Soil Sampling of Inn at Otter Crest and City of Toledo Biosolids Land Application Sites in the Siletz Watershed

State of Oregon
Department of Environmental Quality

DEQ Biosolids Coordinators:
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Site Visit Date: 4/24/19
Report Date: 9/5/2019

Permittee	Land Application Site
Inn at Otter Crest File #41740; NPDES Permit #101269 EPA #OR0026352	Wyscaver #3
City of Toledo File #89103; NPDES Permit #101713 EPA No. OR0020869	Hughes

Introduction
On April 24, DEQ regional biosolids coordinators sampled the above biosolids application sites in the Siletz watershed in Lincoln County to: 1) Determine carryover nitrogen; and 2) Assess whether the land application of biosolids increased the soil carryover nitrogen levels at the above sites.

Soil Sampling Protocols
Attachment 1 provides the approximate locations for soil cores that comprised the representative biosolid amended soils and “control” samples at each site and photos of the sites. Soil samples were collected at the two land application sites specified above using the Oregon State University extension: Farm and Garden Soil Sample guidance (EC 628 Revised Sept 2013) provided in Attachment 2.

Samples were collected from Wyscaver #3 and Hughes on April 24, 2019. Three teams collected two random soil samples from each site. Soils were sampled at 0 to 12 inch and 12 to 24 inch depths. Six soil cores from each depth were composited to create a single representative sample. Setback areas were sampled at 0-12 inch and 12-24 inch soil depths as background and labeled as control samples.

On the afternoon of April 25, 2019, DEQ delivered the samples to the Oregon State University’s Crops and Soil Central Analytical Laboratory for analysis. Chain of custody procedures were followed and documented through a photo log (available upon request).

Overview of Laboratory Results
Attachment 3 provides the analytical data for each soil sample as reported by the OSU laboratory.

Calculation of Soil Carry-Over Nitrogen
Using the data provided by the OSU laboratory, DEQ calculated the soil carry over nitrogen concentrations from the ground surface down 24 inches for each site. The results are listed in the table below.

Note: The NH_4-N results from the OSU laboratory were not utilized in calculating the residual nitrogen in the fields because the soil samples were oven-dried creating an artificially high NH_4-N results. The nitrogen associated with NH_4-N is accounted for in the NO_3-N results as NH4-N readily converts to NO_3-N in aerobic soils.

Field / Soil Depth	NO_3-N (ppm)	NO_3-N (lbs/acre)	Total NO_3-N (lbs./acre) see Note 1
Wyscaver #3 / 0-12”	8.2	33.0	**46.3**
Wyscaver #3 / 12-24”	3.3	13.3	
Hughes / 0-12”	4.9	19.5	**31.1**
Hughes / 12-24”	2.9	11.6	

Note 1: Every 12 inches: NO_3-N ppm X 4 = N lbs/ac. Add 12 inch layers together.)

Conclusion
OSU’s Crop and Soil Science Central Analytical Laboratory analyzed samples for nitrogen and soil nutrients. DEQ calculated carryover nitrogen and determined that nitrate-nitrogen levels at Wyscaver #3 and Hughes application sites are below what a pasture grass needs for the 2019 growing season and compliant with the DEQ site authorizations in effect for these sites in 2018. For acceptable ranges of carryover nitrogen, see Attachment 4, *OSU Extension Service Nutrient Management for Pastures: Western Oregon and Western Washington* EM 9224 (January 2019).

Dr. Dan Sullivan, a soil scientist at Oregon State University’s Soil and Crop Science Department also reviewed the analytical results on May 29, 2019. He indicated through email that the Hughes and Wyscaver #3 fields could improve their production with the addition of potassium and magnesium amendments (Attachment 5).

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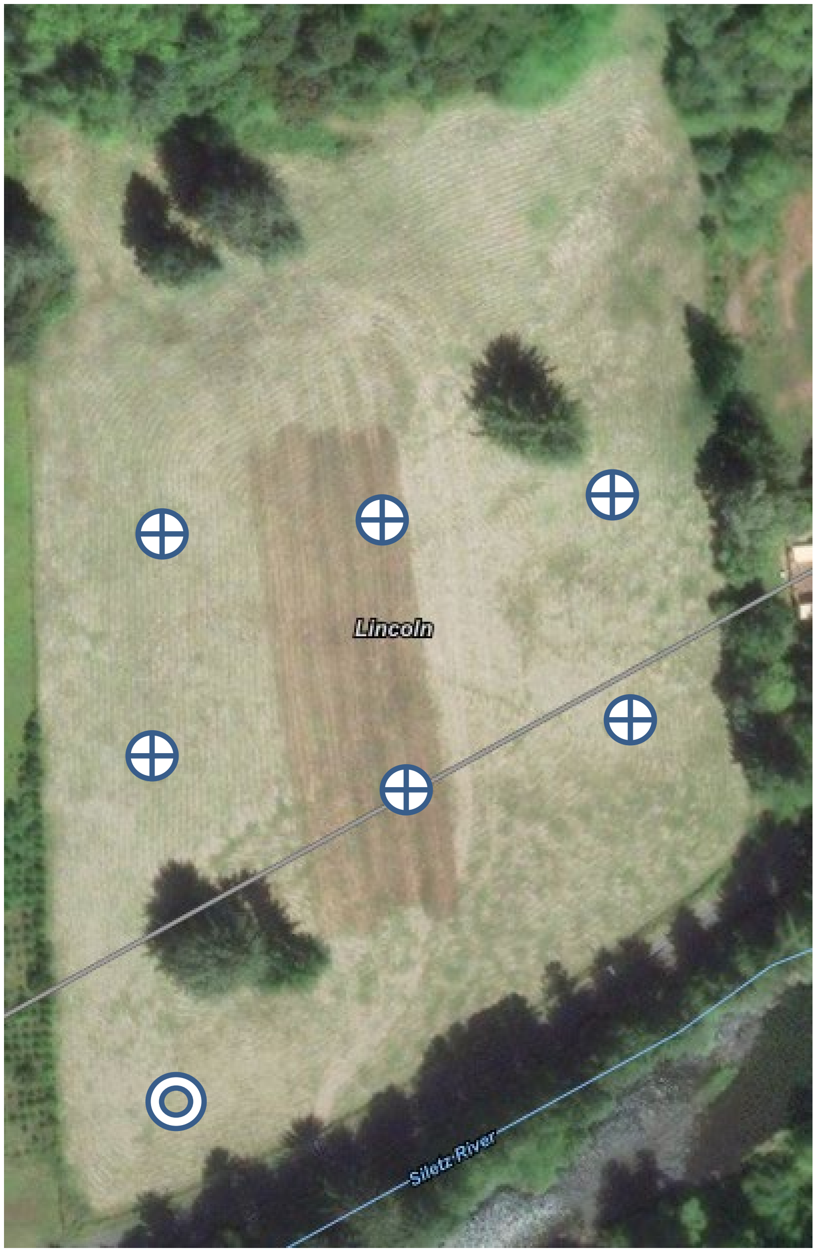
Attachment 1
Sampling Locations & Photos

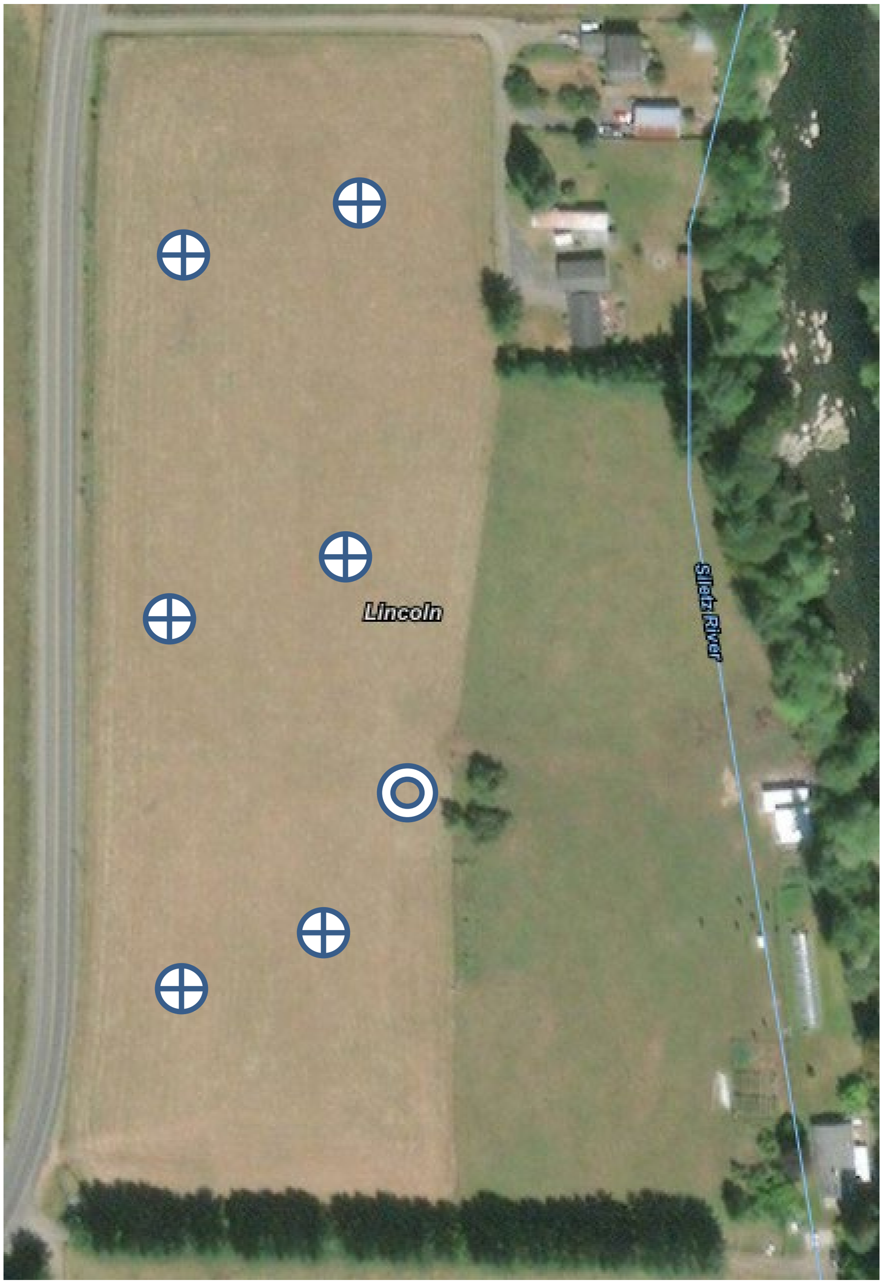
Wyscaver #3, Inn at Otter Crest



Biosolids land application soil sample locations

Control sample in setback area

Hughes, City of Toledo




Biosolids land application sample locations


Control sample in setback area

Site Photos

Photo 1: Wyscaver #3, Inn at Otter Crest

Photo 2: Hughes, City of Toledo

Attachment 2
Oregon State University extension: Farm and Garden Soil Sample guidance (EC 628 Revised Sept 2013)

