lower solubility than the original fertilizer. Phosphorus from these precipitates becomes available to plants; however, they are not as soluble as the original phosphorus fertilizer.

The movement of phosphorus fertilizer is generally 0.5 to 2 inches from the application site, depending upon the soil type and its reactivity.

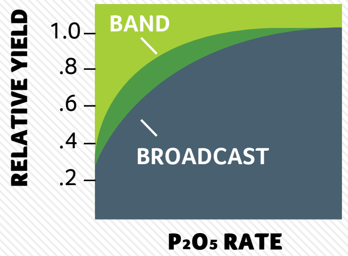
Phosphorus fertilizer is absorbed by soil microorganisms and immobilized in their bodies. This phosphorus enters the organic pool of phosphorus and is slowly released over time.

RELATIONSHIPS BETWEEN BROADCAST AND BANDED PHOSPHORUS



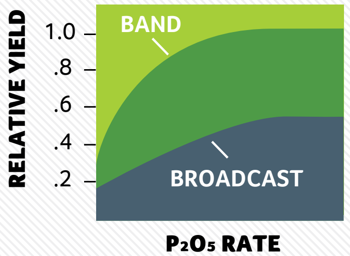
Typical Conditions

- High soil test level
- Warm, moist soil
- Thorough incorporation of broadcast phosphorus



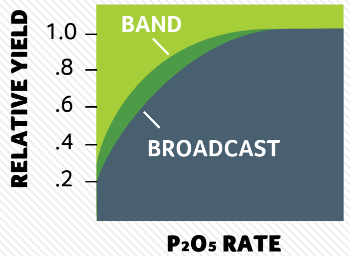
Typical Conditions

- Low soil test level
- Cold, wet soil
- High phosphorus fixing soils



Typical Conditions

- Cold, wet soil
  - Early growth critical
- Low soil test level
  - Minimal incorporation of broadcast phosphorus
  - Dry soil surface



Typical Conditions

- Low phosphorus fixing soil
- Heavy residue cover
- Warm, moist soil surface
- No tillage or cultivation

Seed Placement

When soil phosphorus levels are low and spring conditions are cool and moist, seed placement is generally the most effective method of application.

Cool, moist soil conditions early in the season slow the movement of phosphorus to the roots, resulting in a deficiency. This can occur even when soil phosphorus levels are adequate. For this reason, small amounts of phosphorus are recommended with the seed.

For a double disk press drill, or narrow knife opener (1-inch spread, 6- to 7-inch row spacing), a maximum of 20 pounds of phosphate (P_2O_5) per acre can be seed placed.

Under the same conditions, some combination adding up to, but not exceeding, 20 pounds per acre of phosphate and potash (K_2O) can be safely seed placed.

Higher rates can be seed placed if the fertilizer and seed are scattered over a larger area. Safe levels are also dictated by the amount of other fertilizers placed with the seed.

Banding

Banding is an effective method of placement as it reduces fertilizer contact with the soil. Although this decreases the conversion of highly available phosphorus fertilizer to less available forms, it may limit the portion of roots in contact with the fertilizer. Due to the high reactivity of most western Canadian soils, it is generally preferable to increase availability of phosphorus in soils rather than increase root contact. As a result, most agronomists recommend banding fertilizer phosphorus over broadcast applications, especially if band placement close to the seed-row is possible. Differences between banding and broadcast applications disappear as soil test phosphorus levels increase.

Phosphorus can be banded in late fall or spring with similar results. Bands should be placed 2 to 3 inches below the soil surface into moist soil. Under dry conditions surface-applied fertilizer is stranded in dry soil, reducing availability and plant uptake. Depths greater than 3 inches are generally not economically beneficial and increase equipment stress.

Dual banding nitrogen (ammonium-based form) and phosphorus typically increases phosphorus availability and uptake. Although this does not always improve yield, it does reduce fertilizer handling and save time during the busy spring season.

Broadcast and Incorporating

Broadcast and incorporated phosphorus increases root and soil contact with the fertilizer material. However, due to the reactive nature of most soils in western Canada, the benefits of increased root contact are often negated by decreased phosphorus availability. To obtain performance similar to banding and seed placement, application rates must increase when soil levels are low. Typical relationships between broadcast and band applications are described for a variety of soil and climatic conditions in previous page chart.

