Nitrogen in Irrigation Water
By Carol Frate, Tulare County Farm Advisor and Dr. Rollie Meyer, Ext. Soil Specialist

When accounting for nitrogen applied to crops, dry fertilizers, liquid fertilizers, and manures come to mind. However, significant amounts of nitrogen may unintentionally be applied in irrigation water when either groundwater or animal waste lagoon water, such as dairy lagoon water, is used. This nitrogen should be considered when making crop fertilization decisions.

Farms in Tulare County use two major sources of irrigation water: canal water from Sierra Nevada snowmelt that is distributed through irrigation districts, and groundwater pumped to the surface. Another source of irrigation water for fields near dairies is water from dairy storage lagoons. This water has been used and reused on the dairy until, at last, it is used to flush out the stalls and is collected in a lagoon. When the lagoon is full, the water is pumped to surrounding fields for irrigation. It is often diluted by mixing with canal or groundwater before field application.

Canal water is very low in all salts including nitrate and it can be discounted as a nitrogen source. On the other hand, groundwater and lagoon water may contribute significant nitrogen to crops when used for irrigation.

The form of nitrogen found in groundwater is nitrate nitrogen. Nitrate content varies depending on the location of the well in the county. The east side of the valley and the area west of the town of Tulare are areas where nitrates in groundwater can often be found, but they are not the only areas. Typical nitrogen levels in the county range from 2 to 11 ppm (parts per million) which represents 5 to 30 pounds of nitrogen per acre-foot of water. If 3 acre-feet of pump water are applied during the season, then 15 to 90 pounds of nitrogen would also be applied.

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To determine the nitrogen content of water, collect a sample after allowing the pump to run for at least 30 minutes. About a pint of water will do, placed in a clean, tightly sealed container; deliver to the lab as soon as possible. Lab results will be expressed as either ppm NO₃ (parts per million nitrate) or ppm NO₃ - N (parts per million nitrate nitrogen). See the examples below.

**Example 1: Water analysis reported as nitrate (NO₃).** Analysis of well water indicates that the nitrate (NO₃) concentration is 25 ppm. The conversion factor of "ppm" to "lbs per acre-ft" is 2.7.

\[ 25 \times 2.7 = 67.5 \text{ pounds per acre-ft of nitrate (NO}_3^-) \]

Nitrogen makes up 22% of the nitrate ion.

\[ 67.5 \times 0.22 = 14.8 \text{ lbs of N in each acre-ft of water applied.} \]

**Example 2: Water analysis reported as nitrate N (NO₃-N).** Analysis of well water indicates that the nitrate nitrogen (NO₃-N) concentration is 25 ppm. Remember from the above example that the conversion factor for "ppm" to "lbs per acre-ft" is 2.7.

\[ 25 \times 2.7 = 67.5 \text{ lbs of N in each acre-ft applied.} \]

Since the lab report was for nitrogen, no other calculation is needed. These examples indicate the importance of noting whether the lab reports the nitrogen as "nitrate" or as "nitrate nitrogen".

Once the amount of nitrogen per acre-ft of water is known, then the next step is knowing how much water is applied to the crop. Flow meters give a direct measurement of water but few growers have them. The next easiest method is to know the output of the pump and to calculate the amount of water. To do that it is important to keep the following measurements in mind:

\[ 325,851 \text{ gallons} = 1 \text{ acre-foot} \]
\[ 27,154 \text{ gallons} = 1 \text{ acre-inch} \]
Example 3. Laboratory analysis reports that the nitrate concentration in pumped water is 30 ppm. A 40 acre field was irrigated over a 161 hour period with a pump flowing at 450 gallons/minute. How much nitrogen was applied to the field in the water?

First, figure out how much nitrogen is in one acre-foot. Remember that the conversion factor from ppm to pounds per acre-ft is 2.7.

\[ 30 \text{ ppm} \times 2.7 = 81 \text{ pounds of nitrate per acre-ft.} \]

Nitrate is only 22% nitrogen.

\[ 81 \times .22 = 18 \text{ pounds of nitrogen per acre-ft.} \]

Second, figure out how many acre-ft of water were applied to the field:

\[ 161 \text{ hours} \times 60 \text{ minutes/hour} \times 450 \text{ gallons/minute} = 4,347,000 \text{ gallons.} \]

\[ 4,347,000 \text{ gallons} / 325,851 \text{ gallons per acre-ft} = 13.3 \text{ acre-ft on 40 acres or about 4 acre-inches of water per acre.} \]

Then, calculate how much nitrogen was applied to the field.

\[ 13.3 \text{ acre-ft} \times 18 \text{ pounds of } \text{N per acre-ft} = 240 \text{ pounds / 40 acres} \]

\[ = 6 \text{ pounds nitrogen per acre.} \]

Much has yet to be learned about nitrogen content in lagoon water. Nitrates forms are present, but usually at low levels. Ammonium forms are often at rather high concentrations and soluble organic forms are present in varying amounts. Because of the volatile loss of ammonia from the standing liquid in the lagoon, it should not be stored or agitated. When applied with the irrigation water, it should be mixed or injected early in the irrigation set and followed with water to leach the manure nitrogen into the soil. The nitrogen content probably is not static and may be influenced not only by pH but also temperature, wind, and conditions during irrigation.

