PNW 615

# Nutrient Management for Field Corn Silage and Grain

## in the Inland Pacific Northwest

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**CORN ACREAGE AND PRODUCTION** has increased in the Pacific Northwest (PNW) with growth of the dairy industry. This is particularly true in southern Idaho, where acreage increased from 125,000 in 1997 to 300,000 in 2008.

Adequate nutrition is essential if productive new corn hybrids are to realize their full yield potential. The following fertilizer guidelines are based on land-grant university research. The fertilizer rates suggested are designed to produce above-average yields if other factors do not limit production. The rates will be appropriate provided (1) the soil samples are properly taken and represent the field or management unit to be fertilized; (2) the crop history information is complete and accurate; (3) the yield goal is realistic; and (4) good crop management practices are used.

## NITROGEN

Nitrogen (N) is generally the most limiting nutrient for corn production, and is the most frequently applied nutrient. Fertilizer N represents by far the largest share of total fertilization costs for field corn. High fertilizer prices and groundwater quality concerns make it essential that this nutrient be managed to optimize economic returns while protecting groundwater resources.

Field corn lacking sufficient N at early growth stages is stunted and light green in color, especially in lower leaves. The difference in appearance between lower and upper leaves is more pronounced as the plant develops. Lower leaves indicate a N shortage when the leaves are a light green, the leaf tip becomes yellow, and the yellow extends from the leaf tip into the leaf along the midrib.

The amount of fertilizer N required, if any, depends on many factors that influence total corn production, including length of growing season, corn hybrid, previous crop and residue management, past fertilizer and manure/compost use, soil type, and the leaching potential. Estimates of the N available to corn from the soil during the season and the yield potential of the crop should be considered when determining N fertilizer rates. High plant populations of field corn are more susceptible to N shortages because of greater competition among plants for limited N. Corn yield potential reduced by poor stands or delayed plantings will have reduced N requirements.

Several tools can be used to refine N management for field corn. They include pre-plant, post-emergence (pre-side-dress), and end-of-season soil N testing; and in-season plant analysis of lower stalk, ear leaves, or whole plants. In-field estimates of N shortages are also possible based on chlorophyll meter readings and the number of green leaves below the ear, although there is limited experience with these in the PNW.

### Pre-plant N soil test

In the inland irrigated PNW, limited rainfall normally precludes appreciable loss of nitrogen from leaching caused by winter precipitation. A pre-plant N soil test can evaluate the carryover nitrate-N ($NO_3$-N) and ammonium-N ($NH_4$-N) from previous crops, as well as the N mineralized since the last crop was actively growing. Most of the carryover inorganic N is present in the $NO_3$-N form and N recommendations generally focus on the $NO_3$-N concentrations. In fact, many soil testing laboratories report only the $NO_3$-N results. However, appreciable $NH_4$-N concentrations can occur as a result of ammonium-N fertilizer N (or manure) that has not converted fully to the $NO_3$-N form, or other conditions (e.g. colder soils) that slow the normal conversion of $NH_4$-N to $NO_3$-N. Therefore, we recommend testing for both nitrate-N and ammonium-N.

Soil samples should be collected before planting. Sample in foot increments to a depth of 2 feet, unless roots are limited by restrictive soil horizons or high water tables. Deeper sampling may be justified if the effective rooting depth extends below 2 feet and appreciable N is suspected at those depths due to high N fertilization of previous shallow-rooted crops (carrots, onions, potatoes).

In practice, many pre-plant soil samples are collected from only the first foot. In some cases this may be adequate because nitrate-N measured in the first foot is often related to nitrate-N in the second foot. For example, in low rainfall southern Idaho field corn trials, pre-plant nitrate-N measurements in the second foot averaged about 90% of those in the first foot. However, in western Oregon soil nitrate-N in the first foot at planting was not well correlated to nitrate-N in the second foot, and second-foot nitrate-N averaged only about 40% of that in the first foot. Sampling both depths is the most accurate measure of available N for corn. Fall sampling of soil for carryover nitrate-N has not been evaluated for field corn in the PNW. Early fall sampling would not reflect the N mineralized from organic matter during the fall and spring before corn planting, or the N immobilized by microbial activity. Late fall sampling could reflect available N in the early spring if it is not affected by over-winter precipitation. Collect soil samples in the spring for the best indication of pre-plant available N.