A Guide to Collecting Soil Samples for Farms and Gardens

M. Fery and E. Murphy

Without a soil analysis, it's nearly impossible to determine what a soil needs in order to be productive. Laboratory soil analyses (soil tests) provide information on your soil's available nutrient-supplying capacity. This information helps you select the correct kind and amount of fertilizer and liming material, which helps you develop and maintain more productive soil and increased crop production.

Recommendations in this publication are based on the results of fertilizer experiments, soil surveys, and results obtained by farmers.

Why should I collect a soil sample?

Reasons for soil sampling include the following:

- Establish baseline soil nutrient status for new landowners
- Measure change in soil nutrient status over time
- Document soil nutrient management for certification requirements
- Determine nutrient application recommendations prior to planting
- Assess pH and the need for liming
- Avoid excessive nutrient applications or soluble salt accumulation
- Develop a plan for possible variable-rate fertilizing within a field

When should I collect my soil sample?

For perennial crops such as orchards, tree plantations, alfalfa, grass seed, and permanent pasture, the most important time to have the soil analyzed is before planting, so that necessary nutrients can be mixed into the soil. This analysis is especially important in acidic soils, which are likely to need liming. Apply lime and mix it with the soil several months before planting (for example, in the fall for spring planting), since it reacts slowly with the soil. Following establishment, then:

- For pastures and legumes, test soils every 3 years after planting.
- For Christmas trees, established fruit and nut trees, berries, and grapes, use annual foliar tissue analysis instead of soil

This publication is not intended to be a guide for obtaining soil samples for environmental testing.

Melissa Fery and Elizabeth Murphy, instructors, Extension Small Farms Program, Oregon State University

Oregon State University Extension Service

EC 628
Revised September 2013

testing. Soil samples are recommended every 3 to 5 years or when the tissue analyses indicate a need.

Do periodic soil tests also for annual crops, particularly when you first cultivate a field or change crops or rotations. For annual crops, especially vegetables, test soil in the fall or winter or just before planting. If you plant successive crops in a single season, you don't need to test before each planting. Soil samples are recommended every 2 to 3 years.

More information on soil laboratory analysis, soil test interpretation, and crop nutrient recommendations is available in other OSU Extension publications (see "Resources," page 5).

Where should I collect a soil sample?

The area in which to collect a soil sample may depend on the soil type, crops grown, management history, or all of these. The farm in Figure 1 has three separate sampling areas: A (orchard), B (pasture), and C (vegetable row crops). In this example, a separate soil sample should be collected from each of the three areas.

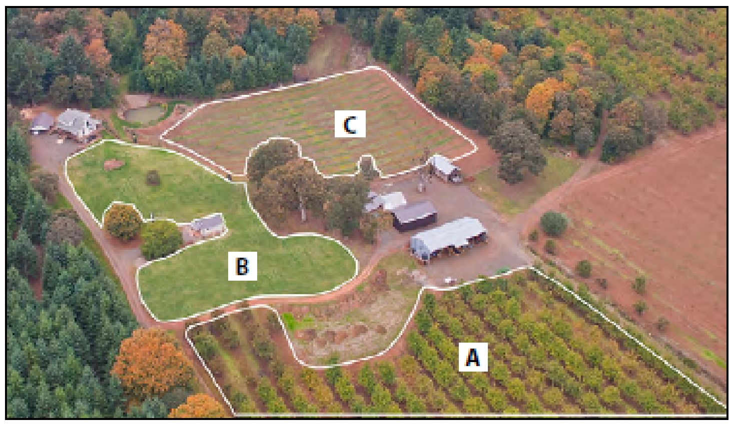


Figure 1. Collect a separate soil sample from each of the three areas (A, B, and C).

How do I collect my soil sample?

Sample where the crop will be planted

If you are using raised beds, such as for vegetable crops, take your samples in the beds, not in the areas between them.

Avoid unusual areas

Avoid sampling in small areas where you know that conditions are different from the rest of the field (for example, former manure piles, fertilizer bands, or fence lines). You often can spot these places by looking for plants growing especially well or very poorly.

Take 15 to 20 subsamples

Each sample should consist of subsamples taken from 15 to 20 locations within the sampling area (marked with x in Figure 2).

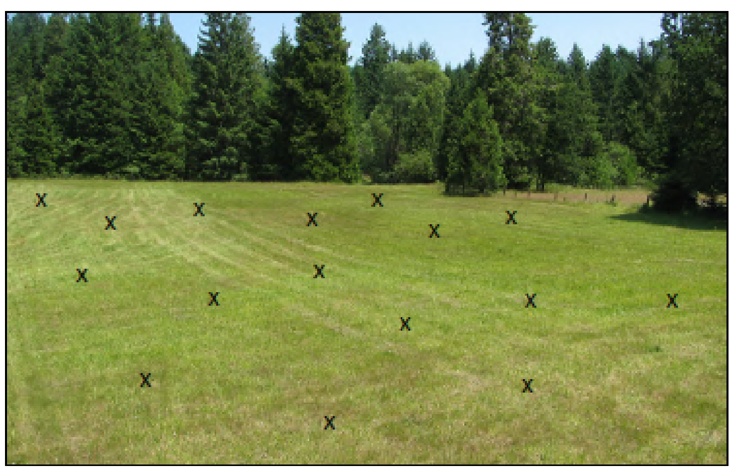


Figure 2. Take 15 to 20 subsamples within one sampling area.

Avoid contaminating the sample

- Use clean sampling tools (Figure 3), and avoid contaminating the sample during mixing or packaging. A small amount of fertilizer residue on tools or hands, for instance, can cause serious contamination of the soil sample.
- Do not include mulch or vegetation in the sample.
- Do not use galvanized metal, brass, or bronze tools to collect samples that will be tested for micronutrients (such as zinc).

Take the soil sample to the correct depth

Sample the part of the soil where the plant roots will grow. For most annual and perennial crops, sample from the surface down to about 6 to 8 inches (Figure 4) or to the depth of tillage. For pastures or soils that have limited or no tillage, refer to *Evaluating Soil Nutrients and pH by Depth* (EM 9014) for more information about collecting your soil sample.

Collect samples at the same depth. For example, if you take initial samples at a 6-inch depth, keep that same depth for all future samples, to get a more accurate comparison.

Carefully mix the soil sample

Place all of the soil subsamples from a single sampling area in a clean container and mix thoroughly (Figure 5, page 4). Do not worry about breaking the sample up into tiny particles. Labs have soil grinders to further mix the sample.

Figure 3. Soil sampling tools.

Analyzing my soil sample

- Find laboratories that perform soil analysis. To search for labs certified by the North American Proficiency Testing (NAPT) program, go to www.naptprogram.org
- Look for a lab that offers a soil test report that you understand.
- Call one or more labs to find out the cost of the soil analysis you need.
- After choosing a lab, request any necessary paperwork (such as an information sheet), find out how you should prepare and submit the sample, and get the address where you should send the sample.
- Prepare and submit the sample according to the lab's instructions. Plastic zipper bags work best; do not use a paper bag unless the lab provides one lined with plastic. Most laboratories ask you to label the sample bag with identifying information and to fill out and include an information sheet with the sample. Don't forget to include payment in a separate, sealed plastic bag.

Figure 4. Measuring sampling depth.

- If you are requesting a nitrate nitrogen (NO_3-N) test, keep the sample cool and send it immediately to the lab. Otherwise, you may choose to dry the sample or send it at your convenience.
- Request that the lab provide both a printed report and an electronic spreadsheet format for more flexible recordkeeping.
- Number each sample, record sample depth, and keep a record of the fields and areas you sampled. Take a photo of the labeled sample bags before mailing them, for future reference (Figure 6).

Figure 5. Use a clean hand tool to mix the subsamples.

What analysis should I request?

- The standard soil analysis from most laboratories measures organic matter, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), and soil pH (acidity).
- For acidic soils, the SMP buffer test is the best way to determine how much lime is needed.
- Certain crops might have higher requirements for specific nutrients. Consult OSU Extension publications (see "Resources," page 5) to determine whether you should test for nutrients such as sulfur (S), boron (B), or zinc (Zn).
- Nitrate nitrogen (NO_3-N) is also commonly reported in standard soil tests. Nitrate nitrogen is not useful to determine soil fertilizer applications in western Oregon, as nitrate is readily leached from the soil profile. To determine a nitrogen application rate for your crop, consult the specific fertilizer guide (see "Interpreting your soil analysis," page 5). Post-harvest testing for soil nitrate is used in some cropping systems to determine if excessive nitrogen was applied. In arid regions, such as eastern Oregon, soil nitrate nitrogen tests are used in conjunction with nutrient management guides to determine nitrogen applications.