The dynamics of nitrogen forms in lagoon waste water storage ponds is an area of research that is beginning to get attention. There is a project currently under way in the San Joaquin Valley. Little research has been conducted up to now in California but in a study conducted by Meyer and Baier in 1971, nitrate-nitrogen levels in a lagoon ranged from 3.7 to 7.0 parts per million (ppm), or 10 - 19 pounds nitrogen per acre-ft. As more knowledge is gained in this area, look for articles providing more detailed information on the nitrogen contribution of lagoon water when used for irrigation.
Manure as a Fertilizer

By Pete Christensen, Ext. Vit. Specialist
and Bill Peacock, Tulare County Farm Advisor

Manure is an excellent fertilizer containing nitrogen, phosphorus, potassium and other nutrients. It also adds organic matter to the soil which may improve soil structure, aeration, soil moisture-holding capacity, and water infiltration.

To determine how much manure is needed, the nutrient content and the rate nitrogen is mineralized (becomes available for plant uptake) needs to be estimated. Actual nutrient content of manures varies depending on source, (the level of protein being fed is more important than even the type of animal - dairy, beef, horse, etc.) moisture content, storage, and handling methods. The following table gives general information of percent moisture, nitrogen (N), phosphorus (P), and potassium (K) content in various manures.

Nutrient Content

The table gives some reported values of nitrogen, phosphorus, and potassium in manures.

<table>
<thead>
<tr>
<th>Approximate composition</th>
<th>% Moisture</th>
<th>Nitrogen</th>
<th>Potassium</th>
<th>Phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh manure with normal quantity of bedding or litter.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dairy</td>
<td>86</td>
<td>11</td>
<td>10</td>
<td>0.55</td>
</tr>
<tr>
<td>Hog</td>
<td>87</td>
<td>11</td>
<td>9</td>
<td>0.55</td>
</tr>
<tr>
<td>Horse</td>
<td>80</td>
<td>13</td>
<td>10</td>
<td>0.65</td>
</tr>
<tr>
<td>Sheep</td>
<td>68</td>
<td>15</td>
<td>8</td>
<td>1.00</td>
</tr>
<tr>
<td>Steer, feedlot</td>
<td>75</td>
<td>12</td>
<td>11</td>
<td>0.65</td>
</tr>
<tr>
<td>Hen</td>
<td>73</td>
<td>22</td>
<td>10</td>
<td>1.10</td>
</tr>
<tr>
<td>Turkey</td>
<td>74</td>
<td>26</td>
<td>10</td>
<td>1.30</td>
</tr>
<tr>
<td>Dried commercial products:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dairy</td>
<td>16</td>
<td>18</td>
<td>31</td>
<td>0.90</td>
</tr>
<tr>
<td>Hog</td>
<td>10</td>
<td>45</td>
<td>20</td>
<td>2.25</td>
</tr>
<tr>
<td>Horse</td>
<td>8</td>
<td>14</td>
<td>10</td>
<td>0.70</td>
</tr>
<tr>
<td>Sheep</td>
<td>9</td>
<td>27</td>
<td>41</td>
<td>1.35</td>
</tr>
<tr>
<td>Steer, feedlot</td>
<td>15</td>
<td>41</td>
<td>38</td>
<td>2.05</td>
</tr>
<tr>
<td>Poultry (droppings)</td>
<td>8</td>
<td>83</td>
<td>31</td>
<td>4.15</td>
</tr>
<tr>
<td>(with litter)</td>
<td>13</td>
<td>41</td>
<td>23</td>
<td>2.05</td>
</tr>
</tbody>
</table>


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Manure as a Fertilizer
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The nutrient content of manure listed in the table should be used as a general guideline when determining rates of application, keeping in mind the wide variability that exists among samples. Also, application rates must take into account mineralization or the rate of release of N as the manure decomposes (see decay series on pages 6 and 7).

Common reasons for the variability of the nitrogen content in manure include type of animal and feed ration, amount of litter, bedding or soil included, and amount of urine concentrated with the manure.