Pre-plant soil N tests are reasonably effective for identifying sites that are not likely to need fertilizer N, especially in non-manured soil. However, pre-plant soil test N is less effective for predicting the amount of fertilizer N required when fertilizer N is needed. While the pre-plant soil N test reflects the readily available N at the time of sampling, it may not reflect the N that will be mineralized during the season. Therefore, the pre-plant soil N test tends to over-estimate the fertilizer N required in manured fields, or other fields with high N mineralization potential. Post-emergence or pre-side-dress N tests can give a better idea of how much N is being mineralized.

### Pre-side-dress soil nitrate-N test (PSNT)

Soil test nitrate-N in the first foot at the V5/V6 growth stage may also be useful for predicting fields that need N. The test at this growth stage reflects the pre-plant carryover N from the previous season, as well as the N mineralized to that point from the organic fraction. In fact, the PSNT often does not differ much from the pre-plant sampling. However, an N test at this stage can be useful if there was an intervening irrigation (especially using furrows), or if there is appreciable N mineralized from organic N, as with manured soils. Another potential advantage of the PSNT is that it may better reflect the N immobilized by microbial decomposition of late fall or spring incorporated corn residues.

The PSNT is especially useful for identifying manured sites where field corn silage or grain yield is not likely to increase with applied fertilizer N. For this determination, it is more effective than pre-plant N testing. Western Oregon research suggests that soil with 25 ppm or above of N in the first foot at the V5/V6 stage will likely not require additional fertilizer N. Unfortunately, if the soil is low in N and needs fertilizer N, the PSNT does not accurately predict the rate of N required to maximize corn production any better than pre-plant soil N testing.

Pre-side-dress samples should be collected prior to the first irrigation. If furrows are irrigated before collecting the pre-side-dress sample, nitrate-N movement can affect nitrate-N concentrations between corn rows.

Since the PSNT is based on a sampling of only the first foot of soil, it may not reflect nitrate-N at lower depths. For PSNT samples collected earlier than V5/V6, critical values may be slightly lower than at the V5/V6 stage.

### Fertilizer N requirement

**Potential yield**—Southern Idaho and western Oregon research (1983 to 2000) suggests that N requirements are affected by yield potential. The greatest yield potential factor in this region is the growing season. Corn is grown in the PNW from near sea level in coastal valleys to the higher elevations (5000 ft) in eastern Idaho. Corn hybrid maturity ratings range from 85 days in eastern Idaho to 135 days in the Columbia Basin. Even with longer growing seasons, shorter season hybrids may be used for double cropping (corn planted after crops harvested earlier during the same growing season). Conceptualized N uptake for corn within a range of maturities and yield potentials is shown in figure 1. Other factors also influence potential yield; these include plant population and hybrid selection.

Fertilizer N rates should reflect the corn yield that growers can reasonably expect under their soil, climate, and management conditions. The historic yield obtained in a specific field or management unit provides a fair approximation of yield potential, given a grower's traditional crop management. Changes in crop management designed to appreciably alter production may require adjustment of yield potential and the N requirement.

