OREGON STATE UNIVERSITY EXTENSION SERVICE

Manure Application Rates for Forage Production in Western Oregon

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Photo: Calvin Christensen

Summary

This publication provides:

1. Planning values for crop nutrient removal by forage crops grown on dairies in western Oregon. Crop nutrient removal values listed in this publication are typical values. Actual nutrient removal is based on site and management factors. Monitoring of actual forage yields and actual nutrient removal in harvested forage amounts is strongly recommended.
2. Examples of how increased management intensity can increase the nutrient uptake capacity of perennial grass fields.
3. Guidance on liquid manure application rates to supply target amounts of nitrogen (N) for forage crops, based on manure N analysis.
4. Recommendations for potassium (K) monitoring in soil and forage to provide suitable forages for dry cows.
5. Recommended Extension publications on related manure management topics.

Contents

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Nitrogen management

This publication assumes a mass balance approach to N; the goal is to balance N inputs from manure with crop N removal via forage harvest:

N inputs (manure) = N outputs (N removed from the field in harvested forage).

This simple N balance is most appropriate for fields where manure has been applied routinely for 3–5 or more years. This balance, sometimes called an agronomic rate approach, is an oversimplification of the real processes that govern N dynamics in the field. Yet it is the most common approach used in N-based management plans (Natural Resources Conservation Service, 2020; Oregon Department of Agriculture, 2016). A more detailed look at N dynamics is provided in EM 8954, *Estimating Plant-available N from Manure*, and EM 9281, *Baseline Soil Nitrogen Mineralization: Measurement and Interpretation*.

When N inputs exceed outputs, you can achieve N balance by reducing manure application rate or by improving management to increase crop yields and N removal.

This publication does not address nutrient balance in pastures that are primarily harvested by grazing animals. Consult EM 9224, *Nutrient Management for Pastures: Western Oregon and Washington* (catalog.extension.oregonstate.edu/em9224) and PNW 549, *Keeping Track of Manure Nutrients in Dairy Pastures* (https://catalog.extension.oregonstate.edu/pnw549) for pasture-specific guidance.

Forage crops in western Oregon

This section provides information to guide your choice of “crop” (a row in Tables 1 or 2) for a nutrient management plan. Each crop has inherent characteristics, such as longevity and season(s) of growth. For some crops (e.g., perennial grass), expected crop nutrient removal by harvest differs with management inputs and with harvest practices.

Red clover. Red clover is short-lived perennial that is usually harvested several times a year and made into silage or planted as part of mix for silage. Often, we expect this will be planted in the fall and be highly productive for several years before the stand thins over time.

Alfalfa hay. Alfalfa is a perennial is harvested multiple times throughout the growing season. The example in Tables 1 and 2 is alfalfa hay with three harvests per year.


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Perennial grass. Three examples of perennial grass management are presented below: low-, medium- and high-intensity systems. Actual yields and nutrient use will vary. Monitoring tonnage, forage dry matter and crude protein will help you define where your fields are along this continuum.

- Low input, low intensity. Example: Native pasture that is not routinely fertilized and is harvested for hay once a year in mid-June, producing 3 tons of dry matter per acre with 10% crude protein in dry matter. Estimated crop N removal is 32 lb N per ton DM or 96 lb N per acre for the year.
- Medium management intensity. Increased management and nutrient inputs can transform a low-intensity pasture to one with increased forage production and nutrient removal. Example: Field is fertilized in March, cut for silage in mid-April (2 tons of dry matter) and cut again at the end of June for hay (2 tons of dry matter). Estimated biomass production is 4 ton of dry matter at 15% crude protein. Estimated crop N removal is 48 lb per ton of dry matter, totaling 192 lb N/acre for the year.
- High management intensity. Further intensification of production factors can increase crop yield and nutrient removal. Example: Improved grass species, active monitoring and management of nutrient inputs, timely and efficient irrigation, and a harvesting schedule that includes four or five cuttings per year. Estimated biomass production is 1.5 tons of dry matter per cutting at 18% crude protein. Estimated crop N removal is 58 lb N per ton DM. With four harvests per year, estimated crop N removal is 348 lb N/acre for the year.

