The narrow, long, slightly twisted cabbage leaves from molybdenum deficiency are the reason for the name "whiptail."

The photo illustrates the important role molybdenum performs in plant growth.

Another example of poor plant growth when molybdenum supplies are too low.

TGD3-4

MOLYBDENUM

Mo

A Micronutrient

Section 1: DEFINITION OF MOLYBDENUM

The chemical symbol is Mo.

Molybdenum is a silvery-white, metallic element.

It is almost infusible—that is, it is almost incapable of being fused or melted.

The use of molybdenum as a fertilizer in growing crops is increasing so rapidly that it may soon be recognized as a major micronutrient.

The nutrient is vitally important, but only minute applications of the element are required. In fact, the application rate is in grams or ounces rather than pounds.

Two crop diseases stem from molybdenum deficiency:

1. Whiptail of cauliflower, broccoli, cabbage, etc.
2. Yellow spot of citrus.

An early symptom of molybdenum deficiency is the missing parts along the edge of the cabbage leaf.

The holes and missing parts in the cabbage leaves suggest molybdenum deficiency.

Molybdenum—Mo

Section 2:
CHEMISTRY OF MOLYBDENUM IN PLANTS

It is generally accepted that molybdenum serves as a catalyst inside plants in their enzyme system.

The enzyme systems reduce nitrate nitrogen to ammonium, which is used in the synthesis of amino acids and protein.

Molybdenum functions in nitrogen fixation by the rhizobia bacteria-producing nodules on roots of leguminous plants and also the nonsymbiotic bacteria (symbiosis is the union or living together of two unlike organisms).

As far as has been established, molybdenum toxicity in plants is in relation to livestock production only.

Toxicity can be experienced in concentrations above 10 ppm (dry weight) in green forage.

Areas of severe molybdenum deficiencies are few, but they do exist—some in California, Florida, Africa, and Australia.

The normal functioning of the life processes of the microorganisms of both green plants and animals depend on available molybdenum.

Applying molybdenum salts to pasture crops must be done with extreme caution.

Molybdenosis disease affects cattle grazing on pastures containing toxic levels of molybdenum. This disease can be fatal to cattle, but it need not occur.

Within plants, molybdenum plays a crucial role in the nitrogen transformation processes.

Following is a list of some of the more sensitive crops to molybdenum deficiency:

The narrow bottom leaves (both left and right sides) of the cabbage plant indicate molybdenum deficiency.

The narrow curled leaves on the red cabbage is whiptail disease, caused from molybdenum deficiency.

The cabbage plants have no deficiency. Notice all the leaves are fully developed.

Molybdenum—Mo

tomato, potato, lettuce, spinach, celery, beet, all brassicas, and rape.

The characteristic symptoms of deficiency in the brassica group are: narrow leaves with a slight twisting effect called whiptail disease.

In legume crops, the symptoms of deficiency are not as specific. They generally resemble nitrogen deficiency.

It is rare that grasses exhibit distinct molybdenum deficiency symptoms.

As a general statement, the most obvious symptoms of molybdenum deficiency in the early stages are similar to the symptoms of nitrogen deficiency in all crops except grasses and the brassicas.

The predominant symptom of molybdenum deficiency is whiptail disease in cauliflower, cracked stem of celery, etc.

Many growers do not recognize molybdenum deficiency symptoms.

The outstanding feature of molybdenum in crop production is the very small amount required to correct a deficiency.

Applications of the nutrient to correct a deficiency are made in grams or ounces.

To the untrained eye, the deficiency is often mistakenly diagnosed as insect damage.

Sometimes just rolling the seed in molybdenum powder is sufficient to satisfy crop needs.

Molybdenum is essential for crops to perform their proper functions.

Crops such as vegetables and legumes respond fast and favorably to applications of molybdenum.

Twelve ounces (360 grams) of molybdic acid in 55 gallons (U.S.) of water is sufficient to treat more than 1,000 cabbage plants to correct molybdenum deficiency.

Here is a typical example of shredded leaf edges caused from molybdenum deficiency.

Another example of shredded leaf edges caused from molybdenum deficiency.

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One foliar feeding with molybdenum salts is usually sufficient to satisfy a crop, and one application may last for several succeeding crops.

Molybdenum toxicity has never been recorded as having adverse effects on people.

Molybdenum toxicity has been recorded affecting ruminants (grazing animals).