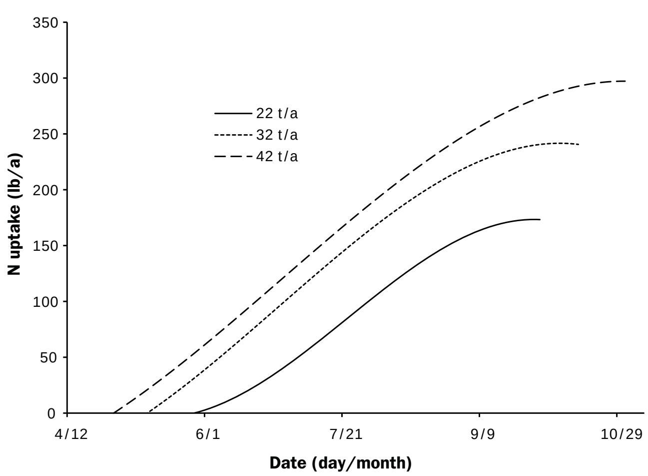


**Figure 1.** Conceptualized field corn nitrogen uptake (lb/acre) throughout the growing season, as affected by silage yield in tons per acre (t/a) limited by growing seasons in the PNW. When yield is limited by the growing season, note that N uptake is both reduced and delayed, and the N uptake period is shortened.

The N rates that maximize economic returns don't differ much as the ratio of the corn price (per bushel) to cost of fertilizer N (per pound) ranges from 9 to 16. When the ratio falls below 9, reduce the recommended N rate by 10 to 15%.

**Non-manured soils**—The fertilizer N requirements for non-manured field corn silage or grain based on pre-plant soil test N and potential yield are shown in tables 1 and 2. The fertilizer N requirements in the tables are based solely on soil test N and yield potential, and do not reflect differences in organic N release among soils. Consequently, heavily manured soils may not require nearly as much fertilizer N as indicated in the tables, or any N fertilizer at all. Research has not shown soil organic matter (SOM) to be an accurate estimate of organic N release in irrigated southern Idaho soils, though SOM is routinely measured by soil testing laboratories.

The recommended N rates for non-manured soil are based on the assumption that it takes about 9 lb of readily available N (pre-plant soil test N and fertilizer N) or less to produce a ton of fresh chopped corn (67% moisture) and 1.4 to 1.5 lb of available N to produce a bushel of corn. The recommendations also assume that pre-plant N is measured to a two-foot depth and that soil test N and fertilizer N are equally effective at producing corn. Using table 1 or 2 based only on a soil sample collected from the first foot will likely overestimate the N required.

**Table 1. Recommended fertilizer N rates for field corn harvested for silage in non-manured soil (lb/acre).**

| Pre-plant soil test N at 0-2 ft (ppm)[1] | Silage yield (ton/acre) | | | | |
|---|---|---|---|---|---|
| | 20 | 25 | 30 | 35 | 40 |
| 0 | 180 | 225 | 270 | 310 | 340 |
| 10 | 140 | 185 | 230 | 270 | 300 |
| 20 | 100 | 145 | 190 | 230 | 260 |
| 30 | 60 | 105 | 150 | 190 | 220 |
| 40 | 20 | 65 | 110 | 150 | 180 |
| 50 | 0 | 25 | 70 | 110 | 140 |
| 60 | 0 | 0 | 30 | 70 | 100 |
| 70 | 0 | 0 | 0 | 30 | 60 |
| 80 | 0 | 0 | 0 | 0 | 20 |

Note: Adjust the recommended N rates for the effects of previous crop and residue management. (See text section, "Nitrogen credits for previous crop"). Adjustment may also be required for samples collected only from the first foot.

[1] Soil test N values ($NO_3$-N and $NH_4$-N) summed for the 0 to 12 and 12 to 24 inch depths.