Annual ryegrass. Annual ryegrass is usually seeded in the fall as a winter cover crop. It is harvested the following spring, using a one- or two-cut system. The first harvest usually takes place in March or April. If the first harvest occurs in March, then another harvest may be feasible in May. If the field cannot be harvested until April, then only one harvest is usually feasible. The two-cut system works best when grass is seeded early in fall and is well-established prior to winter.

Corn silage. Tables 1 and 2 list the planning value for nutrient removal by silage corn presented in EM 8978, *Silage Corn (Western Oregon) Nutrient Management Guide*.

Small grains. Fall seeded cereals are seeded in fall and harvested the following spring at boot or soft dough growth stage. When harvested at boot stage, cereals can regrow and produce a smaller second cutting. A two-cut system works best when cereals are seeded early in fall, and growing conditions in spring are favorable for rapid vegetative growth.

Crop nutrient removal

Tables 1 and 2 estimate aboveground N, P and K removed per ton of harvested forage for crops grown on dairies in western Oregon. Nutrient values in Table 1 are presented on a 100% DM basis. Table 2 expresses nutrient values on a "wet" or "as-harvested" basis. For example, when forage DM is 25 percent, one ton of forage dry matter equals 4 tons of "as-harvested" forage.

Data presented in Tables 1 and 2 demonstrate that N and K removal by harvest is of the same magnitude for many forages, while P removal is much lower. Crop removal values in Tables 1 and 2 represent usual management scenarios for western Oregon. Crop nutrient removal is maximized by good management practices, including:

- Choosing improved forage species and varieties.
- Liming to maintain adequate soil pH.
- Irrigating to maintain growth in summer.
- Controlling weeds.
- Cutting forages to maintain vegetative growth throughout the growing season.

Crop yield potential is also governed by soil characteristics (e.g., pH, fertility and drainage). Relative values for crop yield potential for different soil mapping units can be obtained from the NRCS. Crops grown without irrigation on soils with low water-holding capacities, or crops grown on poorly drained soils without artificial drainage may not achieve the Table 1 and 2 values for crop nutrient uptake.

Keep in mind that crop nutrient removal values in Table 1 and 2 are provided as an initial planning tool. On established dairies, field-by-field monitoring of forage yield and protein content is the best way to obtain accurate values for crop N removal.

Nutrient analysis of manure

Nutrient analysis of manure is critical to determining an appropriate application rate. Nutrient management plans for dairies often specify manure testing frequency and which nutrient analyses are required. At a minimum, we recommend testing for total nitrogen (N), ammonium nitrogen (NH_4-N), phosphorus (P), potassium (K) and dry matter (DM). Laboratories often perform these as a standard analysis package. Consult PNW 673, *Sampling Dairy Manure and Compost for Nutrient Analysis* for details on manure sampling and analysis protocols. Many dairies have more than one form of manure that is applied to fields. Adding bedding or water to raw manure dilutes the manure and decreases manure nutrient concentration. We recommend separate analyses for each manure type (e.g., lagoon water or manure from a reception pit).

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Lagoon water and slurry manure application rates

Table 3 shows how much liquid or slurry manure is required to meet a given target for N application rate. For simplicity, the liquid or slurry application rates in Table 3 assume that all the N in lagoon water or slurry is readily available for plant uptake. See EM 8954, *Estimating Plant-Available Nitrogen from Manure*, for more accurate plant-available N estimates for different management scenarios. Table 3 shows that it is difficult to apply low N rates (less than 50 lb N/acre) of liquid or slurry manure, because those application volumes would be small. The lower application limit for most travelling guns is approximately 0.25–0.30 inches. Slurry manure can be applied at rates ranging from 7,000 to 30,000 gallons per acre. See EM 8768, *Calculating Manure Nutrient Application Rates* for additional calibration instructions for manure application equipment.