Fertilizing pastureland with 200 pounds copper sulfate per acre will neutralize the toxic effect of molybdenum.

Another method used to neutralize molybdenum toxicity in sick grazing animals is to inject copper sulfate directly in the bloodstream. The disease is called molybdenosis.

Whiptail disease can be corrected easily with molybdenum salts, providing the proper amount is used and the correction applied promptly.

The production of nitrogen nodules on leguminous plant roots is dependent on molybdenum supply.

A delicate balance seems to exist within the plant between nitrogen, iron, manganese, and molybdenum. All appear to be interdependent on each other.

Molybdenum deficiency affects the manufacture of chlorophyll within the cells of green plants.

Molybdenum deficiencies are nearly as common today as are deficiencies in nitrogen.

Because molybdenum deficiencies are so common today, the symptoms should be better recognized.

Healthy broccoli plants must have adequate molybdenum.

Severe molybdenum deficiency is seen in the long narrow cauliflower leaves.

Molybdenum—Mo

Section 3:
CHEMISTRY OF MOLYBDENUM IN THE SOIL

Native supplies of molybdenum in the soil are very small.

There is usually only one to three ppm, which is less than six pounds an acre in the first eight inches of soil.

Molybdenum toxicity strong enough to affect cattle is less than 10 ppm an acre, or about 20 pounds.

Molybdenum availability to plants is highest when the soil pH is nearly neutral.

In this respect, molybdenum is unlike most of the other essential trace minerals, which are more easily available to plants in acid soils.

Applying sulfuric acid to the soil as a treatment can reduce the availability of molybdenum mainly because it lowers the pH.

The availability of molybdenum is influenced by the following factors:

1. The pH of the soil, presence of sulfates in the soil, soil phosphates, manganese, and also because of the very small reserves of molybdenum normally in the soil.

2. Applying lime to acid soils usually increases the availability of molybdenum.

3. Through ion exchange, fixed (unavailable) molybdate can be displaced by phosphates.

This chemical reaction indicates that the same soil-fixation compounds may be involved in changing both molybdenum and phosphate into unavailable compounds.

After correction for molybdenum deficiency, the cauliflower plants have no deficiency.

Brassica crops (cabbage family) are especially sensitive to molybdenum deficiency. If not corrected, entire crops such as cauliflower can fail completely.

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Molybdenum deficiencies occur more often in acid soils than on neutral soils.

One and one-half pounds molybdenum per acre is an average application.

The maximum application of molybdenum is not more than six pounds per acre.

The total native supply of molybdenum in mineral soils is very small. And like phosphorus, the molybdenum is fixed (unavailable).

Liming acid soils helps to increase the supply of molybdenum for plant use.

Because of the very low native supply of molybdenum in soils, soil tests are not effective in analyzing for molybdenum and therefore are *not* recommended.

Rhizobia bacteria in the soil cannot perform their valuable functions for legume crops without molybdenum.

The disfigured cauliflower leaves indicate severe molybdenum deficiency.

This brassica crop has no deficiency.

The partial leaf (bottom right) is the result from molybdenum deficiency.

Molybdenum—Mo

Section 4:
FORMS OF MOLYBDENUM UTILIZED BY PLANTS

Following is a list of the most frequently used molybdenum fertilizer compounds:

1. Molybdic acid (powdered or liquid)
2. Sodium molybdate
3. Ammonium molybdate

In addition, for special cases, molybdenized phosphate or molybdenized calcium are used to supply molybdenum.

Regular commercial fertilizers seldom contain more than a few parts per million of this element.

Molybdenum fertilizers are effective in foliar feeding and are recommended for this purpose.

Snow-white, well-filled heads of cauliflower have no deficiency.

Sometimes a few grams of molybdenum is all that is needed to produce prize-winning heads of cauliflower.

Molybdenum—Mo

Section 5:
ACTIONS AFFECTING THE SUPPLY OF MOLYBDENUM

Deficiencies of molybdenum in crops can originate from two sources:

1. The year-by-year weathering of the soil removes the total supply of the element to very low amounts.

2. Acid soils may contain a good total supply, but it may be fixed (unavailable) in forms that plants and soil microorganisms cannot utilize.

Liming acid soils lifts the soil pH, and this frequently releases adequate molybdenum for crop and microorganism needs.

It frequently occurs that the soils that are low in molybdenum are low also in copper.