Broadcasting phosphorus can be an effective method when applying greater rates to build up low soil test levels. Large applications of phosphorus can be made to increase yield for a number of years. Residual phosphorus can remain in the soil phosphorus reserves for many years. The effectiveness of this application depends on the type of soil, climatic conditions, and the rate of application. On highly reactive soils some additional phosphorus may be required to maintain maximum yields.

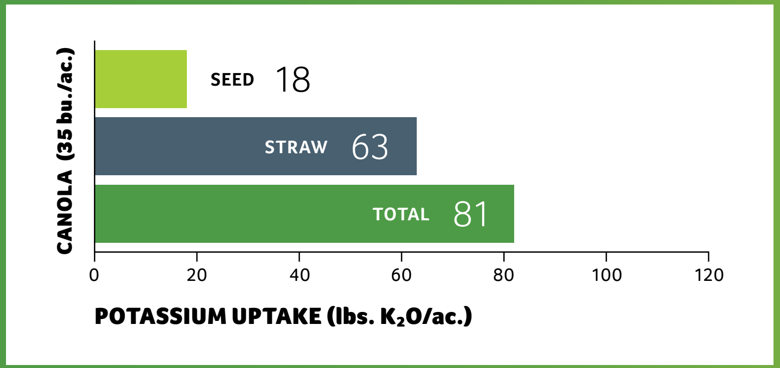
Broadcast phosphorus is best incorporated. Phosphorus left on the soil surface can be lost by runoff and become a contaminant in surface drainage waters. This risk is somewhat greater for fall broadcast phosphorus than for spring applications.

Split Application

Due to the limited amount of phosphorus that can be seed placed and the benefits that seed placement offers, many producers have chosen to place 10 to 20 pounds phosphate per acre with the seed and remainder in a band. Research consistently shows this method of application to be among the top methods of placement.

Potassium

A typical canola crop requires about 2.6 pounds of potassium (K_2O) per bushel of yield produced.



Under severe potassium deficiency, canola may exhibit some or all of the following symptoms:

- Reduced growth and yield
- General wilting
- Increased lodging
- Increased incidence of disease

Potassium deficiency is commonly confused with:

- Restricted rooting
- Water stress
- Soil salinity
- Herbicide stress

Potassium Importance

Potassium is required in large quantities for healthy crop growth and development.

A typical canola crop requires about 2.6 pounds of potassium (K_2O) per bushel of yield produced.

Canola yields are not often limited by potassium, as most soils in western Canada have large soil potassium reserves. However, well drained, coarse textured soils are often low in potassium and deficiencies are becoming more common as soil nutrient levels are depleted.

Potassium regulates water balance, the activity of many enzymes, starch synthesis, nitrogen uptake, and protein production. Most of the plant potassium is contained within the stems and leaves.

Deficiency symptoms appear as marginal and interveinal chlorosis (pale green to yellow color) in older leaves. The chlorosis usually occurs on the plant's older leaves first and progresses to the upper, younger leaves next.

As with all nutrient deficiencies, these symptoms can be easily confused with symptoms caused by other problems. To confirm deficiencies, soil and tissue testing is recommended in combination with a review of the cropping history and scouting information. When possible, a comparative soil test between good and poor growth areas should be used. This test provides additional information that can be used in the diagnosis.

Potassium Placement and Timing

The method used to apply potassium is important because of the reactive nature of this nutrient. When potassium contacts certain clay minerals (mostly 2:1 clays), it can become fixed between clay layers. Application methods which reduce fixation and increase root contact are preferred.

Seed Placement

Seed placement is an effective method of application as soil contact is minimal and root contact is optimal. However, this method of application can cause seedling damage from elevated salt levels resulting from the potassium fertilizer.

For a double disk press drill or narrow knife opener (1-inch spread, 6- to 7-inch row spacing), a maximum of 20 pounds of potash (K_2O) per acre can be seed placed.

Under the same conditions, some combination adding up to, but not exceeding, 20 pounds per acre of potash and phosphate (P_2O_5) can safely be seed placed.

Seed placement rates for potash are greater when the seed and fertilizer are spread over a large area.

Banding

Banding is an excellent method of application. It is typically more efficient than broadcasting when low application rates are used; however, differences disappear as application rates increase (table below).

Band applications can be made in the fall or spring with similar results. However, spring banding may have a negative effect on seedbed quality and soil moisture.

Broadcasting and Incorporating

When broadcasting potassium, application rates are often increased to provide benefits similar to those obtained by banding. When using small amounts of potassium, rates are commonly doubled for broadcast applications. As application rates increase, differences in efficiencies are less apparent.

