Lagoon Water, Manures, and Biosolids Applied to Alfalfa

Roland D. Meyer
Cooperative Extension Specialist Emeritus, Department of Land, Air, and Water Resources, University of California, Davis
Blake L. Sanden
Farm Advisor, University of California Cooperative Extension, Bakersfield, CA
Khaled M. Bali
Farm Advisor, University of California Cooperative Extension, Holtville, CA

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Corresponding Author:
Roland D. Meyer
(rdmeyer@ucdavis.edu)

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Alfalfa is the major forage used for feed in the dairy and other animal industries in California and the United States. It is grown on approximately 10 percent of the irrigated acreage in California and is a major forage crop in many other states. The large numbers of animals as well as a sizeable human population generate substantial amounts of waste materials that need to be utilized or disposed of in an environmentally safe manner. Application to alfalfa is one option for recycling animal wastes and municipal wastes (biosolids).

Advantages and Limitations to Utilization of Manures by Forages

Animal wastes are a valuable resource in the production of a number of crops. Many crops, including alfalfa, require large quantities of nitrogen (N), phosphorus (P), potassium (K), and other nutrients that can be supplied by lagoon water (the wastewater containing liquid and solid manure from a dairy facility) and solid manures. Since alfalfa is a legume and is able to symbiotically fix all or any part of its N requirements, no yield decrease is observed when the N supply from these waste products declines. Alfalfa is particularly well suited to receiving organic waste materials because it can use large amounts of N, and its deep-roots allow utilization of nitrate–nitrogen that has leached to the lower depths of the soil profile. Besides providing nutrients, application of manures and biosolids can increase the organic-matter content of soils, aid in the reclamation of salt-affected soils through increasing water infiltration, and assist in developing soil structure.

Alfalfa is particularly well suited to receiving organic waste materials because it can use large amounts of N, and its deep-roots allow utilization of nitrate.

Although there are clear benefits to recycling animal and municipal wastes with forages, there are limitations in application rate, timing, and distribution that should be considered. Unfortunately, manures may contain weed seeds, and high levels of salts, such as sodium and chloride. In some cases, manures may promote root and crown disease problems, similar to those which occur with excess irrigation water. Sewage sludge or biosolids may contain elevated concentrations of elements such as molybdenum and heavy metals that could contribute to animal health problems.

Nutrient uptake limits should also be considered. The primary nutrient of concern for water quality regulators in California for manure applications to crops is N, because of the potential for nitrate contamination of groundwater. Thus, the upper limits of manure or biosolids application to alfalfa from an environmental point of view are likely to be determined by levels of N uptake by the plant. Nitrogen in the form of nitrate is very mobile and moves with the soil water from manures or biosolids, and with excessively high rates, can be leached beyond the root zone of crops to contaminate groundwater. Thus, for alfalfa, N applications should not exceed the crop uptake levels for N.

Secondarily, P can be of concern in some regions where surface runoff containing high soil sediment loads may occur. Phosphorus can accumulate in soils after years of manure or biosolids applications—but this is not a significant problem where off-site runoff does not occur.

High rates of K applications from manures or biosolids are primarily a concern from an animal feeding perspective. High K concentration in forages produces an ion imbalance with calcium and magnesim which must be corrected in the ration. This can lead to milk fever and other physiological problems. Pregnant dry animals in a herd just prior to calving, or just after calving (often called “close-up” cows), are the most sensitive animals. This sensitive group represents less than 15 percent of the herd at any time, but high K levels in heavily manured forages create a challenge for ration balancing for all animals.

The N contained in lagoon water, manures, and other wastes provides significant economic benefits when applied to corn, cereals, and other non-legume crops, since manures can replace expensive N fertilizers. However, alfalfa growth and yield can be enhanced by the P and perhaps K from wastes, and alfalfa serves as a desirable crop to receive these waste materials due to its high growth rate and large nutrient uptake potential.

Lagoon Water Applications

Many dairies in California have liquid flush systems that move manure from concrete lanes and alleys to lagoons or storage ponds (Fig. 20.1). Some solids are removed from the liquid by mechanical separating devices, settling ponds, or basins. The solids may be hauled and spread on fields surrounding the dairy or adjacent farms, dried and used for bedding or composted, or moved off the dairy to export some of the excess plant nutrients to meet comprehensive nutrient management plans (CNMP’s) required by federal and state agencies. Depending on the waste handling system used on the individual dairy, the solids percentage in the lagoon water may vary considerably. In one study, total solids concentrations in lagoon water samples collected from dairies in California ranged from 0.5 to 2.5 percent. Recent sampling indicates that manure waters may be up to 5 percent or more solids.

Lagoon water is stored on the dairy (Fig. 20.1) with piping systems conveying it to mixing chambers or "boxes" where it is mixed with incoming irrigation water and delivered to the fields. In a few cases, the lagoon water may be pumped out, but it must also be delivered to a mixing chamber to ensure adequate mixing with the irrigation water prior to being applied to the field. Even with adequate mixing, once the velocity of the water is reduced as it spreads out in the irrigation check or furrows, the solid particles begin to settle. A higher percentage of the solids are deposited within a few hundred feet of the head of the irrigation checks and a slightly higher rate at the end of the check if considerable tailwater accumulates.