As an ion, when the pH is below 6.0, molybdenum is tightly adsorbed to the soil colloids and minerals. Ions carry negative charges of electricity.

Heavy intensive farming of soils that have a low native supply of molybdenum and are neutral to alkaline pH values may deplete the available molybdenum.

Increasing the supply of phosphorus improves the assimilation of molybdenum by plants.

Using sulfate fertilizer materials may increase the problem of molybdenum deficiency where both sulfur and molybdenum supplies are low. This may be because molybdenum is required in greater amounts because of the increased growth, which the sulfate fertilizer produced.

The citrus leaf on the right is normal. The three to the left show molybdenum deficiency.

The missing portion in the leaf and crinkled center portion on the cucumber plant are signs of molybdenum deficiency.

These perfect cucumber leaves have no deficiency.

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There are reports that indicate manganese can intensify (bring forward) molybdenum deficiency.

Prolonged use and heavy applications of ammonium sulfate fertilizer may intensify molybdenum deficiency by increasing the acidity of the soil and because the sulfate reduces the absorption of molybdenum.

In some soils with a pH below 5.0, molybdenum becomes deficient.

Liming these soils increases the availability of phosphorus and molybdenum.

The poorly shaped or missing tissue in the melon leaves is molybdenum deficiency.

The deformed leaves on the melon plant are from molybdenum deficiency.

The missing portions in the leaves are typical for molybdenum deficiency.

Molybdenum—Mo

Section 6:
METHODS OF APPLYING MOLYBDENUM TO PLANTS

The usual method is to take a soluble molybdenum compound, such as sodium or ammonium molybdate or molybdic acid powder, and mix it with superphosphate or other mixed fertilizers and apply all together to crops.

Sometimes these are broadcast on the soil before seedbed preparation.

Sometimes they are banded at the time of planting seed.

For drill-seeded crops such as soybeans, bushbeans, alfalfa, melons, corn, peas, etc., the soluble molybdenum powder can be mixed directly with the seed along with the rhizobia bacteria powder in the seedbox at the time of planting.

Another method is to mix soluble molybdenum powder with water and apply as a foliar spray on crops.

Frequently, phosphate, sulfate, and molybdenum deficiencies occur at the same time.

This field condition prompted the manufacture of molybdenized superphosphate.

As the name implies, this product contains all three elements listed above and is used to correct all three deficiencies in one fertilizer compound.

Because molybdenum requirements and application rates are so very small, it is necessary to mix it with other materials to increase the volume so it can be applied evenly and accurately on the soil or to the crop.

Frequently, the only early symptom revealing molybdenum deficiency is missing portions along the leaf edges or sometimes in the leaves.

Notice the difference! When insects eat plant leaves, the damaged areas have sharp edges. In molybdenum deficiency the edges are rounded—not sharp.

Molybdenum deficiency affects the manufacture of chlorophyll within the cells of green plants.

Molybdenum—Mo

Sometime molybdenum is mixed with slightly damp peat moss, sawdust, perlite, or sand before it is applied to the crop or field.

Whiptail disease of cauliflower and other brassica crops can be cured if the proper application of molybdenum is dissolved in water and applied as a foliar spray directly on the crop.

To be most effective, the treatment must be applied promptly. Early detection of deficiency symptoms is important.

Severe molybdenum deficiency is seen on the melon leaves.

Notice the difference a ready supply of molybdenum has on the leaves and plant growth.

Molybdenum—Mo

Section 7:
SYMPTOMS OF MOLYBDENUM DEFICIENCY

The predominant symptoms of molybdenum deficiency are whiptail disease on cauliflower and other brassica crops; cracked stem of celery, etc.

Whiptail disease in cauliflower develops characteristic narrow, twisted leaves with irregular edges.

The symptoms of acute deficiency are death of small areas of leaf tissue between the veins; the leaves lengthen abnormally and twist slightly.

In mild deficiency, the cauliflower heads do not develop. This can occur even though the deficiency is too mild to produce whiptail disease in the leaves.

If corrective treatment is applied promptly, whiptail disease can nearly always be corrected.

The practice to routinely apply one pound or more per acre of soluble molybdenum salts is becoming an accepted precautionary procedure by many vegetable growers.

Molybdenum is essential for nitrogen utilization in plants.

Molybdenum-deficient plants are stunted and have varying shades of yellow discoloration closely resembling nitrogen deficiency.