Figure 6. Take a photo of your sample bags before you mail them, for future reference. Do not use a paper bag unless the lab provides one lined with plastic.

Sampling over time

Once you have researched and selected a laboratory, plan to use the same lab for future tests to keep sample analysis consistent and detect changes in soil nutrients. Also, plan to take your soil sample at the same time of year, same depth, and same approximate field location.

Interpreting your soil analysis

Once you have received the analysis results for your soil, use the following tools to make decisions:

- *Soil Test Interpretation Guide* (EC 1478), 2011 version
- OSU Extension Fertilizer and/or Nutrient Management guides. To search for your crop-specific guide, go to the OSU Extension Catalog at http://extension.oregonstate.edu/catalog/ and search by keywords (nutrient management guide, fertilizer guide, and crop).

You can also consult your local OSU Extension Service agent.

Resources

OSU Extension Catalog publications

Visit the OSU Extension Catalog at http://extension.oregonstate.edu/catalog/ to find these publications.

Applying Lime to Raise Soil pH for Crop Production (Western Oregon) (EM 9057)

Christmas Tree Nutrient Management Guide (EM 8856)

Eastern Oregon Liming Guide (EM 9060)

Evaluating Soil Nutrients and pH by Depth (EM 9014)

Fertilizing with Manure (PNW 533).

Fertilizing Your Garden: Vegetables, Fruits, and Ornamentals (EC 1503)

Monitoring Soil Nutrients Using a Management Unit Approach (PNW 570)

Pastures: Western Oregon and Western Washington Fertilizer Guide (FG 63)

Soil Fertility in Organic Systems: A Guide for Gardeners and Small Acreage Farmers (PNW 646).

Soil Test Interpretation Guide (EC 1478), 2011 version

WSU Extension publication

Soil Management for Small Farms (EB 1895). Washington State University Extension.

All photos by Lynn Ketchum, © Oregon State University

This publication was reviewed by Dan Sullivan, Sam Angima, and John Hart (emeritus); all of the Department of Crop and Soil Science, Oregon State University.

Revised July 2002. Revised September 2013.

Attachment 3
Oregon State University's Crops and Soil Central Analytical Laboratory Results

Oregon State University
Central Analytical Laboratory

Crop and Soil Science Department 3079 Ag-Life Sciences Bldg Corvallis, OR 97331 541-737-2187

Producer's Soil Nutrient Analysis Report

Name:	Paul Kennedy
Organization:	DEQ
Contact for results:	kennedy.paul@deq.state.or.us
Date submitted:	4/25/2019
Date delivered:	5/16/2019
Group number:	219274

Sample ID		%	%			ratio	ppm		pH		dS/m
Cust ID	Lab ID	rocks	C	N	OM	C:N	NH4-N	NO_3-N	pH	BpH	EC
Wyscaver 0-12	1	0.5	6.14	0.53	12.29	11.6	16.9	8.2	6.09	5.44	0.105
Wyscaver 12-24	2	0.2	3.82	0.32	7.65	12.0	7.2	3.3	6.06	5.93	0.035
Hughes 0 - 12	3	1.2	7.41	0.63	14.81	11.7	16.4	4.9	5.75	5.19	0.049
Hughes 12-24	4	1.8	4.71	0.41	9.42	11.5	12.3	2.9	5.80	6.00	0.026
Airport Control 0 - 12	5	15.6	3.41	0.19	6.82	17.9	8.0	15.1	5.33	4.98	0.051
Airport Control 12-24	6	6.8	3.64	0.19	7.28	19.7	7.8	1.6	5.11	5.02	0.046
Wyscaver Control 0 -12	7	0.6	7.72	0.58	15.43	13.4	25.7	5.8	5.95	5.27	0.029
Wyscaver Control 12-24	8	0.0	3.33	0.28	6.66	12.1	9.0	2.4	6.26	6.03	0.294
Airport 0 - 12 Biosolids	9	0.6	8.18	0.52		15.7	7.4	33.3	7.59	7.21	0.341
Airport 12-24 Biosolids	10	0.2	5.87	0.32		18.3	4.8	20.3	7.32	7.20	0.119

Sample ID		ppm = mg nutrient/kg soil								meq/100g		
Cust ID	Lab ID	P	K	Mn	Cu	Zn	Fe	SO4-S	B	Ca	Mg	CEC
Wyscaver 0-12	1	10.8	133	17.3	1.0	1.8	87	7.8	0.6	7.6	3.0	10.9
Wyscaver 12-24	2	4.0	76	6.3	0.7	0.1	74	14.6	0.3	5.5	2.1	7.9
Hughes 0 - 12	3	21.2	21	9.5	1.4	1.6	119	14.5	0.4	4.0	0.4	4.5
Hughes 12-24	4	4.1	9	5.4	0.3	0.0	60	55.6	0.2	1.8	0.0	1.9
Airport Control 0 - 12	5	3.4	84	1.7	0.6	1.2	130	10.8	0.5	3.3	2.7	6.2
Airport Control 12-24	6	2.3	52	0.9	0.4	0.3	184	12.2	0.4	0.8	1.1	2.0
Wyscaver Control 0 -12	7	13.1	219	14.9	8.8	7.7	152	11.2	0.6	12.4	2.0	14.9
Wyscaver Control 12-24	8	3.5	69	9.5	1.4	0.3	136	16.3	0.3	10.3	2.0	12.5
Airport 0 - 12 Biosolids	9	88.5	198	6.9	5.4	14.9	125	15.7	0.8	78.2	1.6	80.2
Airport 12-24 Biosolids	10	39.1	147	5.2	2.3	5.1	92	49.5	0.5	41.0	1.0	42.4

Rocks	% by mass of mineral matter that would not pass a 2mm sieve
Moisture	Gravimetric moisture of the sample at the time of submission
C, N	Dry combustion with direct measure of total nitrogen, carbon and sulfur by Elementar Macro Cube
OM	Total organic matter, calculated by multiplying total C by 2 for samples with pH <7
NO_3-N	Extracted with 2M KCl. Sulfanilamide and NEDD colorimetric reaction measured on spectrophotometer
NH4-N	Extracted with 2M KCl. Salicylate colorimetric reaction measured on Lachat FIA
pH + EC	Soil shaken in 1:1 ratio with water for 15 minutes prior to measurement on Hanna benchtop meter
BpH	After pH measurement Sikora buffer added, shaken for 15 minutes and measured on Hanna benchtop meter
Nutrients	Extracted with Mehlich 3 solution. Quantified on Agilent 5110 ICP-OES
B	Extracted using dilute hot calcium chloride solution. Quantified on Agilent 5110 ICP-OES
SO4-S	Extracted using calcium phosphate soluion. Quantified on Agilent 5110 ICP-OES
	All values reported on a dry soil basis

Data Entry for Soil Nutrient Analysis

Sample ID			Fresh sample process				Air Dry sample							pH EC Sikora RE-Do							Calculated Values			
			g	g	g	g	g	g	g	g	g	g	g	g				µS/cm			%			
Group #	Cust ID	CAL ID #	Total Sample Mass	Tin weight	Tin + wet soil	Tin + dry soil	Rock Cup	Rock Cup + Rocks	OM Cup	OM Cup + OM	Tin weight	Tin + wet soil	Tin + dry soil	Mass for pH	pH 1:1 water	Sikora	EC	EC (should be ~50-999)	write non-standard pH method	non standard pH measure	Rock >2mm by mass	Fresh Gravimetric Moisture	DM from Fresh	DM from Air Dry
219274	Wyscaver 0-12	1	875	1.02	6.82	4.79	20.39	23.38	20.54	21.5	1.28	5.42	4.76	20.04	6.09	5.44	104.7	104.7			0.005257	0.538462	0.65	0.84058
	Wyscaver 12-24	2	950.6	1.31	9.62	6.65	20.39	21.39	20.54	20.63	1.37	5.67	5.2	20.02	6.06	5.93	35.2	35.2			0.001637	0.55618	0.642599	0.890698
	Hughes 0 - 12	3	867.9	1.01	9.66	6.71	20.39	27.34	20.54	21.69	1	4.21	3.78	20.03	5.75	5.19	49.36	49.36			0.012152	0.517544	0.65896	0.866044
	Hughes 12-24	4	839.2	1.02	6.06	4.25	20.39	29.93	20.54	20.55	1.03	6.03	5.33	19.99	5.8	6	26.04	26.04			0.017738	0.560372	0.640873	0.86
	Airport Control 0 - 12	5	530.6	1.33	10.45	7.89	20.39	79.92	20.54	20.81	1.32	6.12	5.78	19.98	5.33	4.98	51.34	51.34			0.155977	0.390244	0.719298	0.929167
	Airport Control 12-24	6	385.1	1.27	7.97	6.2	20.39	39.57	20.54	20.69	1.33	4.41	4.32	20.02	5.11	5.02	45.57	45.57			0.067687	0.359026	0.735821	0.970779
	Wyscaver Control 0 -12	7	164	1.32	8.28	5.64	20.39	21.05	20.54	20.89	1.38	4.21	4.07	20.02	5.95	5.27	29.36	29.36			0.006484	0.611111	0.62069	0.95053
	Wyscaver Control 12-24	8	156.4	1.32	6.59	4.7	20.39	20.39	20.54	20.58	1.32	4.08	3.61	20.01	6.26	6.03	293.8	29.02			0	0.559172	0.641366	0.82971
	Airport 0 - 12 Biosolids	9	293	1.33	7.14	5.16	20.39	21.52	20.54	20.74	1.31	5.25	4.85	19.98	7.59	7.21	340.7	293.8			0.00585	0.516971	0.659208	0.898477
	Airport 12-24 Biosolids	10	556.7	1.33	9.08	5.91	20.39	21.2	20.54	20.87	1.02	5.19	4.42	20.02	7.32	7.2	119	340.7			0.002462	0.69214	0.590968	0.815348