Monitoring P and K balance via soil testing

When N inputs from manure and N outputs in harvested forages are balanced, manure almost always supplies more P and K than is removed by harvest (Table 1). Agronomic soil tests for P and K reflect the balance between manure nutrient inputs and crop removal. Consult EM 9224, *Nutrient Management for Pastures: Western Oregon and Western Washington* (catalog.extension.oregonstate.edu/em9224), and EM 8978, *Nutrient Management for Silage Corn in Western Oregon* (catalog.extension.oregonstate.edu/em8978) for more information on soil sampling, appropriate laboratory analyses and soil test interpretations. Your nutrient management plan may also prescribe soil sampling depth, soil testing frequency and required laboratory analyses. The Phosphorus Index for western Oregon (NRCS, 2013) estimates risk of off-site P loss based on a soil sample collected from 0 to 12-inch depth.

Monitoring K in soil and forage

Potassium (K) fertilization is only recommended to maximize forage growth when soil test K is less than 200 ppm. Soil test K almost always exceeds 200 ppm on dairies, so K fertilization is generally not required to maximize forage production. For soils testing less than 200 ppm K, consult EM 9224 for K fertilizer recommendations for pasture, and EM 8978 for silage corn.

Elevated concentrations of K in dry cow rations can lead to problems with milk fever at freshening. In most situations, forages for dry cows should contain less than 2% K on a DM basis. As soil test values increase above 200 ppm K, forage K concentrations increase, but forage yields do not. This is called “luxury consumption” and is characterized by plants taking up additional K beyond that needed to produce maximum forage yields.

Maintaining low K concentrations in forage is often difficult when N is supplied by manure, and the farm imports K in feeds and mineral supplements. Potassium is not lost from manure as a gas, and it is usually not lost from the soil profile by leaching. As a consequence, much of the K that is imported in feeds will accumulate in soil over time. To reduce K concentrations in forage, we recommend monitoring the quantity of K imports in feedstuffs, especially in mineral mixtures, and reducing K imports in feed when possible.

Monitoring of soil test K and forage K can also identify fields with suitable forage for dry cows. Often hayfields away from the barn that do not receive regular manure application have the lowest K concentration in forage.

Table 1. Crop yield, nutrient concentration and removal by common perennial and annual forage crops grown in western Oregon[z]

Values expressed on a dry matter (DM) basis.

Crop	Cuttings per year	Dry matter (DM)	Annual yield	Crude protein	N	P	K	N removed	P removed	K removed
		%	ton DM/ acre	% in DM	lb/ton DM	lb/ton DM	lb/ton DM	lb/acre	lb/acre	lb/acre
Red clover	1	100	4	18	58	8	50	230	32	200
Alfalfa hay	3	100	5	20	64	8	50	320	40	250
Perennial grass (low intensity)	1	100	3	10	32	6	40	96	18	120
Perennial grass (medium intensity)	2	100	4	15	48	6	50	192	24	200
Perennial grass (high intensity)	4	100	6	18	58	8	60	346	48	360
Annual ryegrass	1	100	3	12	38	6	50	115	18	150
Annual ryegrass	2	100	4.5	15	48	7	50	216	32	225
Corn silage	1	100	8	8	26	4	24	205	32	192
Small grains (boot stage)	2	100	5	12	38	5	40	192	25	200
Small grains (soft dough)	1	100	4	8	26	5	30	102	20	120

[z]Typical forage analyses in this table reflect the best professional judgment of the authors. Additional estimates of book values for forage analyses can be found in Nutrient Requirements of Dairy Cattle (National Research Council, 2001).

[y] Forage N concentration (%) based on crude protein analyses, assuming that 6.25% protein = 1% N = 20 lb N/ ton DM.

Table 2. Crop yield, nutrient concentration and removal by common perennial and annual forage crops grown in western Oregon[z].

Values expressed on an "as-harvested" moisture basis.

Crop	Cuttings per year	Dry matter (DM)	Annual yield	Crude protein	N	P	K	N removed	P removed	K removed
		% of harvest wet wt	wet ton/ acre	% of harvest wet wt	lb/wet ton	lb/wet ton	lb/wet ton	lb/acre	lb/acre	lb/acre
Red clover	1	25	16.0	4.5	14	2.0	13	230	32	200
Alfalfa hay	3	30	16.7	6.0	19	2.4	15	320	40	250
Perennial grass (low intensity)	1	30	10.0	3.0	10	1.8	12	96	18	120
Perennial grass (medium intensity)	2	30	13.3	4.5	14	1.8	15	192	24	200
Perennial grass (high intensity)	4	30	20.0	5.4	17	2.4	18	346	48	360
Annual ryegrass	1	30	10.0	3.6	12	1.8	15	115	18	150
Annual ryegrass	2	25	18.0	3.8	12	1.8	13	216	32	225
Corn silage	1	25	32.0	2.0	6	1.0	6	205	32	192
Small grains (boot stage)	2	30	16.7	3.6	12	1.5	12	192	25	200
Small grains (soft dough)	1	30	13.3	2.4	8	1.5	9	102	20	120