Water content is another major reason for nutrient content variations and should always be considered when buying manure on a per-ton basis. Fresh manures generally contain 70% to 85% water. Air-dried manures will always retain some moisture -- typically around 10% to 15%. As manure dries, the nutrients not only concentrate on a weight basis, but also on a volume basis due to structural changes (settling) of the manure. Volatilization of urine nitrogen can result in considerable loss of nitrogen, up to 50% or more of the total nitrogen.

Generally, dry manure contains 2 to 3 cubic yards per ton; 2.5 cubic yards per ton is a typical figure used for dry poultry and steer manures but must be adjusted with higher moisture contents.

Handling Manure

Handling can greatly alter the value of manure, particularly its nitrogen content. Nitrogen is present in manure in a variety of forms, most of which gradually converts to ammonium and nitrate nitrogen.

The ammonium form can be lost to the air and the nitrates leached by rainfall. Ammonium losses can be minimized by not stockpiling manure while it is moist, minimizing its handling, and discing it under immediately after spreading. Such effects are demonstrated in the following chart.

<table>
<thead>
<tr>
<th>Nutrient composition</th>
<th>Nutrient composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>Potassium</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Manure source</th>
<th>History</th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Droppings</td>
<td>Prompt drying</td>
<td>4.2</td>
<td>2.5</td>
</tr>
<tr>
<td>Center of moist stockpile</td>
<td>Enzyme hydrolysis and volatilization of ammonia.</td>
<td>2.1</td>
<td>2.5</td>
</tr>
<tr>
<td>Outside of stockpile</td>
<td>Leaching by rain, enzyme hydrolysis, and volatilization of ammonia.</td>
<td>1.8</td>
<td>1.6</td>
</tr>
</tbody>
</table>

* From Rackman et al. (1965)
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Some ammonia can be lost to the air each time manure is moved or hauled. Much of the loss is from hydrolysis of the NH₂ groups (enzymatic) and then volatilization of N₂O and NH₃. This loss can be very high when spreading manure, especially during warm, dry weather. Here, at least 50% of the ammonium nitrogen can be lost within 12 hours. Studies have also shown that, by one week after spreading, almost 100% of the ammonia nitrogen can be lost. This loss can represent up to 50% of the total nitrogen available in stockpiled, manure.

Thus, the importance of discing in manure immediately after spreading is obvious.

Nutrient Availability and Manure Application

Manure is a source of many nutrients including: nitrogen, phosphorus, potassium and many others. However, nitrogen is often the main nutrient of concern for most crops.

Potassium deficiency is usually quite localized within a field and would not be corrected with common rates of manure. However, some improvement might be expected with high rates above 10 tons per acre. The high rates needed to correct a potassium (K) deficiency would supply an excess amount of nitrogen for many crops, and this should be avoided.

Rates of Manure for Nitrogen Needs

The nitrogen compounds in manure are eventually converted to the available nitrate form. Nitrate is soluble and is moved into the root zone with water. It is the same form ultimately available to plants from commercial nitrogen fertilizers.

However, the release of available nitrogen from the complex organic compounds during manure decomposition is very gradual. This slow release of nitrogen is manure's most important asset. It extends nitrogen availability and reduces leaching -- of particular importance in sandy soils.

"Decay series" of nitrogen availability

The nitrogen carry-over from previous years of manuring should always be taken into account in fertilizer programs. This can be done by using a "decay series". This is an estimate of the annual release of nitrogen from manure.

The idea is to first apply enough manure to meet the first year's need of available nitrogen. Decreasing amounts are then applied in following years because of the carry-over organic nitrogen that will be released from previous applications.

If the same rate of manure is applied each year, it is possible for a field originally low in nitrogen to accumulate unnecessarily high levels in successive years.

The calculations of this "decay series" can be complicated and change with year to year variations of soil microbial activity in the field. However, it provides a general idea how to adjust for carry-over nitrogen in manuring.

The nitrogen in poultry manure is released fastest, as most is in the urea or uric acid form, with 90% of nitrogen released in the first year.

Fresh manure which contains both the urine and solid portions and has a large amount of urea or uric acid provides a somewhat slower release rate, with approximately 75% of the total nitrogen released the first year.

An even more gradual nitrogen release can be expected from dry feedlot steer manure, with only 35% of the total nitrogen released the first year.

The following example gives the rates of three manure sources needed to maintain the equivalent rate of 50 lbs nitrogen per acre annually up to 5 years. This is adapted from a "decay series" published by Pratt et al. (1973).