	Moisture		KCl - NO3					Mehlich 3											Hot Water Boron		
CAL Sample #	Fresh DM	Air DM	Mass soil	Volume KCl	Fresh or Dry	NH4	NO3	Mass soil	Volume Mehlich	Fresh or Dry	Ca	Cu	Fe	K	Mg	Mn	P	Zn	Mass soil	Volume CaCl2	B
	decimal	decimal	g	mL	F D	ug/mL	ug/mL	g	mL	F D	ug/mL	ug/mL	ug/mL	ug/mL	ug/mL	ug/mL	ug/mL	ug/mL	g	mL	ug/mL
1	0.65	0.8406	7.52	30	D	4.24	2.06541	2.04	20	D	154.8	0.1	8.88	13.58	36.47	1.76	1.1	0.18	5.04	20	0.14
2	0.6426	0.8907	7.55	30	D	1.82	0.83741	1.99	20	D	110	0.07	7.38	7.55	25.54	0.63	0.4	0.01	5.04	20	0.07
3	0.659	0.866	7.55	30	D	4.13	1.22814	2	20	D	80.8	0.14	11.94	2.12	4.83	0.95	2.12	0.16	5.08	20	0.11
4	0.6409	0.86	7.54	30	D	3.1	0.72578	2.07	20	D	38.1	0.03	6.24	0.9	0.46	0.56	0.42	0	5.11	20	0.06
5	0.7193	0.9292	7.52	30	D	2.01	3.79576	2.06	20	D	68.02	0.06	13.41	8.61	33.13	0.18	0.35	0.12	5.14	20	0.12
6	0.7358	0.9708	7.5	30	D	1.96	0.39087	2.06	20	D	16.82	0.04	18.97	5.38	13.19	0.09	0.24	0.03	5.06	20	0.1
7	0.6207	0.9505	7.53	30	D	6.45	1.45141	2.01	20	D	249.8	0.88	15.28	22.01	23.52	1.5	1.32	0.77	5	20	0.14
8	0.6414	0.8297	7.56	30	D	2.28	0.61414	1.99	20	D	205.2	0.14	13.49	6.9	24.19	0.95	0.35	0.03	5.03	20	0.08
9	0.6592	0.8985	7.52	30	D	1.85	8.34492	2.01	20	D	1571	0.54	12.52	19.94	18.76	0.69	8.89	1.5	5.05	20	0.19
10	0.591	0.8153	7.55	30	D	1.21	5.10748	2.07	20	D	848.1	0.24	9.5	15.18	12.74	0.54	4.05	0.53	5.15	20	0.13

	Final ICP Data - dry soil basis									Final Lachat		Elementar			SO4 quantification			
CAL Sample #	Ca	Cu	Fe	K	Mg	Mn	P	Zn	B	NH4	NO3	pH check	C	N	sample mass	extractant volume	SO4-S ICP raw	DMB
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm		%	%	g	ml	ppm	ppm
1	1517.94	0.98	87.06	133.14	357.55	17.25	10.78	1.76	0.56	16.9149	8.2397	6.09	6.14	0.53	10.01	25	3.14	7.84216
2	1105.63	0.70	74.17	75.88	256.68	6.33	4.02	0.10	0.28	7.23179	3.3275	6.06	3.82	0.32	10.03	25	5.85	14.5813
3	808.00	1.40	119.40	21.20	48.30	9.50	21.20	1.60	0.43	16.4106	4.88	5.75	7.41	0.63	9.98	25	5.79	14.504
4	368.12	0.29	60.29	8.70	4.44	5.41	4.06	0.00	0.23	12.3342	2.8877	5.8	4.71	0.41	10.02	25	22.27	55.5639
5	660.39	0.58	130.19	83.59	321.65	1.75	3.40	1.17	0.47	8.01862	15.143	5.33	3.41	0.19	9.96	25	4.3	10.7932
6	163.30	0.39	184.17	52.23	128.06	0.87	2.33	0.29	0.40	7.84	1.5635	5.11	3.64	0.19	10.12	25	4.94	12.2036
7	2485.17	8.76	152.04	219.00	234.03	14.93	13.13	7.66	0.56	25.6972	5.7825	5.95	7.72	0.58	10.11	25	4.52	11.1771
8	2062.71	1.41	135.58	69.35	243.12	9.55	3.52	0.30	0.32	9.04762	2.4371	6.26	3.33	0.28	9.98	25	6.52	16.3327
9	#######	5.37	124.58	198.41	186.67	6.87	88.46	14.93	0.75	7.38032	33.291	7.59	8.18	0.52	10.17	25	6.37	15.6588
10	8194.11	2.32	91.79	146.67	123.09	5.22	39.13	5.12	0.50	4.80795	20.295	7.32	5.87	0.32	10.12	25	20.04	49.5059

Manual Nitrate

Curve 1		Curve 2				
ppm	spec	ppm	spec	sample ID	spec	
0	0.473	0	0.473	1	0.542	2.0654
0.2	0.477	0.2	0.487	2	0.498	0.8374
0.5	0.487	0.5	0.49	3	0.512	1.2281
1	0.506	1	0.505	4	0.494	0.7258
2	0.535	2	0.538	5	0.604	3.7958
5	0.635	5	0.641	6	0.482	0.3909
10	0.833	10	0.864	7	0.52	1.4514
15	1.061	15	1.094	8	0.49	0.6141
20	1.344	20	1.392	9	0.767	8.3449
Slope	0.036			10	0.651	5.1075
Interce	0.468					

Attachment 4
OSU Extension Service Nutrient Management for Pastures: Western Oregon and Western Washington EM 9224 (January 2019)

OREGON STATE UNIVERSITY EXTENSION SERVICE

Nutrient Management for Pastures: Western Oregon and Western Washington

Photo: Amber Moore, © Oregon State University

A. Moore, G. Pirelli, S. Filley, S. Fransen, D. Sullivan, M. Fery, and T. Thomson

Forage production is of primary importance to livestock enterprises and the agricultural economy in the Pacific Northwest. When properly managed, pastures can produce forage for pennies per pound of dry matter and can serve as the main feed source for western Oregon and Washington livestock operations.

Good soil fertility is an essential part of a successful forage management program. Science-based nutrient management, combined with a dense stand of grass or grass/clover species, can provide a sustainable source of forage. This publication provides nutrient management concepts and recommendations for western Oregon and western Washington pastures used primarily for grazing. It also includes concepts related to conserving forage as hay or silage when forage production exceeds grazing needs. The topics discussed in this publication will help livestock producers develop a sustainable forage production system.

Nutrient management practices may not be beneficial unless system-wide best management practices for pasture systems are implemented. Animal management practices have a tremendous influence on pasture productivity. Poor management practices, such as overgrazing and grazing animals on saturated soils, will greatly reduce or even eliminate the positive effects of soil fertility improvements. Therefore, a secondary goal of this publication is to address general pasture management practices that may affect the pasture's ability to respond to recommended nutrient management practices.

Forage management practices and nutrient use efficiency

The biological and economic response to a nutrient application to a pasture depends on several factors:

- **Species composition:** A dense stand of cool-season pasture grasses (e.g., tall fescue, orchardgrass, perennial ryegrass) and a clover species (e.g., white clover, subclover, red clover) will respond well to nutrient applications, assuming that the soil pH is appropriate for the species in the mix.
- **Plant density:** Early-establishment stands will likely be thin. As the pasture stand ages, tillering increases in grasses and branching increases in legumes, resulting in a denser stand. Younger, thinner stands are subject to weedy species invasion, while aged, dense stands provide a more competitive environment against invading weeds and native grasses.
- **Stage of growth:** Plants in the vegetative growth phase with adequate leaf area are more likely to show a response to a nutrient application than are overgrazed plants or plants that are close to maturity. Pasture plants are classified as being in growth phase I, II, or III, with phase II being the optimal phase for fertilizer application. Further guidance on how to adjust fertilizer applications and grazing management based on growth stage is provided in Appendix 1 (page 12). For more information on managing plants in pasture

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Oregon State University

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January 2019

systems, see *The Western Oregon and Washington Pasture Calendar* (PNW 699).

- **Stand age:** The longer a pasture plant is present in a stand, the older are its genetics. Plant breeders have focused on genetic improvements that allow new forage cultivars to outperform older versions of the same species in growth rate, yield, digestibility, and other attributes. When a new stand is established, the resulting increase in pasture productivity may also promote an improved response to fertilizer applications.
- **Balance of soil nutrients before N applications:** If pasture soils are very low in an essential nutrient, forage yield will be limited by that nutrient even if other nutrients are applied. For example, if phosphorus (P) is the most limiting factor in a pasture, nitrogen (N) application will not provide the expected outcome. To get the best response from N applications, make sure all other essential plant nutrients are at recommended levels.
- **Amount of defoliation by grazing animals:** As animals graze the forages in a pasture, plant regrowth replaces the consumed forage. However, excessive defoliation caused by overgrazing will slow the rate of regrowth and will prevent plants from effectively using N and other critical plant nutrients in the soil.

Soil testing

Soil nutrient testing is essential to determine the amount of nutrients available in the soil for plant growth and how much fertilizer is needed to optimize forage yield and quality.

For new, conventionally tilled seedings, test the soil prior to planting. For established and no-till pastures, plan to have soil analyzed every 2 years if fertility is within recommended levels. Test annually if fertility is below recommended levels and nutrient deficiencies are common. Collect the samples near the same date each year, since nutrient levels vary seasonally.