Estimating Applied Nutrients

To estimate the amount of applied nutrients, the piping systems must be equipped with (1) a flow measuring device, and (2) sampling ports to determine nutrient concentrations delivered to each irrigation check while irrigating. The final application amounts can be calculated after laboratory analyses have been received for each irrigation event.

During the summer of 1996, 19 ponds were sampled and found to have total N concentrations in the lagoon water ranging from 115 to 848 ppm (mg kg^{-1}) with ammonium–nitrogen concentrations being 35 to 77 percent of the total N. A more recent sampling study found even higher (2,400 ppm or mg kg^{-1}) concentrations of total N. In the lagoon water applied in one of the case study dairies, the P ($P \times 2.29 = P_2O_5$) content ranged from trace to approximately 35 percent of the total N, and K ($K \times 1.21 = K_2O$) ranged from 50 to 150 percent of the total N. Recent investigations suggest that K concentrations may be twice the N concentrations.

Developing Upper Limits of Applications

Nitrogen and K are the major considerations for lagoon water applications to alfalfa. Since a major fraction of the N, and even more of the K, will be contained in the lagoon water rather than the solids, it may be necessary to use the K concentration in lagoon water to set the upper limit or rate of application to alfalfa. At a minimum, plant K levels should be monitored on alfalfa that receives manures and rations adjusted accordingly. Producing alfalfa that contains higher than 3 percent K may be undesirable when balancing rations, especially for pregnant and newly calved cows.

Applying no more than 50–60 pounds total N and 40–60 pounds K_2O per ton (20–25 kg total N and 17–25 kg K_2O per Mg) of expected alfalfa yield per acre during the growth of each cutting will reduce the likelihood of excessively high K concentrations in the forage, and match crop N uptake. At these rates, excessive N is unlikely to volatilize as ammonia to desiccate leaves or accumulate as nitrate and be leached to groundwater, salts in solution are less likely to damage the alfalfa stand, and the biological oxygen demand (BOD) from suspended organics in the lagoon water will remain sufficiently low so that little or no plant damage will occur.

FIGURE 20.1

Lagoon for liquid dairy waste storage.

Because there is a wide range of low to high magnesium in the soils of California, applying high rates of K can reduce the magnesium concentration in the alfalfa, particularly when there is low magnesium in the soil. This is a major concern for animal feed rations. On the other hand, there are sandy soils where magnesium as well as K levels may be low enough to limit production of high-yielding, high-quality alfalfa. Magnesium applications may be necessary to increase the forage concentrations up to the desired range (>0.25%). Magnesium potassium sulfate, having 18 percent magnesium (and 22% K_2O), is perhaps the most readily available magnesium fertilizer. Epsom salts may also be used. Some dolomite lime sources with relatively high concentrations of magnesium are also available for soils with a low pH (<6.3). Higher application rates of K may be beneficial in areas having high sodium in the soil in order to reduce sodium concentrations in alfalfa. Soil, plant tissue, and forage sampling and analyses discussed in Chapter 6 ("Alfalfa Fertilization Strategies") should be used to monitor soil fertility and forage quality.

FIGURE 20.2

Spreading manure or biosolids at 10 tons per acre.

Solid Manure Applications

Plant-available P, K, and other nutrients in the soil are known to increase following the application of manure. Alfalfa yields are often higher following manure applications, compared to equal rates of mineral fertilizer P and K. It is not well understood why this occurs, whether the manure is supplying other nutrients or if it has an effect on the physical properties of soil, such as water infiltration, soil aggregation which improves aeration and drainage, or if manure affects some other aspects of plant growth. Considerable research has shown that applying manure increases soil organic matter and water infiltration, as well as greatly reduces total infiltration times in the latter part of the alfalfa growing season. When incorporation into the soil is not possible, applications of manures should be made in the fall when the alfalfa becomes dormant, to allow winter rains to move the solids off of the plant crowns.

Research has indicated that alfalfa is capable of taking up significant amounts of nitrate–nitrogen from deeper depths in the soil profile before it is leached to the groundwater following the application of solid manures. Significant reductions in nitrate concentrations were observed in the 0–6 foot (0–180 cm) depth and the 6–12 foot (180–360 cm) depth as well during 2 years of growing alfalfa.