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"Decay Series"

<table>
<thead>
<tr>
<th>Manure Source</th>
<th>Nitrogen Content %</th>
<th>% of Nitrogen released in 1st year</th>
<th>Tons manure/acre required to release 50 lbs of Nitrogen each year.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time, years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Chicken (dry)</td>
<td>3.0</td>
<td>90</td>
<td>1.0</td>
</tr>
<tr>
<td>Dairy (fresh)</td>
<td>0.7</td>
<td>75</td>
<td>4.8</td>
</tr>
<tr>
<td>Feedlot, steer (dry)</td>
<td>1.5</td>
<td>35</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Based on "decay series" of chicken -- .90, .10, .05; dairy -- .75, .15, .10, .05; and feedlot -- .35, .15, .10, .05.

These figures demonstrate the need to adjust rates with time among the various manure sources, especially feedlot manure with its more gradual nitrogen release.

**Other Benefits of Manure**

The use of manure helps to maintain the organic matter content of the soil which may improve soil structure and water infiltration. However, manure is quickly decomposed under warm, moist soil conditions. With the manure rates used for most crops, organic matter content in soil is only temporarily increased.

**Possible Disadvantages**

Weeds... Weed seeds are common in some manures. They may enter the animal with its feed and then pass through the digestive tract, still viable, or they may have simply blown into the feed yard.

Poultry droppings typically have fewer weed seeds surviving the digestive processes. However, other animal manures may contain numerous viable weed seeds if the original feeds were contaminated. Compositing and stockpiling manures can reduce the number of viable weed seeds.

Salts... Manures commonly contain 4 to 5% soluble salts (dry weight basis) and may run as high as 10%. To illustrate, an application of 5 tons of manure containing 5% salt would add 500 lbs of salt.

Normally, irrigation and rain water will sufficiently leach well-drained soils to prevent damaging salt accumulations. However, one should be cautious with poorly drained soils, soils with existing salinity problems, or unusually high application rates, especially when concentrated near young plants.

Induced zinc deficiency... Zinc deficiency can be induced or increased with repeated high rates of manure, especially on sandy soils.
Possible Disadvantages
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Moderate or infrequent applications do not normally present a zinc problem. However, growers should be aware of the potential problem, especially with soils and varieties or crops of known susceptibility to zinc deficiency.

Summary

The principal value of manure is its extended availability of nitrogen — of particular value in the more readily leached sandy soils. Manure is also helpful in improving soil fertility in cut areas from land leveling.

Nutrient content and rate of availability varies widely, depending mostly on manure source, handling methods, and water content. Fresh manure which includes both liquid and solid fractions with the least handling and then disced in immediately after spreading will retain the most nitrogen. A laboratory analysis of the manure for nitrogen content is useful. Be sure to take an accurate sample of the manure (requires a composite of many samples throughout the pile or lagoon).

Generally, poultry manure is highest in nitrogen content, followed by hog, steer, sheep, dairy, and horse manure. Feedlot, steer manure requires fairly high rates to meet first-year nitrogen requirements because of its lower nitrogen percent and gradual nitrogen release characteristics.

However, this feature provides for more continued nitrogen availability in succeeding years, allowing for progressively lower annual application rates to meet plant requirements.

Faster nitrogen-release sources, such as poultry manure, require more constant and lower annual rates to maintain nitrogen availability.

The possible advantages of organic matter content and disadvantages of weed seed and salt content should be considered in using manure.

References


Bell, D. Chicken Manure as a Fertilizer. Univ. of CA Cooperative Extension, Riverside County bulletin (1971).


Meyer, R.D. Personal communication.


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The Effects of Nitrogen on Crop Quality
Michelle Le Strange, Tulare County Farm Advisor

Every grower is aware of the contribution that nitrogen fertilizer has on crop yield, but the effects on crop quality are not as easily understood. Much of what is produced in California is evaluated on high standards of quality or high nutrient value. Quality is critical in the grading of fresh fruits, vegetables, and nuts whereas protein content is critical in the grading of feed stocks.

The relationship between nitrogen, yield, and quality is not the same for all crops. For small grains, leafy vegetables, and other non-legume forage species, crop quality will continue to increase while yield will start to decline with higher levels of nitrogen.

For other crops the opposite is true: yield will continue to increase but quality will decline with additional nitrogen. Grapes, cotton, certain stone fruits, sugar beets, potatoes and tomatoes are just a few examples. Growers of nitrogen sensitive crops manage accordingly by accounting for residual soil nitrogen and that contained in the irrigation water in their overall fertility programs.

Overfertilization with nitrogen also contributes to increased disease and insect problems. Delays in maturity are also common for crops in which the fruit (fruits, nuts, grains, vegetables) is harvested. Nearly every crop grown in California can site specific cases.

For more complete information about specific crops and their relationship with nitrogen fertilization contact the farm advisor that works with your commodity.

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