Summary

Before planting

Lime	When soil pH is below 5.5, broadcast lime according to Table 2. See page 4.
Nitrogen (N)	Broadcast or band 20 to 25 lb N/acre. See page 5.
Phosphorus (P)	When soil test P is below 30 ppm, broadcast or band P according to Table 4. See page 10.
Potassium (K)	When soil test K is below 200 ppm, broadcast K according to Table 5. Banding K is permitted at less than 60 lb K_2O/acre. See page 10.
Sulfur (S)	Sulfate-S may be broadcast or band applied to new fields at a rate of 15 to 25 lb S/acre. See page 10.
Magnesium (Mg)	When soil test Mg is below 0.8 meq/100 g or 100 ppm, replace 1 ton lime/acre of the lime requirement with 1 ton dolomite/acre. See page 5.
Calcium (Ca)	When soil test Ca is below 5 meq/100 g or 1,000 ppm, apply 1 ton lime/acre. See page 4.
Boron (B)	For clover pastures, 2 to 3 lb B/acre is recommended when soil test B is below 0.7 ppm. Use a broadcast application; do not band B. See page 11.

Established stands

Lime	For stand age under 5 years, top-dress lime if pH in the top 6 to 8 inches is below 5.5. For stand age over 5 years, top-dress lime if pH in the top 2 inches is below 5.5. Follow Table 2, page 4.
Nitrogen (N)	Top-dress N when grass is actively growing in early spring and early fall. On irrigated pastures, apply additional N in the summer. See Table 3, Figure 4, and pages 6–9.
Phosphorus (P)	When soil test P is below 30 ppm, top-dress P in either the fall or spring. See Table 4 and page 10.
Potassium (K)	When soil test K is below 200 ppm, top-dress K in either the fall or spring. See Table 5 and page 10.
Sulfur (S)	Top-dress sulfate-S in the spring or fall at a rate of 20 to 30 lb S/acre every year or 40 to 50 lb S/acre every other year. See page 10.
Magnesium (Mg)	When soil test Mg is below 0.8 meq/100 g or 100 ppm, apply either 1 ton dolomite/acre (if pH < 5.5) or 500 lb K-Mag/acre (if pH > 5.5). See page 5.
Calcium (Ca)	When soil test Ca is below 5.0 meq/100 g or 1,000 ppm, apply 1 ton lime/acre. See page 4.
Boron (B)	For clover pastures, broadcast application of 2 to 3 lb B/acre is recommended when soil test B is below 0.7 ppm. See page 11.
Selenium (Se)	Refer to *Selenium Supplementation Strategies for Livestock in Oregon* (EM 9094) to determine whether you should consider correcting Se deficiencies in grazing animals via fertilizer applications. See page 11.
Molybdenum (Mo)	For clover pastures, Mo deficiencies can be corrected by following lime recommendations in this guide. See page 11.

Collect samples from the tillage depth, about 6 to 8 inches for pastures in this region. For complete instructions on how to take a soil sample, see *A Guide to Collecting Soil Samples for Farms and Gardens* (EC 628). Additional information on soil sampling frequency and the management unit approach can be found in *Monitoring Soil Nutrients Using a Management Unit Approach* (PNW 570).

For fields that have been established for more than 5 years and for no-till systems, a stratified sampling approach provides additional information for long-term management. Dividing the sample into two parts, surface to 2 inches and 2 to 6 inches, for separate analyses can reveal accumulation of less mobile nutrients near the soil surface. To learn more about the stratified sampling approach, see *Evaluating Soil Nutrients and pH by Depth in Situations of Limited or No Tillage in Western Oregon* (EM 9014).

For pastures west of the Cascades, soil samples should be analyzed for the following:

- pH (1:2 soil:water ratio)
- Lime requirement test (SMP buffer method)
- Plant-available phosphorus (P) (Bray P1 method)
- Extractable potassium (K), calcium (Ca), and magnesium (Mg)

In fields where clover and other legumes are grown, also analyze for hot-water-extractable boron (B).

Soil testing for nitrogen (N) and sulfur (S) in pasture systems is not recommended, as these tests are poor predictors of the plant availability of these nutrients.

When selecting a laboratory to analyze samples, contact the lab to confirm that they do the recommended tests and to determine shipping and handling procedures. To find a lab specializing in soil testing, refer to *Analytical Laboratories Serving Oregon* (EM 8677). A current list of soil testing labs that are accredited through the North American Proficiency Testing Performance Assessment Program (NAPT-PAP) can be found at https://www.naptprogram.org/pap/labs.

Soil acidity, lime, Ca, and Mg

Soil acidity

Soils in western Oregon and western Washington are naturally acidic. Repeated applications of ammonium-based N fertilizers can contribute to additional soil acidification.

Soil pH is a measure of soil acidity. Acidic soil conditions occur when soil pH levels are below 7.0. Soil pH decreases with increasing acidity.

As soils become more acidic, forage yields are reduced due to a combination of nutrient toxicities (aluminum or manganese) and nutrient deficiencies (P, K, Ca, Mo, or N). Highly acidic soils greatly limit the effectiveness of fertilizer applications, as chemical and biological processes in the soil prevent many nutrients from being in a plant-available form.

The recommended minimum soil pH for most grasses and legumes grown in pasture systems is between 5.5 and 6.0, depending on the plant species. Minimum recommended soil pH values for specific species are listed in Table 1.

Some plants may persist below these soil pH levels, depending on factors such as soil type and rooting depth. However, when soil pH is below recommended levels, forage yield and quality can decline dramatically in response to even a minor decrease in soil pH. Plant species shift can also occur at pH levels below 5.5, with acid-tolerant grasses such as bentgrass persisting over less acid-tolerant plant species such as white clover and orchardgrass. To learn more about general concepts related to soil acidity, see *Soil Acidity in Oregon* (EM 9061).

Applying N fertilizer will not combat acidity. More information on acidification and N fertilizers can be found on page 9 under “Nitrogen fertilizer source.”

Table 1. Minimum recommended soil pH levels for pasture plant species commonly grown in western Oregon and western Washington.

	Recommended minimum soil pH				
	5.0	**5.2**	**5.5**	**5.8**	**6.0**
	More acid tolerant ----→				**Less acid tolerant**
Grass	Bentgrass	—	Annual ryegrass Tall fescue Perennial ryegrass	Orchardgrass	—
Legumes	—	Subterranean clover	Crimson clover Peas Vetch	White clover	Red clover

Adapted from *Soil Acidity in Oregon: Understanding and Using Concepts for Crop Production* (EM 9061) Appendix A.

Lime

The most cost-effective method for correcting soil acidity is lime application. Lime products originate from ground limestone, which is composed of calcium carbonate compounds. The Ca ions from lime replace acidifying H^+ ions on soil particles. The carbonate compounds then react with the replaced H ions to form water and carbon dioxide, thereby decreasing the proportion of H ions in the soil and raising soil pH. Calcium alone does not increase soil pH, so gypsum ($CaSO_4$), $CaCl_2$, $CaNO_3$, and other soluble Ca products are not recommended for addressing soil acidity issues.

Lime applications are often considered to be one of the most important management practices in a productive pasture system. Research conducted in Tillamook and Lane counties in Oregon showed a yield increase of 1,000 and 3,000 lb forage/acre, respectively, when lime was top-dressed at a rate of 2 ton/acre (Rogers, 1995). The effects of a lime application may last only 2 or 3 years. Therefore, plan to apply lime regularly to maintain forage quality and yields.

Lime applications are costly, and growth response to lime may take between 6 months to a year. To reduce yearly cost, apply lime to one or two fields each year. Avoid spreading a small amount of lime over a large number of fields, as applications of less than 0.5 ton/acre may be too small to significantly increase soil pH. Think of lime as an "investment" that will pay back over many years each time livestock graze and with each hay or silage harvest.

Lime application recommendations are based on SMP buffer test results. Follow the guidelines in the soil testing section of this guide (page 3) to determine the appropriate soil sampling depth for your specific pasture conditions.

Apply lime to grass and grass/clover pastures if the soil pH is below 5.5. Use the soil test SMP buffer value and Table 2 to determine the amount of lime required. Note that lime application rates are reduced for established fields to avoid smothering plants with the lime material.

The lime recommendations in Table 2 are based on a target soil pH value of 5.8. For fields with less acid-tolerant species, consider using the upper end of the recommended lime application rate. If it is cost-prohibitive to add the recommended amount of lime, even a lower lime rate of 1 to 2 ton/acre will be beneficial.

To ensure adequate soil pH for several years and to avoid the need for a top-dress lime application, a reasonable approach is to raise soil pH to 0.2 to 0.3 pH unit above the recommended minimum pH level in Table 1. To achieve this goal, increase lime application rates by approximately 0.5 ton/acre above the recommendations in Table 2.

For new seedings established with tillage, preplant application of lime to bare soil is the most effective application method and produces the fastest response. The material can be thoroughly mixed into the soil ahead of planting so that it has time to react and change the pH throughout the tillage depth. In addition, a large amount of lime can be added during field cultivation, thereby quickly raising a low soil pH to desired levels.

For existing pastures or no-till pastures, top-dress lime before fall rains begin and soils become muddy and waterlogged. During the first winter, lime will move only about 1 inch below the soil surface.

When top-dressing, apply no more than 2 ton/acre of the appropriate lime source to avoid smothering or injuring plants (Table 2). Top-dressed lime applications above 2 ton/acre will produce little or no additional soil pH or crop response (Rogers, 1995).

Avoid grazing livestock on recently limed fields, as lime materials can cause eye injury and respiratory issues. To avoid this risk, producers often delay grazing until the spring following a lime application.

Calcium (Ca) and magnesium (Mg)

Calcium is needed by plants to support cell wall structures, while Mg is needed for chlorophyll and protein synthesis. Calcium and Mg usually exist in the soil in adequate quantities when soil pH is above 5.5. If the Ca soil test is below 1,000 ppm (5 meq Ca/100 g of soil) and soil pH is above 5.0, add 1 ton lime/acre.