Yellowing at leaf margins is typical of potassium deficiency.

Image by Canola Council of Canada

YIELD INCREASE (BUSHELS PER ACRE) OF BARLEY IN RESPONSE TO METHOD OF POTASH PLACEMENT AND RATE OF APPLICATION

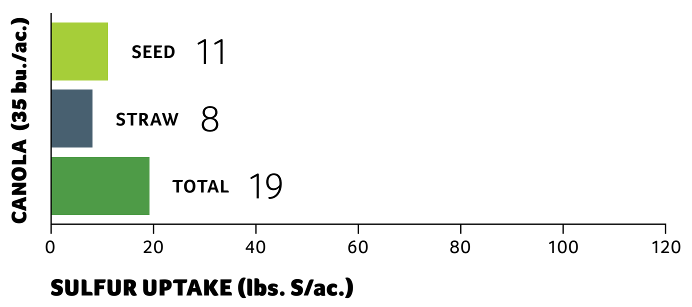
Source: Agriculture Canada Research Station, Lacombe.

Placement Method	Rate of K_2O Application (lbs./ac.)	
	15	30
Broadcast	8.6	17
Band*	12.8	18.8
Drill-in	28.8	21

* Approximately 1 inch below and 1 inch to the side of the seed-row.

Sulfur

A typical canola crop
requires about 0.6 pounds
of sulfur (S) per bushel
of yield produced.



Sulfur Importance

Under severe sulfur deficiency, canola may exhibit some or all of the following symptoms:

- Stunted or tall, spindly growth
- Younger leaves are yellow
- Leaves are curled and cupped inward
- Under portion of the leaf may turn purple
- Flowers appear white
- Seed set is reduced, pods are thin, short, and aborting

Sulfur deficiency is commonly confused with:

- Restricted rooting
- Phosphorus deficiency
- Herbicide stress
- Root rot

The importance of sulfur in a canola fertility program cannot be overemphasized. A typical canola crop requires about 0.6 pounds of sulfur per bushel of yield produced.

Due to canola's high sulfur requirement, many soils are incapable of supplying sufficient sulfur to produce a high-yielding crop. Soils with low organic matter or coarse texture typically have a low sulfur-supplying capacity and often require fertilization. Sulfur deficiencies can appear on any soil that is continuously cropped or subject to leaching.

Cereal crops demand considerably less sulfur than canola, making it difficult to determine sulfur requirements based on past cereal production.

Sulfur is a building block of proteins, enzymes, and vitamins and a key ingredient to the formation of chlorophyll. Inadequate sulfur will restrict the yield potential and effective use of other nutrients.

Marginal sulfur deficiencies can reduce yields without visual symptoms appearing. Visual symptoms normally occur when the deficiency becomes more severe.

Sulfur is immobile within the plant, causing symptoms to occur on the younger, upper leaves first. Growth is typically restricted, resulting in stunted or spindly growth. Leaves tend to be narrow and more erect, particularly on the upper parts of the plant. Initial stages of moderate sulfur deficiencies show general yellowing of younger leaves, gradually progressing to older leaves. Leaves may cup inwards and develop a pink or red color on the underside, later extending to the surface of the upper leaves. The red color may later turn purple as plant growth progresses under the stress of sulfur deficiency.

At later growth stages, flowering is delayed and prolonged, and flowers may be pale yellow to white. Seed set is reduced, and pods tend to be thin and short, decreasing in number towards the top of the plant. Plants tend to stand erect because pods are poorly filled, and seeds are small. Maturity is delayed and susceptibility to disease may increase.

Nitrogen:Sulfur Balance

If a proper nitrogen:sulfur balance is not maintained, yields can be severely impaired. Adding nitrogen to soils that are marginally deficient in sulfur can distort the nitrogen:sulfur balance and reduce crop yield.

Nitrogen and sulfur are used in the formation of amino acids, which combine to form protein. When there is insufficient sulfur to convert all of the absorbed nitrogen into protein, an accumulation of non-protein nitrogen (nitrates and amino acids) can occur. Large amounts of non-protein nitrogen will disrupt metabolic functions within the plant, reducing seed production.