**Table 2. Recommended fertilizer N rates for field corn harvested for grain in non-manured fields (lb / acre).**

| Pre-plant soil test N at 0-2 ft (ppm)[1] | Grain yield (bu/acre) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 100 | 130 | 160 | 190 | 220 | 250 | 280 |
| 0 | 150 | 195 | 240 | 285 | 315 | 360 | 405 |
| 10 | 110 | 155 | 200 | 245 | 275 | 320 | 365 |
| 20 | 70 | 115 | 160 | 205 | 235 | 280 | 325 |
| 30 | 30 | 75 | 120 | 165 | 195 | 240 | 285 |
| 40 | 0 | 35 | 80 | 125 | 155 | 200 | 245 |
| 50 | 0 | 0 | 40 | 85 | 115 | 160 | 205 |
| 60 | 0 | 0 | 0 | 45 | 75 | 120 | 165 |
| 70 | 0 | 0 | 0 | 5 | 35 | 80 | 125 |
| 80 | 0 | 0 | 0 | 0 | 0 | 40 | 85 |
| 90 | | | | | | 0 | 45 |
| 100 | | | | | | | 5 |

Note: Adjust the recommended N rates for the effects of previous crop and residue management. (See text section, "Nitrogen credits for previous crop"). Adjustment may also be required for samples collected only from the first foot.

[1] Soil test N values summed for the 0 to 12 and 12 to 24 inch depths.

**Nitrogen credits for previous crop**—The recommended fertilizer N rates (tables 1 and 2) do not account for N cycling from some previous crop residues. Add 20 pounds N per acre for each ton of corn stover or small grain residue plowed under in late fall, to a maximum of 50 pounds N per acre. Wheat and barley residue incorporated the previous summer or early fall will largely immobilize N by the following spring due to microbial activity. The N immobilization is normally reflected as lower pre-plant soil test N which leads to higher N fertilizer recommendations. More N is required for residue incorporated in late fall or spring than residue incorporated in early fall. Residue of irrigated winter wheat is normally 3 to 4 tons per acre (assuming none is baled), and is not always related to grain yields. Winter wheat normally produces more straw than spring wheat or barley.

Fertilizer N rates should be reduced 60 to 100 pounds per acre when field corn follows alfalfa grown for forage or seed. Shorter growing seasons likely will not mineralize as much N from alfalfa residues as longer growing seasons. Also, poor alfalfa stands won't release as much N the following year as good stands. Reduce the alfalfa N credit by 20 to 30 lb N per acre if the alfalfa stand is less than two plants per square foot.

Residues of grain legumes such as peas or beans are normally incorporated in late summer or early fall with ample time for decomposition and N release to occur. Consequently, N contributions from these legumes are largely reflected in the pre-plant or pre-side-dress soil N test, so further adjustment of fertilizer N rates is not required.

**Manured soils**—Corn silage is one of the most common forages used in the Pacific Northwest for dairy and beef rations. Since the forage is typically grown as a part of the livestock operation, there is appreciable manure applied to fields where the corn is grown. Depending on the history of manure applications, manured fields frequently do not require fertilizer N. Western Oregon research indicated that yield increased in only two of 23 manured fields in the Willamette Valley with fertilizer N applications. If N is required, it is typically only a portion of that indicated for non-manured soils. The pre-plant soil N test is not the most appropriate test for indicating the N required for manured soils, unless they were only lightly manured. The PSNT is the more appropriate soil test for manured soils, as it better reflects N derived from manure and more accurately identifies fields likely to be N sufficient.

The fertilizer N requirements for corn in manured soils based on the PSNT are shown in table 3. For additional information on manure N contributions see the appendix below.

**Nitrogen timing and placement**—Applying N using sprinkler irrigation of corn under center pivots or linear move systems is an efficient, flexible way to provide N during the season, match N applied with corn N uptake requirements, and minimize N losses from leaching or denitrification. For maximum application uniformity of water (and possibly late applied N), sprinkler nozzles should be higher than the corn canopy. Otherwise, the canopy at full height interferes with the wetting pattern.