Table 2. Lime application rates for grass or grass/white clover pastures.[1]

	At seeding	Established field
If the SMP buffer test for lime is[2]	**Apply this amount of lime and incorporate (t/a)**	**Top-dress this amount of lime (t/a)**
Below 5.5	4 to 5	2
5.5 to 5.8	3 to 4	2
5.8 to 6.1	2 to 3	2
6.1 to 6.5	1 to 2	1 to 2
Above 6.5	0 to 1	0 to 1

[1]Liming rate is based on 100-score lime, which is an index of calcium carbonate content, moisture, and fineness. For more information about lime materials and lime score, see EM 9057, *Applying Lime to Raise Soil pH for Crop Production (Western Oregon)*.
[2]OSU lime recommendations are calibrated specifically for the SMP buffer. Recommendations have not been established for Sikora or other buffer pH methods.

Maintaining sufficient levels of Mg in the soil is especially important in pasture systems to prevent grass tetany, a livestock disease caused by Mg-deficient forage. When soil requires lime and is low in Mg (less than 100 ppm or 0.8 meq Mg/100 g of soil), use 1 ton/acre dolomitic lime as a source of both Ca and Mg. Dolomitic lime and ground limestone have about the same ability to neutralize soil acidity. If lime is not needed and Mg levels are low, apply K-Mag (21% K, 10% Mg, 21% S) at a rate of 500 lb K-Mag/acre. For more information on managing soils to prevent grass tetany, see the sidebar "Grass tetany" or visit "Spring Pastures—Grass Tetany and Bloat" at http://www.ansc.purdue.edu/beef/articles/GrassTetanyBloat.pdf.

Nitrogen (N)

Nitrogen fertilization is an important practice in pasture production systems, as N is needed by forage crops to support plant growth, protein synthesis, and tillering (see the sidebar "Grass yield and protein response to N fertilizer"). Forage yield and feed quality are reduced when N is insufficient, while excessive N can result in forage nitrate toxicities, nitrate leaching, and production of forage in excess of what can be consumed by grazing animals. Nitrogen deficiencies in pastures often can be detected visually. The majority of the stand will appear pale green, with urine and manure areas remaining dark green.

New pastures

For new pasture stands, an application of 20 to 25 lb N/acre is recommended at seeding. Fertilizer N can be broadcast or banded approximately 1 to 2 inches below the seed. If fertilizer is banded, application rates

Grass tetany

Grass tetany, also called hypomagnesemia or low blood serum magnesium, is characterized by an uncoordinated gait, convulsions, coma, and animal death. It is primarily due to low dietary Mg but can also be caused by a certain combination (ratio) of minerals in the diet. Several factors associated with fertilizing practices can lead to grass tetany in grazing livestock.

Soil conditions:

- Soils low in Mg lead to forages low in Mg.
- Rapid plant growth after N fertilizer application can reduce plant Mg concentration.
- Excessive K fertilization leads to high K concentrations in forage, which can reduce Mg concentrations.

Forage conditions:

- Forage Mg percentage is an indicator of tetany risk:
  - — *Tetany-prone*: less than 0.12 percent Mg
  - — *Marginal*: 0.12 to 0.18 percent Mg
  - — *Safe*: 0.2 to 0.25 percent Mg
- A forage tetany ratio greater than 2.2 is not safe for livestock consumption. This ratio is calculated as: *(%K/39) / [(%Ca/20) + (%Mg/12.1)]*

Avoid these conditions by following recommendations for Mg, N, and K fertilizer applications. Delay K fertilization until after the early-spring tetany period. Avoid grazing animals with high Mg requirements, such as cows in early lactation, on pastures that might contribute to grass tetany. To be safe, add supplemental Mg to the ration or to a mineral block.

Grass yield and protein response to N fertilizer

Grass responds to applied N by increasing dry matter yield and protein. Forage protein requirements differ, depending on the type of livestock and its age/maturity. Forage analyses for crude protein can be used to adjust the N fertilizer application rate to meet site-specific forage quality goals.

Figure 1 demonstrates the relationship between N fertilizer rate, grass yield, and protein. At low rates of N fertilizer input, grass yield increases, while protein remains low. Each increment of additional N fertilizer increases yield by a smaller amount (diminishing returns). When grass no longer responds to N input with increased yield, the added N contributes to an accelerated rate of increase in grass protein.

Although grass in this field trial was not grazed, the growth stage harvested (late vegetative growth; 15- to 18-inch height) and the harvest interval (30 to 40 days) was similar to that recommended for grazing.

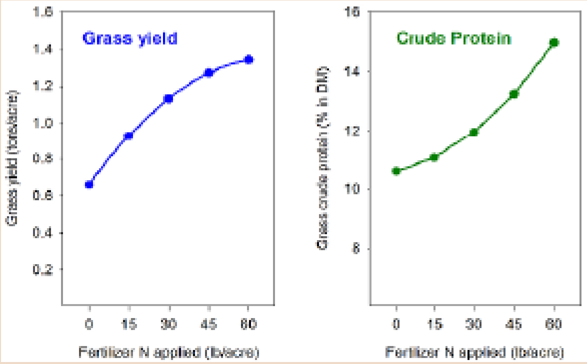


Figure 1. Nitrogen fertilizer increases yield and crude protein in tall fescue harvested at the late vegetative growth stage. Granular N fertilizer (34-0-0) was applied at 0 to 60 lb N/acre after each harvest, a few days prior to sprinkler irrigation. Puyallup, WA, Puyallup sandy loam soil, 3 percent soil organic matter. Adapted from Sullivan, et al., 2002.

should not exceed 100 lb N + K_2O/acre to avoid seed germination issues caused by salt burn.

Established pastures

For established fields, factors such as plant species, forage yield potential, and time of year influence the optimal amount of N required by the pasture crop to produce high-quality and high-yielding forages. See the following guidance to understand how each of these factors affects N use in forage pastures.

Plant species

Forage pastures are typically composed of high-yielding grasses (e.g., annual ryegrass, perennial ryegrass, orchardgrass, tall fescue) and legumes (e.g., white clover, subclover and other annual clovers, red clover, annual or hairy vetch, birdsfoot trefoil) or a combination of the two. High-yielding grasses will readily absorb plant-available forms of N (nitrate-N and ammonium-N). Low-yielding grasses, including bentgrass, velvetgrass, and rattail fescue, have naturally low forage yield and quality potential. Thus, they have a lower requirement for N than high-yielding species.

The presence of legumes in a pasture (Figure 2) reduces the amount of N fertilizer needed to support forage production. Legumes can produce their own N through the process of biological N fixation. *Rhizobium* or *Bradyrhizobium* bacteria infect legume roots, and the resulting root nodules convert N_2 gas from the atmosphere to ammonium-N compounds that can be used by the plant. An example of the N contribution of legumes is shown in Figure 3.

Although most pasture fields have naturally abundant *Rhizobium* bacteria, naturally occurring bacteria often are less efficient than those in commercially available inoculum. Thus, inoculation of legume seed is recommended when legumes are planted.

When excessive amounts of N are available, N fixation is reduced, and legumes behave like grasses by using N from the soil instead of fixing N_2 from the atmosphere. Applying excessive N to a mixed grass/legume stand will also shift the stand composition toward grass species, resulting in lower forage quality and increased N fertilizer requirement over time.

Realistic yield potential

Effective N management practices in pasture systems are based on realistic estimates of forage yield for individual fields. Each pasture has an upper limit to how much yield can be achieved. Yield potential is influenced by soil texture, soil depth, drainage, forage type, precipitation, temperature, weed pressure, manure application history, and irrigation practices. For more information, see Appendix 2 (page 13).

Nitrogen fertilizer response of mixed grass/legume stands

Nitrogen fertilizer application rates should take into consideration the species and density of grasses and legumes present. Forage stands that contain significant amounts of legumes require less N from fertilizer.

Figure 2 shows that relatively high forage yields can be produced with minimal N fertilizer inputs when legumes are present. In Figure 2, the same dry matter yield was produced with:

- Grass alone, with a fertilizer rate of 125 lb N/acre
- Grass/legume mix with no N fertilizer applied

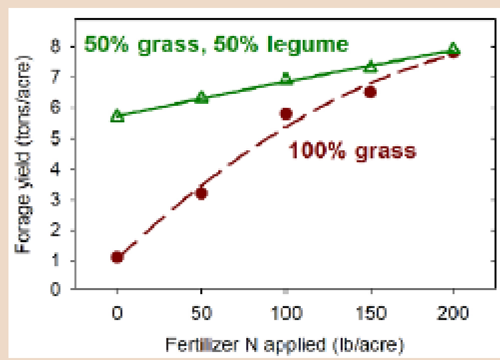
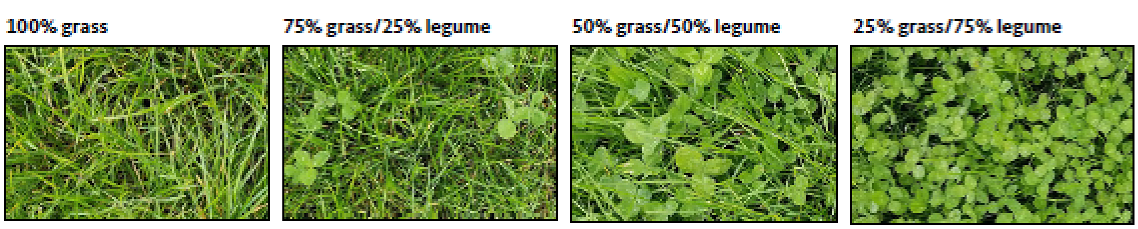


Figure 3. Forage dry matter yield response to N fertilizer in irrigated grass/legume pastures. Pastures were grazed by beef cattle three or four times annually. Approximately half of the annual forage dry matter yield was produced by a hay crop. Data collected at field sites near Ogden, UT. Adapted from Koenig, et al. (2002).



Photos: Amber Moore, © Oregon State University

Figure 2. Visual guide for grass:legume ratio in pasture. Legumes contribute plant-available N, so N fertilizer applications can be reduced as the percentage of legume increases.