A very common deficiency symptom is missing parts of leaves, either on the edges or in the tissues in the leaves; or it can resemble scar tissue on leaves.

The old melon leaf (bottom) has molybdenum deficiency. The new leaf (center) is normal after the deficiency was corrected.

This melon field recovered completely from molybdenum deficiency.

Molybdenum—Mo

Section 8:

SYMPTOMS OF MOLYBDENUM EXCESS

Molybdenum toxicity or excess is rare and seldom recognized in the field.

Plants seem to tolerate high concentrations of this element in their tissues.

For livestock (ruminant animals), molybdenum excess can be especially serious.

Molybdenum toxicity is known by several names:

1. Molybdenosis
2. Teart disease
3. Peat scows

Encounters with ruminant animals having molybdenum toxicity have been from naturally occurring excess molybdenum, either in the soil or in the irrigation water.

Treating forage crops with copper sulfate has been successful in counteracting the harmful effects of molybdenum toxicity in ruminant animals.

Plants may accumulate 100 ppm or more of molybdenum without noticeable symptoms of toxicity to the plant itself.

Molybdenosis disease in livestock may be encountered on forage crops that contain less than 10 ppm of molybdenum in their tissue.

Well-shaped melon leaves with dark-green color and strong vines indicate to the grower that the essential nutrients were adequate.

Blue-green color on leaves, dying older leaves, and poor growth of the onions are symptoms of molybdenum deficiency.

Molybdenum—Mo

Section 9: CAUTIONS REGARDING THE USE OF MOLYBDENUM

Nearly all the toxic elements in the soil may occur naturally, or they may result from applying salts of the various elements in fertilizers, insecticides, or fungicides.

Under certain conditions of toxicity, indicator plants thrive and reveal the toxic elements.

In the case of molybdenum, cattle grazing on the forage crops may be poisoned.

Molybdenum is unique among all the essential trace elements in the very small amount required. Applications are always figured in grams or ounces instead of pounds.

For many soils that are low in this element, fertilizing with one to one and one-half pounds to the acre is liberal and frequently one application will satisfy crop needs for two or three years.

General field applications of molybdenum, however, are usually 1 to 4 pounds per acre.

Rhizobia bacteria are very dependent on molybdenum to perform their normal functions in legume plants.

Molybdenum is essential to the processes of nitrogen transformation in plants.

Phosphorus and sulfur are often deficient under the same conditions that bring about molybdenum deficiency.

But increasing the supply of molybdenum through fertilizers will produce only negative crop response until the phosphorus or sulfate fertility levels are increased adequately.

The narrow, long radish leaf is a symptom of molybdenum deficiency.

The missing tissues in the squash leaf indicate molybdenum deficiency.

Molybdenum—Mo

Section 10:
SUGGESTIONS REGARDING MOLYBDENUM

Molybdenum materials are very expensive.

Prices range from $2.90 to $55.00 per pound. The average price being around $15.00 per pound.

For small greenhouse or family garden, the recommended molybdenum fertilizer application is four grams per each 25 pounds of mixed fertilizers.

In whole numbers, about 30 grams is equal to one ounce, and 16 ounces equals 480 grams.

The use of molybdenum in growing family gardens is not widely practiced, but is increasing rapidly.

The melon field has no deficiency.

The missing parts in the tomato leaves indicate molybdenum deficiency.

Notice the narrow, ill-shaped leaves? This is a typical pattern in molybdenum deficiency.

Molybdenum—Mo

Section 11:
SUMMARY AND REVIEW OF MOLYBDENUM

Partial List of Molybdenum Fertilizer Materials

Sodium molybdate

Ammonium molybdate

Molybdic acid

Effects of Molybdenum Deficiency on Miscellaneous Crops

Bean	Leaves are pale-green color with interveinal mottling; brown scorched areas develop rapidly in the interveinal tissue; green bands remain close to the middle ribs and veins, even after death of affected tissue.
Beet	Blades are pale-green and curl upward from the middle rib; red veins are conspicuous because of chlorotic leaves.
Broccoli	Leaves develop whiptail appearance; necrosis develops in the interveinal areas; cotyledon leaves usually remain green.
Brussels sprouts	Leaves become cupped; young leaves become twisted; plants are gray-green color.
Cabbage	Older leaves are mottled, scorched, bleached, and cupped; heart formation is poor.