**Table 3. Recommended fertilizer N rates for field corn harvested for silage in soils manured for extended periods (lb / acre).**

| Pre-side-dress soil nitrate-N (ppm)[1] | Silage yield (tons/acre) | | | | |
|---|---|---|---|---|---|
| | 20 | 25 | 30 | 35 | 40 |
| 0-10 | 100-175 | 140-215 | 180-255 | 220-295 | 260-335 |
| 10-20 | 50-100 | 90-140 | 130-180 | 170-220 | 210-260 |
| 20-25 | 0-50 | 40-90 | 80-130 | 120-170 | 160-210 |
| 25-30 | 0 | 0 | 30-80 | 70-120 | 110-160 |
| >30 | 0 | 0 | 0 | 30-80 | 70-120 |

[1] Soil test nitrate-N values for only the first foot of soil.

The N management options during the season are more limited for furrow-irrigated corn. Nitrogen applications with furrow-irrigated corn are typically accomplished with pre-plant and side-dress applications of N. There is limited opportunity to apply N after corn growth precludes additional trips through the field with equipment. Soluble N is at times added to the irrigation water applied in the furrows, but there is risk of the N loss in the runoff from field ends. With furrow irrigation, losses of N from leaching are greater in coarse-textured soils, including sandy loams, loamy sands, and sands. For these soils, side-dress a portion of the N at the time of the last cultivation. On silt loam and other fine-textured soils, split applications of N in the spring have not proven more effective than pre-plant N, as long as pre-plant broadcast N is adequately incorporated, and early season irrigation minimizes N leaching. Fertilizer N applied early the previous fall has not been as effective as late fall or spring applied N, especially where previous crop residues are returned to the soil.

Modern corn hybrids with narrow rows (22-inch vs. traditional 30- or 32-inch rows), high plant populations (36,000 to 40,000 plants per acre vs. 30,000), and high yield potential can have high fertilizer N requirements. However, only a limited amount of N can be applied preplant to field corn without stunting seedlings, slowing initial growth, or reducing stands.

If high N rates (greater than 240 lb/acre) are needed, split applications should be considered. Split the applications between pre-plant broadcast and post-emergence side-dressings or applications through sprinkler lines. Side-dressing may cause root pruning depending on plant size, distance of applicator shank or knife from the row, and placement depth. Side-dressing N no closer than 7 inches from the corn row will avoid root pruning of plants that are 10 to12 inches tall.

Moreover, modern hybrids may not only have higher N requirements, they may also take up a larger portion of their N requirements after silking than older hybrids. This provides all the more incentive to consider split applications where feasible.

Closer row spacing (22-inch) is more common in some PNW corn production systems, particularly where corn is grown by producers using 22-inch row spacing for other rotation crops of beans, onions, alfalfa seed, and sugarbeets. Narrower row spacing and beds of furrow-irrigated corn can increase the potential for nitrate-N leaching unless irrigation or N management is adapted to the narrower beds. Irrigating every furrow or even alternating between furrows can lead to greater nitrate leaching with 22-inch beds than in more traditional 30-inch beds. In narrow beds, placement of N as a band on the side of the corn row away from a consistently wetted furrow increased N effectiveness more than broadcast N in southern Idaho research.

Crop residues on the soil surface can reduce broadcast fertilizer N effectiveness by either increasing ammonia N volatilization from urea, or by increasing microbial N immobilization. When previous crop residues remain at the surface, as with direct seeded or no-till planted corn, banding or shanking N below the residue is more effective.

**Enhanced N fertilizers**—Enhanced N fertilizers include "controlled release" or "stabilized" N fertilizers. The N release is controlled or stabilized using coating technology or adding compounds to the N formulation that affect conversion rates from the urea or ammonium-N form to the nitrate form. Pre-plant controlled-release or stabilized N sources can improve applied N effectiveness under conditions that normally cause N losses from leaching, denitrification, volatilization, or immobilization when using conventional products. These are marketed as dry or solution N formulations. They are typically more expensive than conventional N fertilizers such as urea, ammonium sulfate, Solution 32 (urea - ammonium nitrate solution), or anhydrous ammonia. When N losses are minimized, either lower N rates can be used or additional application costs avoided. However, the modes of action differ among these products, and they can't always substitute for each other. For example, coated fertilizers may control the release of the nutrient, while others contain compounds that affect microbial or enzymatic processes.