Time of year

Nitrogen application should be coordinated with appropriate temperatures, moisture availability, and the need for an increase in forage yield. Nitrogen applications are not recommended in November and December, as N applied to cold, wet soils in winter can be leached beyond the root zone or washed off the fields in runoff before slow-growing plants can use the fertilizer.

Winter to early spring (January to April). Proper N management is especially important during winter and early spring, as adequate N is needed to support rapid plant growth between April and June. Local temperatures impact the start date for winter/early-spring fertilization. For example, pastures in the warmer south-coast region may respond to N fertilizer applied in January or early February, while pastures in the cooler Cascade regions may not respond to N fertilizer applications until mid-March or early April. An N application timing schedule specific to pastures in subregions of western Washington and western Oregon is illustrated in Figure 4.

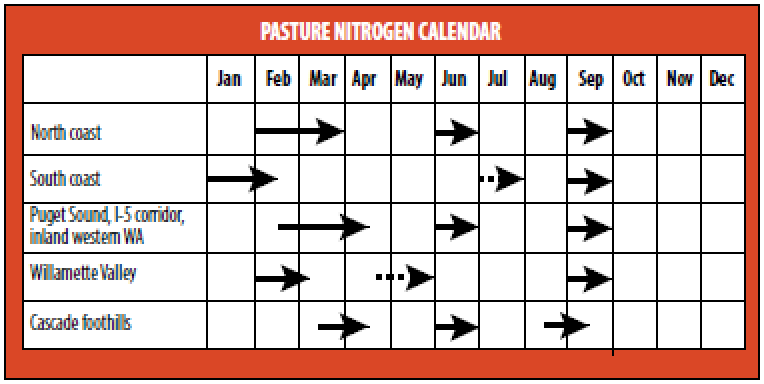


Figure 4. Pasture N calendar. Additional applications for irrigated pastures are indicated by dashed lines. This calendar is only an approximation, based on typical climatic conditions of pasture production subregions in western Oregon and western Washington. Other site-specific factors should be considered when determining the exact timing of N fertilizer application, as described in the "Time of year" section.

T-Sum method for early-spring forage production on grazed pastures

For well-managed pastures containing grass species, the T-Sum method can be used to estimate the appropriate date for the first N fertilizer application. T-Sum 200 is an accumulation of growing degree days (or heat units) on a Celsius degree basis, starting on January 1. See Appendix 3 (page 14) for T-Sum calculation details.

The T-Sum 200 date falls between late January and early February, depending on the year and location. Typical early-spring N fertilizer application dates based on T-Sum are:

- **Western Oregon** (Willamette Valley): January 25 to February 15
- **Western Washington** (30-year average): Aberdeen (February 8), Centralia (February 10), Buckley (February 14), Mt. Vernon (February 16)

Nitrogen applied at T-Sum 200 can increase the amount of early forage produced for grazing livestock. Field research in Coos, Douglas, Tillamook, and Benton counties (Oregon) demonstrated an average increase in harvestable dry matter of 750 to 1,000 lb/acre from a T-Sum 200 application of 60 lb N/acre (Pirelli, et al., 2004; Peters and Hart, 2007). The recommended N application rate at T-Sum 200 is 40 to 60 lb N/acre, depending on the grass yield potential.

The T-Sum 200 method for early N application is not appropriate for all pastures, as a pasture with a poor stand may have growth-limiting factors that would prevent plant growth response to an early N application. Below are characteristics of a field that would be well suited for use of the T-Sum 200 method:

- *Fields containing grass or a grass/legume forage mix*, such as tall fescue, orchardgrass, or perennial ryegrass combined with a clover. Bentgrass and legume-only pastures are not ideal for early-spring N application.
- *Fields that are not overgrazed in the fall.* Adequate leaf area in the fall ensures that plants have sufficient carbohydrate for winter survival and early-spring growth. For optimal response to T-Sum fertilization, 3 inches of forage should remain throughout the winter.
- *Well-drained fields free of standing water.* Wet, poorly drained soil does not permit forage growth.
- *The field is accessible to equipment for N application in January/February.*
- *The field has enough plant growth to support grazing in March or early April* without damaging the grass stand or the field. Three inches of forage should remain after spring grazing.
- *Soil pH and fertility are properly managed*, following recommendations provided in this publication.
- *Soil compaction and other production factors are not greatly limiting crop growth.*

In summary, the N application at T-Sum 200 can be used in western Oregon and western Washington to increase forage yield on fields that are well positioned to respond to an early application of N.

Another site-specific factor that impacts winter/early-spring fertilization is precipitation and drainage. In western Oregon and western Washington, heavy rainfall may cause pastures to become saturated. On poorly drained soils, N applications must be delayed until there is no standing water and the soil water table has dropped enough to allow safe use of fertilizer application equipment.

See the sidebar "T-Sum method for early-spring forage production on grazed pastures" (page 7) for more information.

Late spring to early summer (April to July). Intensively grazed pastures that are expected to produce a high level of forage through June should receive additional applications of N. For grass pastures, N fertilizer applications should follow each cutting or major grazing event, so multiple applications may be required. For grass/legume pastures, N fertilizer applications may be less frequent.

After mid-May, apply N only if moisture is sufficient for additional growth. July applications are recommended only for irrigated coastal pastures.

Late summer to fall (August to September). In western Oregon and western Washington, the pasture growing season begins when fall rains begin. Do not apply fall N if adequate rain does not fall until late October or if the air temperature drops below freezing in October, as these conditions will greatly limit fall tillering and growth.

Many growers apply fertilizers to dry soil and note that the granules disappear before any rain falls, raising concerns that fertilizer N may have been lost to the atmosphere through ammonia volatilization. Although a small amount of fertilizer N may be lost this way, most of the "missing" N fertilizer has been dissolved by dew and has moved into the surface soil.

Although limited use of N fertilizer in the fall can stimulate forage regrowth after fall rains, it is important to recognize that too much fall N can lead to vigorous plant growth that reduces winter hardiness. As temperatures decline in the fall, plants produce a type of "antifreeze" called proline. This antifreeze accumulates in every living plant cell, but only when excessive N is not available. Thus, excess N inhibits plants from preparing for winter, leaving them susceptible to injury or death from the first major cold event.

Other factors

Other factors may increase N requirements above recommendations in this publication, including low soil organic matter content (less than 2 percent) and harvesting of forage for hay. Factors that can decrease N requirements below recommendations include a history of manure or biosolids applications, N recycling from intensive grazing, high soil organic matter content (greater than 4 percent), and anything that limits plant growth (weed pressure, high water table, acidic soil conditions, extreme weather conditions, etc.).

Recommended N rates

Annual N recommendations are provided in Table 3 to give a general idea of the amount of N needed for optimal growth. However, because so many factors influence N management in pasture systems, you should expect to adjust these values as needed to reflect your specific situation. The N recommendations in Table 3 are based on those found in *Pasture and Grazing Management in the Northwest* (PNW 614). For information on estimating yield potential, see Appendix 2 (page 13).

Table 3. Annual nitrogen recommendations for grazed pasture systems in western Oregon and western Washington, based on realistic yield potential and plant composition.

	Yield potential of the field			
	1–2 ton/acre[1]	2–4 ton/acre	4–6 ton/acre	6–8 ton/acre
	N recommendation (lb N/acre)			
100% grass	50	75[2]	100 to 150[2]	150 to 200[2]
75% grass/25% legume	25	50	75 to 100[2]	100 to 150[2]
50% grass/50% legume	0	25	50	75
25% grass/75% legume	0	0	25	50

Adapted from *Pasture and Grazing Management in the Northwest* (PNW 614)
[1]T-sum applications are not economical for low-yielding pastures.
[2]For higher yielding pastures with grass-dominated plant species, split the total N rate into two or three separate applications following guidelines in this publication and the N application calendar in Figure 4 (page 7).

Nitrogen fertilizer source

Common granular N fertilizers for pasture include urea (46-0-0) and ammonium sulfate (21-0-0-24S). Common liquid fertilizers include urea-ammonium nitrate (32-0-0) and ammonium polyphosphate (10-34-0).

Some of the N from some granular or liquid N fertilizers can be lost as a gas (ammonia; NH_3) during the first week after N fertilizer application to pasture. This type of N loss is of concern only with urea and fertilizer mixtures that contain urea (e.g., urea-ammonium nitrate). Fertilizers that do not contain urea (e.g., ammonium sulfate) do not lose a significant amount of N as NH_3 gas. Losses of N as ammonia gas can be high (10 to 30 percent of N applied). However, on western Oregon pastures, losses typically are less than 5 percent of N applied. Irrigation or rain (more than 0.5 inch) within a few days after application moves urea into the soil and reduces the amount of N lost as gas.

Newer N fertilizer products include additives to reduce ammonia loss following fertilizer application. Products such as polymer-coated urea or urea treated with a urease inhibitor (e.g., Agrotain) can reduce ammonia loss from surface-applied urea. However, they are unlikely to routinely prevent enough NH_3 loss to justify their extra cost. The risk of NH_3 loss is highest with early-fall N fertilizer applications to dry soil, so fertilizer additives that reduce ammonia loss are most likely to provide benefit under these conditions.

Nitrogen fertilization is the most important driver for soil acidification (decreased soil pH) in pastures. The most acidifying fertilizers supply all of their N as ammonium-N. Fertilizers that supply some N as urea are less acidifying per pound of N. Manure, compost, and other organic N sources are generally less acidifying than commercial N fertilizers, as they contain mostly organic N and also supply basic cations (Ca, Mg, K, and sodium). *Soil Acidity in Oregon: Understanding and Using Concepts for Crop Production* (EM 9061) provides a quantitative comparison of acidity produced by various N fertilizer materials in soil.