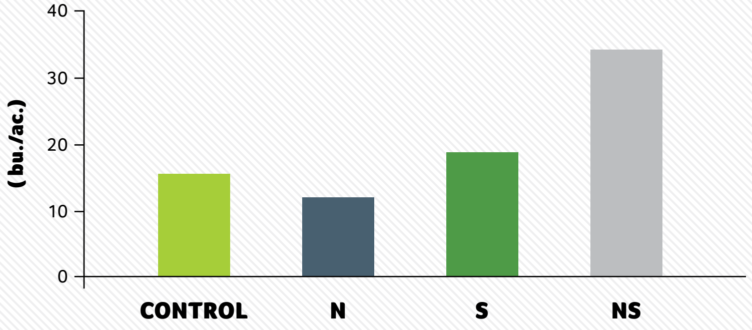
Nitrogen and sulfur should be added in a ratio of 7:1 when soil testing information is not available, and the soil is thought to be marginally deficient in sulfur. Severe deficiencies will require additional sulfur.

Sulfur deficiency symptoms such as inward purpled-cupped leaves may appear as a result of imbalanced nitrogen:sulfur ratio in the soil.

Image by Canola Council of Canada

EFFECT OF NITROGEN AND SULFATE-SULFUR FERTILIZERS ON YIELD OF CANOLA ON GRAY SOILS VERY DEFICIENT IN AVAILABLE SULFUR (N.W. SASKATCHEWAN)

Source: Alberta Agriculture, Food and Rural Development



Sulfur Placement and Timing

The most effective method of application depends on the sulfur source selected. Sulfate-sulfur products are immediately available to the plant, while elemental sulfur must oxidize to sulfate-sulfur before it can be used by the plant. Oxidation of elemental sulfur requires time, warm moist soil, and microbial activity. The most important factor affecting the rate of conversion is the particle size. Small particles (150 microns or less) convert to sulfate-sulfur much faster than large particles. It is critical to consider this when choosing the method of application for elemental sulfur products.

Generally, if an elemental form is used, it should be applied prior to the crop's actual need and attention should be paid to product characteristics. Some products should be broadcast and incorporated, while others are best broadcast without incorporation. If an elemental sulfur product is considered, discuss its management with an agronomist. Nutrien's Smart Nutrition™ MAP-MST® with micronized sulfur is an excellent choice if using an elemental sulfur form. It combines nitrogen and phosphorus with very fine sulfur particles to provide more rapid sulfur oxidation than traditional elemental sulfur fertilizers.

Seed Placement

Seed placement of sulfate-sulfur is an efficient and agronomically sound practice. However, care should be taken to ensure that application rates do not exceed safe levels. Seed placement levels for sulfur are typically set by nitrogen placement recommendations. For example, if 30 pounds of nitrogen per acre can be safely seed placed using your equipment, and your sulfur source is 20.5-0-0-24, then 145 pounds of 20.5-0-0-24 may be applied:

145 lbs./ac. x 20.5% N = 30 lbs. N

145 lbs./ac. x 24% S = 35 lbs. S

In this example, 30 pounds of nitrogen and 35 pounds of sulfur may be seed placed. The sulfur provincial seed placement recommendations are determined by using ammonium sulfate, not elemental sulfur, as it is not considered a seed placement sulfur source.

Elemental forms of sulfur may be safer for seed placement but may not provide the maximum response in the year of application. Nutrien's Smart Nutrition MAP-MST can provide both improved seed safety and sufficient sulfur availability when properly used.

Recommendations for seed placement have been developed that consider many of these factors. These recommendations can be obtained from your Nutrien retailer.

Banding

Banding sulfate-sulfur is recommended for fall or spring. The effectiveness of each application is dictated by weather conditions. Under dry spring conditions, fall banding can produce a better seedbed and crop yield. If the fall or spring conditions are wet, some leaching of the sulfate-sulfur can occur on coarse textured soils.

Banding elemental sulfur forms is generally not preferred when maximum response is needed in the year of application. Nutrien's Smart Nutrition MAP-MST can provide greater sulfur availability in banded applications than traditional elemental sulfur fertilizers because of its very small sulfur particle size.

Broadcast and Incorporating

Sulfate-sulfur can be fall broadcast and incorporated, however this sulfur may be exposed to leaching. Broadcast and incorporating sulfate-sulfur can be as effective as banding when there is adequate rainfall to move the sulfur into the rooting zone.

Broadcasting is the method most commonly recommended for applying elemental sulfur. Fall applications are best as this provides additional time for conversion.