Research and experience with enhanced N fertilizers in the PNW for field corn are limited. Some have proven effective in high rainfall areas of the Midwest where early season applied N is lost due to leaching. Information is needed on these materials in the irrigated PNW. Enhanced N fertilizers are likely most effective when the N released from them is slow enough initially to reduce leaching early in the season, but is rapid enough not to limit N uptake from the ten leaf stage through silking, which is the period of maximum N uptake.

## Monitoring N management

Formulating N rate decisions based on soil test N, either pre-plant or pre-side-dress, is an inexact science and involves some risk. Therefore, monitoring the effectiveness of the N management practices used is wise in order to make mid-season corrections or refine future N management. A variety of monitoring tools have been proposed for this purpose, ranging from plant-based monitoring at midseason, to soil-based post-harvest monitoring.

Monitoring plant tissues for their N status is possible at various growth stages. Early season (12 inches tall) whole plant tissues should have from 3.5 to 5.0% total N. For midseason growth stages, use ear leaf tissue total N concentrations (sufficiency N level is 2.7 to 3.5% N). While most in-season monitoring procedures can identify N shortages, unfortunately we cannot give recommendations for the exact amount of N to apply to correct an N shortage.

For end-of-season indicators, measuring whole plant N or nitrate-N concentrations at harvest in lower stalks can be useful. Whole plant N of 1.0 to 1.2% N, or 6.5 to 7.5% protein, indicates that the N fertilization was adequate for maximum yield, as does nitrate-N concentrations in the lower stalks of 3500 to 5500 ppm.

If you find that your residual soil nitrate-N at harvest is above 20 ppm in sprinkler irrigated fields, N was most likely adequate for near maximum yield. A rough visual measure of N adequacy at silage harvest is the number of green leaves below the ear (more than 3.5 is desired).

## PHOSPHORUS

Adequate phosphorus (P) is necessary for maximum production of corn, although field corn is not as sensitive to low P as are vegetable crops such as potatoes and onions, or small grains produced under cooler soil conditions. Phosphorus-deficient corn is stunted and seedlings may have purple pigment as a result of increased anthocyanin content. However, higher anthocyanin content is a response to general plant stress, and may not be specific to a P deficiency. A shortage of P causes a delay in the development of corn, and thus later maturity. Plant symptoms should be used along with soil testing to confirm a P shortage.

Soil test P provides a reasonable indication of whether field corn requires P fertilization. In neutral to calcareous soils, the Olsen P (sodium bicarbonate extractable P) soil test is used. In more neutral to acid soils, the Bray ($NH_4F$ and HCl extractable P) test is used. Soil samples should be collected from the first foot of soil. Cost effective response to fertilizer P is more likely with (1) early plantings where cooler soil temperatures may limit P availability, (2) soils with appreciable lime content, or (3) where longer season hybrids may have difficulty maturing in the season available.

Soils that regularly or periodically receive manures to satisfy field corn N requirements often do not require fertilizer P. The contributions from manures and composts should be reflected by the soil test, though possibly not to the extent that fertilizer P additions are, depending on the time since the applications. Soil test P may respond more slowly with manures and composts.

Fertilizer P application rates based on soil test P are given in table 4. Phosphorus is an immobile nutrient that does not move appreciably from where it is placed. It should be mixed into the seedbed or banded within easy reach of the seedling roots before or during the planting operation. Banding P fertilizer to provide early access to developing roots typically improves P fertilizer effectiveness, in some cases by two fold in soils requiring P. Banded P fertilizer should be applied at half the recommended broadcast rate.

Banding P with the seed can be effective, but the rates are limited by the type of mixed fertilizer used. Seed germination can be reduced by excessive N and potassium (K) fertilizer salts, or by high ammonia or ammonium concentrations. Urea and diammonium P should be avoided as seed popup or starter placements. Total N amounts in mixed fertilizers banded with seed should not exceed 5 to 10 lb N plus K per acre.