Estimating Applied Nutrients

Whenever applying waste materials such as manures, it is important to determine the amount or weight of material applied per acre and the concentration of nutrients in the manure being applied. Collecting a representative sample from the pile prior to spreading or as it is applied followed by chemical analysis is essential to determine nutrient application rates. Since it is difficult for most spreading equipment (Fig. 20.2) to apply less than 10 tons per acre (22 Mg per ha), higher rates of solid manure should be applied and incorporated into the surface 6–8 inches (15–20 cm) of soil before alfalfa is seeded. Even if lower rates of manure (5–10 tons per acre, 11–22 Mg per ha) can be applied on the soil surface to established stands of alfalfa, this may reduce the effectiveness of herbicides used to control weeds. As with lagoon water, manures often contain weed seeds, and the N applications may encourage grass and other weed growth in alfalfa. Some dry manure may even be picked up during the swathing or windrowing operation, which may have a detrimental effect on the market value of the hay.

Application rates of manure, like those of lagoon water, should not exceed 50–60 pounds total N and 40–60 pounds K_2O per ton (20–25 kg total N, and 17–25 kg K_2O per Mg) of expected alfalfa yield per acre during the growth of each cutting. Maximum rates of solid manure nutrients incorporated into the soil prior to planting alfalfa or applied during the dormant period should not exceed 200–300 pounds N per acre, 200–300 pounds P_2O_5 per acre, and 300–400 pounds K_2O per acre (224–336 kg N per ha, 224–336 kg P_2O_5 per ha, and 336–448 kg K_2O per ha). The lower rate is suggested for sandy or coarse-textured soils, and the higher rate for clay or heavier-textured soils. Approximately 20–35 percent of the N will become available the first year, 5–10 percent the second year, and 2–3 percent for each year thereafter. As indicated earlier, Chapter 6 ("Alfalfa Fertilization Strategies") should be used as a guide to monitor soil fertility and forage quality.

Sewage Sludge or Biosolids Applications

Biosolids or sewage sludge represents another waste product with considerable variation in nutrient concentrations and potential detrimental elements. Nitrogen, P, K, and other nutrient concentrations in biosolids may be nearly in the same range as animal manures but generally have considerably higher concentrations of some micronutrients and other elements, such as zinc, copper, chromium, cadmium, lead, molybdenum, and others. In some areas, like the San Joaquin Valley and Imperial Valley, as well as large areas in several of the western states where molybdenum concentrations in alfalfa and other forages are naturally very high, even to the point of causing animal health problems, additions of this element, if they result in increased concentrations in the forages, exacerbate an already serious problem. Little research has been conducted to indicate just how serious a potential problem this increase in molybdenum and decrease in copper concentration may be following the application of biosolids.

Preliminary sampling of alfalfa grown on soils that have received multiple applications of biosolids has indicated smaller than expected increases in molybdenum and lower than expected copper concentrations. Sampling of corn and Sudangrass indicated similar trends, with slightly lower than expected forage copper levels. In all cases, copper–molybdenum ratios were near 1:1, rather than the desired 2:1 ratio.

Biosolids generally have considerably higher concentrations of some micronutrients and other elements, such as zinc, copper, chromium, cadmium, lead, molybdenum, and others.

The large amounts of organic matter from biosolids applications increase water infiltration and the rate of reclamation of saline soils, and may in fact aid in the leaching of native mobile ions like molybdenum and boron that can cause plant or animal toxicities.

As is the case with manure, biosolids should be sampled before application to determine the nutrient and metal concentration. This information, along with the amount or weight of material applied per acre, can be used to determine the nutrient and metal application rates. Since it is difficult for most spreading equipment to apply low rates (<10 tons per acre or 22 Mg ha^{-1}) of biosolids, applications are normally made during land preparation for alfalfa seeding and incorporated into the surface 6–8 inches (15–20 cm) of soil. If lower rates of biosolids (5–10 tons per acre or 11–22 Mg ha^{-1}) are applied after establishment, they should be applied in the fall, when the alfalfa becomes dormant, to allow winter rains to move the solids off of the plant crowns.

The benefits of utilizing biosolids in soil reclamation where sodium levels are very high also need to be more clearly documented.

Food processors have taken a firm stand in that they will not accept produce for human consumption grown on soils that have received any biosolids, but many dairies across the United States have no problem feeding forage from biosolids-applied fields to their milking or dry stock. This is usually a market-oriented, risk-based decision and not necessarily based on scientific investigations.

As with manures, biosolids have most of the N in the organic form that is not released in a consistent pattern. Based on a number of field observations, N release rates the first year after application are generally in the 30–35 percent range, rather than the often-suggested 20 percent range. Nitrogen release rates during the second year are generally in the 5–10 percent range; release rates in the third and subsequent years are in the 0–5 percent range. Application rates of biosolids should be based on the N, K, or perhaps even the molybdenum (Mo) and copper concentrations in forages. Follow the guidelines for N and K application rates suggested for solid manure prior to each cutting, or the maximum rates suggested for single applications prior to planting or during dormant periods. Maximum annual rates of molybdenum application should not exceed 0.5–1.0 pound Mo per acre (0.56–1.12 kg ha^{-1}). Forage and plant tissue sampling to monitor nutrient composition represent the best approach to guide biosolids applications (see Chapter 6, "Alfalfa Fertilization Strategies").

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