Top Dressing

Although not a common practice, sulfate-sulfur can be top dressed. The effectiveness of this application will depend upon the crop stage and post-application moisture to move the fertilizer into the rooting zone.

Research shown in the table below clearly demonstrates that yield and crop quality can be recovered when ammonium sulfate is top dressed up to bolting or 42 days after seeding. Other research indicates that small increases can be obtained when applications are made as late as flowering.

EFFECT OF TIME OF BROADCASTING GRANULAR SULFATE-SULFUR FERTILIZER FOR CANOLA

Source: H. Ukrainetz, Agriculture Canada, Saskatoon

Timing of Sulfur Application	Two Year Average Seed Yield Increase Over Check (bu./ac.)	Oil in Seed (%)
At seeding	7.1	44.1
7 days after seeding	8.4	44.3
14 days after seeding	6.7	43.6
28 days after seeding	7.1	43.6
42 days after seeding	5.6	43.4

Micronutrients

Micronutrients are required
in relatively small
amounts but can produce
impressive results.

Micronutrients

Micronutrients are required in relatively small amounts, but this does not mean that they are less important than other plant nutrients.

Micronutrient deficiencies have a limited impact on canola yields in western Canada. However, boron, copper, and zinc deficiencies have been documented in certain areas of the prairie provinces. Information on manganese, iron, chloride, nickel, and molybdenum is limited and few specific responses have been recorded.

Crop scouting, soil, and plant analysis, along with the input of a qualified agronomist, can assist when determining the need for micronutrients. Observe other crops in the rotation to help with diagnosing micronutrient deficiencies (especially if they have clearer visual symptomologies). A history of micronutrient deficiencies can also be an indication of potential future issues.

Copper

Canola is seldom affected by copper deficiencies. However, when they occur, deficiency symptoms appear as yield reductions, loss in dry matter production, reduced seed set, reduced seed quality, or increased susceptibility to disease.

Copper problems often occur on peat soils, and the amount of deficiency on mineral soils has increased in recent decades. Problems are more prevalent in dry years on soils with a pH greater than 7.5 or in areas with high rates of poorly spread manure.

Copper is not mobile within the plant; therefore, symptoms appear on the upper plant parts. Copper deficiency symptoms on canola are not well defined. At present our experience suggests watching for smaller-than-normal upper leaves, reduced seed production, pale-green and dying upper leaves, stunted or shrunken upper pods, and poor or absent flowers. Probably the most noticeable symptom is aborted flowering, in which the flowers partially develop and open.

Boron

The symptoms of boron deficiency may be confused with sulfur deficiency, although boron deficiency is not known to cause leaf curling and cupping. Canola with boron deficiency may have seed production and pod set reduction, upper plant parts may be stunted, and the plant may appear shorter and bushier than normal.

Boron deficiencies can occur on sandier-textured Grey Wooded soils. Soils under irrigation can test low in boron; however, this is not a certainty as some water used for irrigation will contain boron. Research information documenting canola response to boron is limited and producers are cautioned to only apply recommended rates as excessive levels may result in boron toxicity.

Zinc

Zinc deficiency is not considered to be a widespread problem. Deficiencies are usually localized to specific areas, soil types, or management practices. Severely eroded soils, soils that have been leveled for irrigation (both cases where the topsoil has been removed and subsoil is being farmed), calcareous soils, soils with pH levels above 7.5, and peat soils are frequently low in zinc.

Zinc deficiency symptoms for canola are not well defined. The plants may appear shorter and branched, and the leaves can appear much smaller than expected.

Other Micronutrients

Manganese, chloride, iron, nickel, and molybdenum potential for deficiency in certain soil types and conditions. At the present time, documented responses to these nutrients are limited.

Boron deficiency.

Micronutrients are required in relatively small amounts, but this does not mean that they are less important than other plant nutrients.

Conclusion

Fertility management for canola is exceptionally important due to its high nutrient demand. However, there are many other factors which affect yield and quality. Consider the following management practices used by top producers:

- Use at least a three- to four-year rotation of beneficial crops before growing canola
- Ensure that the seedbed is firm, moist, and free of weeds
- Use treated pedigreed seed
- Grow varieties adapted to the soil, climate, and management conditions
- Seed shallowly
- Seed at the appropriate time for the variety and area
- Minimize weed competition
- Walk fields frequently to identify yield limiting factors
- Swath at the correct stage
- Harvest at a low seed moisture

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