[z]Typical forage analyses in this table reflect the best professional judgment of the authors. Additional estimates of book values for forage analyses can be found in Nutrient Requirements of Dairy Cattle (National Research Council, 2001).

Values given in this table for annual yield per acre and for nutrient removal per acre are equivalent to the values in Table 1. Values in this table have been adjusted using an assumed crop dry matter percentage at harvest, using these equations:

- Yield (wet ton per acre) = Dry matter yield (from Table 1; ton/acre) x (100/DM% at harvest)
- Nutrient concentration in "as harvested" forage (lb/ton) = Dry matter nutrient concentration (lb/ton; Table 1) x (as-harvested DM%/100)

Table 3. Volume of liquid or slurry manure to apply, based on manure N analysis and target N application rate.

Manure	Manure N analysis		Target N application rate (lb per acre)		
	lb N per thousand gallons	parts per million (ppm)	50	100	150
			---------	acre-inches to apply	-------------------
liquid	2	240	0.9	1.8	2.8
	4	480	0.5	0.9	1.4
	6	720	0.3	0.6	0.9
	8	960	0.2	0.5	0.7
			---------	thousand gallons per acre to apply	-------------------
slurry	10	1200	5	10	15
	15	1800	3	7	10
	20	2400	3	5	8
	25	2990	2	4	6
	30	3590	2	3	5

1 acre inch = 27,000 gallons per acre.

For more information

Nutrient management guides

Nutrient Management for Pastures: Western Oregon and Western Washington. 2019. EM 9224. https://catalog.extension.oregonstate.edu/em9224

Nutrient Management for Silage Corn in Western Oregon. EM 8978. https://catalog.extension.oregonstate.edu/em8978

Manure nutrient analyses

Sampling Dairy Manure and Compost for Nutrient Analysis. 2015. PNW 673. https://catalog.extension.oregonstate.edu/pnw673

Interpreting Compost Analyses. 2018. EM 9217. https://catalog.extension.oregonstate.edu/em9217

Monitoring and recordkeeping

Calculating Dairy Manure Nutrient Application Rates. 2015. EM 8768. https://catalog.extension.oregonstate.edu/em8768

Date, Rate, & Place: The Field Book for Dairy Manure Applicators. 2017. https://catalog.extension.oregonstate.edu/pnw506

End-of-Season Corn Stalk Nitrate-Nitrogen Test for Post-Harvest Evaluation. 2019. WSU Extension Factsheet FS336E. https://pubs.extension.wsu.edu/end-of-season-corn-stalk-nitrate-nitrogen-test-for-post-harvest-evaluation

End-of-Season Corn Stalk Nitrate-Nitrogen Test for Post-Harvest Evaluation—A Case Study. 2019. WSU Extension Factsheet TB66E. https://pubs.extension.wsu.edu/end-of-season-corn-stalk-nitrate-nitrogen-test-for-post-harvest-evaluation-2

Estimating Plant-Available Nitrogen from Manure. 2020. EM 8954. https://catalog.extension.oregonstate.edu/em8954

Keeping Track of Manure Nutrients in Dairy Pastures. 2001. PNW 549. https://catalog.extension.oregonstate.edu/pnw549

Post-Harvest Soil Nitrate Testing for Manured Grass and Silage Corn (West of the Cascades). EM 8832. https://catalog.extension.oregonstate.edu/em8832

Nutrient management planning

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Oregon Department of Agriculture. 2016. Animal Waste Management Plan (AWMP) Implementation and Compliance. Section S3.A (p.17). In: State of Oregon Confined Animal Feeding Operation Permit Program CAFO NPDES General Permit #01 and Evaluation Report and Fact Sheet. https://www.oregon.gov/ODA

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