Soils with higher free lime content (>5%) can reduce the effectiveness of applied P. Phosphorus fertilization rates should be increased 30 to 60 lb $P_2O_5$ per acre for each 5% increase in lime content.

Specialty P fertilizers are marketed to increase applied P effectiveness. However, there is little field corn research in the PNW with these products.

**Table 4. Broadcast fertilizer $P_20_5$ rates based on soil test P.**

| Soil test P (ppm) | | Application rate (lb/acre) |
|---|---|---|
| Olsen[1] | Bray[2] | |
| 0 | 0 | 120 |
| 5 | 8 | 80 |
| 10 | 16 | 40 |
| 15 | 24 | 0 |

Note: $P_2O_5$ x 0.44 = P, or P x 2.29 = $P_2O_5$

[1] Soil extractant for the Olsen test used in slightly acid and calcareous soil is $NaHCO_3$.

[2] Soil extractant for the Bray test used in acid soils is $NH_4F$ and HCl.

## POTASSIUM

Field corn requires adequate potassium (K) for optimum growth. Soil test K can be useful in determining the need for K fertilizers. The soil sample is taken from the first foot of soil and extracted with sodium bicarbonate in Idaho, and ammonium acetate in Oregon. Fertilizer K rates based on soil test K are given in table 5. Potassium should be plowed down or banded well away from seed to avoid salt injury. Manured soils should not require K fertilizer.

Potassium fertilizers can differ in their performance. Potassium sulfate (0-0-52) provides sulfur in a readily available form and is useful for soils low in sulfur. Potassium chloride (0-0-62) provides chloride, which has been shown to reduce corn stalk rot.

## MICRONUTRIENTS

The DTPA extraction is normally used to test for the micronutrients copper (Cu), zinc (Zn), iron (Fe), and manganese (Mn). Soil samples should be collected from the first foot of soil. Zinc deficiencies occur primarily in soils that are eroded, leveled, or where the exposed subsoil is higher in lime. Apply 10 lb Zn per acre when the soil test measures less than 0.6 ppm.

Other micronutrients have not been shown to limit corn production. “Shotgun” applications of micronutrient mixtures containing Fe, Mn, Cu, and boron (B) “for insurance” have not been shown to be economical, and are not recommended.

Copper foot baths are commonly used in dairies for controlling foot-related maladies in the livestock. Lagoon water high in Cu that is applied to soils can increase soil Cu well above normal concentrations. It is not clear whether higher soil Cu from lagoon waste applications is detrimental to corn, but additional Cu should not be applied to these soils.

## SULFUR

The major irrigated corn-growing regions of the PNW should not experience shortages of sulfur (S). Irrigation water from the Snake River and other rivers receiving irrigation return flows are known to have high S concentrations. Soils receiving periodic potassium sulfate or ammonium sulfate fertilizer should not require additional S applications. Sulfur deficiencies can occur in some irrigated areas where both the soil and irrigation water are low in S. Coarse-textured soils including sandy loams, loamy sands, and sands will be more susceptible to S shortages than silt loam soils because S in the readily available sulfate form ($SO_4$-S) is a mobile nutrient that can leach to lower depths. Where the need for S is evident, use 30 pounds per acre of sulfate-S ($SO_4$-S).

**Table 5. Fertilizer $K_2O$ rates based on soil test K.**

| Soil test K (ppm)[1] | | Application rate (lb/acre) |
|---|---|---|
| Olsen | Acetate | |
| 0 | 0 | 240 |
| 50 | 60 | 160 |
| 100 | 120 | 80 |
| 150 | 180 | 0 |

Note: $K_2O$ x 0.83 = K, or K x 1.20 = $K_2O$

[1] Soil extractant is sodium bicarbonate or ammonium acetate.

Soil testing for S in the first foot alone is not a reliable indicator of the need for S. Deeper sampling may be necessary to identify S available in the second foot.

## SALINITY

Field corn has a low to moderate tolerance to accumulated salts. Salts in soil are measured using an electrical conductivity (EC) test. Soils with EC readings above 3 or 4 mmhos/cm can be cropped effectively with good water management. Corn can even handle readings of up to 6 mmhos per cm, if water is managed very carefully. Typically, with high salts present, soil moisture should be maintained at higher available moisture values.

## APPENDIX

## MANURES AS NUTRIENT SOURCES FOR CORN

When managed properly, manures can be inexpensive and effective sources of plant nutrients for corn. Compiled averages can be used as a starting point for estimating nutrient content in manures. See the publication *Fertilizing with Manure,* PNW No. 533 for averages:
http://cru.cahe.wsu.edu/CEPublications/pnw0533/pnw0533.pdf. However, unlike chemical fertilizers, nutrient concentrations among liquid manures sampled from even the same farm can vary tenfold or more. Factors such as animal species, feed ration, maturation of manure, storage method, time of year, amount and type of bedding added, location within a pile or a lagoon, and many others will impact nutrient concentrations.

To obtain a reliable value for nutrient content, follow procedures outlined in *Manure and Wastewater Sampling,* University of Idaho CIS 1139 (http://www.cals.uidaho.edu/edComm/detail.asp?IDnum=1393). Samples should be submitted to a manure testing laboratory certified by the Minnesota Dept. of Agriculture (MDA). Requested analyses should include total nitrogen, ammonium-N, total phosphorus, total potassium, salts (EC), and dry matter or dry solids. When submitting composted manures, also request a test for nitrate-N. The most current list of MDA-approved manure testing labs can be found at:
http://www2.mda.state.mn.us/webapp/lis/manurelabs.jsp.

A large proportion of nitrogen in manures is organic nitrogen in undigested forage, which cannot be used by plants until converted through the microbial process of mineralization to the plant-available forms of ammonium and nitrate. Organic nitrogen content can be calculated by subtracting the ammonium and nitrate-N content from the total nitrogen. There is no quick test for readily mineralizable organic nitrogen in manures. Therefore, we must rely on research and personal experience when estimating plant-available nitrogen. For example, despite lower C-N ratios in dairy manures, organic nitrogen is mineralized more slowly than organic nitrogen in poultry litter. To learn more about how to predict nitrogen mineralization rates in manures, refer to *Estimating Plant Available Nitrogen from Manure*, Oregon State University EM No. 8954-E:
http://extension.oregonstate.edu/catalog/pdf/em/em8954-e.pdf.

Excessive manuring can result in soil that is highly enriched with phosphorus and other nutrients. Phosphorus (P) is a particular concern because with runoff from fields it can be transported to surface waters and cause nuisance aquatic growth, increased biological oxygen demand, and fish kills. Consequently, manuring rates are subject to state and federal rules and regulations. The regulations often differ for each state. In Idaho, the manuring rate can be limited by the P removed with crop removal (manure P applied=crop P removal). To comply with local manuring statutes, and to avoid costly fines and negative environmental impacts, learn the phosphorus regulations for your state. On-line state guidelines are available at:

**Idaho**
http://efotg.nrcs.usda.gov/references/public/ID/590.pdf

**Oregon/Washington**
http://extension.oregonstate.edu/catalog/html/em/em8848-e/

To learn more about strategies for reducing the environmental impact of phosphorus in manures, refer to *Mitigating High-Phosphorus Soils*, University of Idaho BUL 851:
http://www.cals.uidaho.edu/edComm/pdf/BUL/BUL0851.pdf.

Manures and lagoon waters can also contain salts and other constituents that can affect soil productivity with repeated application. For information on the risks of excessive manuring refer to *Dairy Manure Field Applications- How Much is Too Much*, University of Idaho CIS 1156:
http://www.cals.uidaho.edu/edComm/pdf/CIS/CIS1156.pdf.

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