See the sidebar "Supplying nutrients to pasture with manure or municipal biosolids" for additional information about using organic materials to supply N for pastures. Not all "organic" sources are allowed under certified organic production rules (e.g., National Organic Program). Contact your organic certifier regarding appropriate organic sources.

Supplying nutrients to pasture with manure or municipal biosolids

Animal manures or municipal biosolids can be used to supply a portion of the nutrients needed for pasture. Both biosolids and manure supply N, P, Ca, Mg, S, and micronutrients. Manure also provides K, but biosolids do not contain significant amounts of K.

Manure and biosolids vary in nutrient composition depending on water content, added materials (e.g., bedding), and processing (composting or "aging"). A recent nutrient analysis of your manure or biosolids source is always recommended. General "book values" for manure nutrient content can be found in *Fertilizing with Manure and Other Organic Amendments* (PNW 533). You can read more about municipal biosolids in *Fertilizing with Biosolids* (PNW 508).

Manure or biosolids contain both rapidly available N (in ammonium form) and slowly available N (in organic form). Relative to urea, biosolids and manure are generally 30 to 50 percent as effective per unit of total N applied during the first year after application (Sullivan, et al., 2000; Cogger, et al., 2001). Thus, biosolids or manure applied at 100 lb total N/acre will supply 30 to 50 lb plant-available N/acre. Most of the plant-available N from manure or biosolids is utilized by the first two or three forage harvests after application.

Unlike mineral fertilizers (e.g., urea), biosolids or manure can be applied in fall and will stimulate pasture growth early in the following spring. Fields for fall or early-spring manure or biosolids application must be managed carefully to prevent runoff.

When any N source (manure, biosolids, or urea) is applied, soil becomes more acidic with time. The acidity results from the nitrification process (conversion of ammonium to nitrate-N). At a given rate of plant-available N application, biosolids and urea have a similar soil acidification effect. Manure is slightly less acidifying than urea.

Only a few manures (e.g., dairy solids from lagoons or mechanical solids separators) are suitable for high-rate application to supply P and K prior to reseeding a pasture. These manures generally contain 1 to 2 percent total N and have a C:N ratio of 15 or greater. Most other manures or biosolids will supply too much N if applied at rates needed to supply P and K.

Photo: Dan Sullivan, © Oregon State University

Figure 5. Application of dairy slurry at a research trial (Sullivan, et al., 2000), Buckley, WA.

Phosphorus (P)

Adequate levels of soil P are important for root production in grass and clover pastures. Phosphorus applications favor legumes; therefore, they can be used to support legume growth in a grass/legume pasture.

Visual symptoms of pastures with inadequate P include limited root mass and depth (which can be difficult to quantify without a comparison), stunted aboveground forage (short, small leaves), and a light to dark purple color on leaves and/or stems of both grasses and clovers.

Because P binds to the soil, it can accumulate in the soil and does not need to be applied as often as N. Phosphorus accumulation can be documented with soil testing.

Recommendations for P application rates based on the Bray P soil test are provided in Table 4.

For new seedings, P fertilizer may be banded with the seed or broadcast and incorporated prior to seeding. Band 1 to 2 inches to the side or below the seed to avoid burning newly emerging seedlings.

For established fields, P can be applied in either the fall or spring. Fall P applications can be advantageous, as pasture grasses are developing their primary growing points and roots at this time. Spring applications can also be useful, as cool spring temperatures and acidic soil conditions reduce P solubility, thus inhibiting new root development and P uptake by plants. In either case, apply P to established pastures before growth begins.

Potassium (K)

Potassium supports water transport and metabolic function in pasture plants and, therefore, is essential for optimal growth of clover/grass pastures. Potassium is particularly important for legume species, as grasses compete with clovers for K.

High-producing pastures can rapidly decrease soil test K values. Potassium deficiency is indicated by light-colored spots around the margins of clover leaves and yellow to brown coloring of grass leaf tips. However, growth responses to K fertilizer often can be obtained before deficiency symptoms are detected.

If you apply K-rich animal manures to your pasture, be mindful of the potential for excessive levels of K, which can lead to grass tetany issues for grazing animals.

Potassium fertilizer guidelines are found in Table 5. For new pastures, broadcast K and incorporate into the seedbed prior to seeding. If the soil test is below 125 ppm, band an additional 20 lb K_2O at the time of planting. Potassium can be banded with N and P. If fertilizer is banded, application rates should not exceed 100 lb N + K_2O/acre to avoid seed germination issues caused by salt burn. At least 1 inch of soil should separate the seed and fertilizer. Note that K fertilization at planting will not meet the need for K in subsequent years.

For nonirrigated established pastures, apply K in the fall or spring, following recommendations in Table 5. In high-yielding irrigated pastures, split applications (late spring and midsummer) are recommended to reduce K-induced Mg deficiencies that may lead to grass tetany. For more information, see the sidebar "Grass tetany" (page 5) or "Spring Pastures—Grass Tetany and Bloat" (http://www.ansc.purdue.edu/beef/articles/GrassTetanyBloat.pdf).

Sulfur (S)

Plants take up S in the form of sulfate (SO_4). For new fields, broadcast or band sulfate-S fertilizers at a rate of 15 to 25 lb S/acre. On established fields, top-dress S at a rate of 20 to 30 lb S/acre annually or 40 to 50 lb

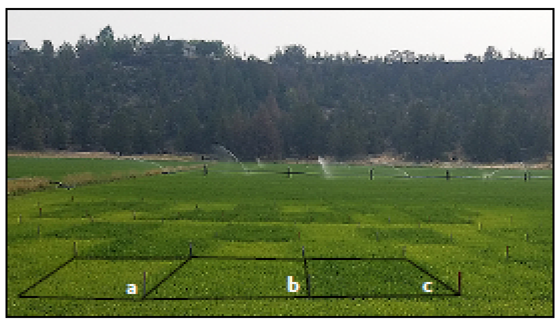


Photo: Mylen Bohle, © Oregon State University

Figure 6. Experimental plots compare N and S treatments: (a) no N or S application, (b) 60 lb N/acre with no S, and (c) 60 lb N/acre with S added. Orchardgrass in Terrebonne, OR.

Table 4. Phosphorus application rates for pastures.

If the Bray soil test for P is (ppm)	Apply this amount of phosphate (P_2O_5) (lb/a)
0 to 15	100 to 60
15 to 30	60 to 0
Above 30	0

Table 5. Potassium application rates for pastures.

If the soil test for K is (ppm)	Apply this amount of potash (K_2O) (lb/a)
0 to 125	150 to 100
125 to 200	100 to 70
Above 200	0

S/acre every 2 years. Sulfate-S fertilizers can be applied in fall or spring with good results. Figure 6 (page 10) shows plant response to S application.

Nitrogen fertilizer applications without adequate S fertilization can result in rapid decline of the clover component of a grass/clover mixture. An N:S ratio greater than 10:1 in a forage tissue analysis may indicate S deficiency. Sulfur-deficient plants respond rapidly to sulfate-S application. During the rainy season, plants can recover from S deficiency in 3 to 4 weeks following a broadcast sulfate-S application.

Fertilizers containing sulfate-S include ammonium sulfate (24% S), gypsum (16 to 19% S), and potassium magnesium sulfate (21% S; often called K-Mag or Sul-Po-Mag). Fertilizer dealers also offer fused prills of urea-ammonium sulfate, such as Urea-Sul (33% N, 11% S). Sulfate fertilizers are not very water soluble, so they typically are not fertigated. Liquid fertilizer N:S mixes typically contain thiosulfate (S_2O_3); the most common is ammonium thiosulfate (12% N, 26% S).

Sulfur can also be supplied as elemental S. Elemental S acidifies soil and slowly releases plant-available sulfate-S. To be an effective S source, elemental S must be applied well ahead of crop demand or be of very fine particle size (less than 0.1 mm diameter; Rasmussen and Kresge, 1986).

Selenium deficiencies can be triggered by S applications. See PNW 614, *Pasture and Grazing Management in the Northwest* (chapter 3, "Soils, Fertility, and Nutrient Management for Pastures") for more details.

Boron (B)

Legumes have a higher B requirement than grasses, as B is used to support root nodulation in legume crops. Too much B can be highly toxic to plants and animals. Therefore, apply B only if soil tests indicate a need. Do not exceed suggested rates.

If the soil test for B is below 0.7 ppm, an application of 2 to 3 lb B/acre is recommended. Spring applications are preferred because B, like N and S, can leach. However, fall applications are also appropriate.

To avoid acute B toxicity issues, never band B-containing fertilizer materials. Distribute B evenly over the field. Solubor (sodium borate) is a suitable source of B. It can be applied evenly over a field via spray application. Dry B fertilizer can be mixed with other fertilizers. However, be aware that crop damage can occur if too much B is added or if B is not evenly dispersed throughout the fertilizer blend.

Selenium (Se)

Selenium is not an essential plant nutrient, but it is an essential nutrient for animals. A variety of methods can be used to provide Se to animals, including applications of Se-enriched fertilizers to pastures and forage crops. To learn more about strategies for providing Se to grazing animals via Se fertilization, see *Selenium Supplementation Strategies for Livestock in Oregon* (EM 9094).

Molybdenum (Mo)

Molybdenum is used by legumes to facilitate N fixation. Existing Mo in the soil becomes more plant-available as pH increases in acidic soils. Therefore, liming to maintain soil pH above the recommended threshold (pH 5.5 for most pasture species) is an effective way to ensure adequate Mo supply.

If soil acidity can't be overcome with lime applications, and tissue Mo is below 0.3 ppm, legumes may benefit from an application of 0.4 lb Mo/acre. Molybdenum can be applied in a foliar spray as sodium molybdate.

Keep in mind that an application of Mo will correct only Mo deficiency issues. It will not correct Mn toxicity, Al toxicity, P deficiency, Ca deficiency, Mg deficiency, or other issues caused by acidic soil conditions. Therefore, liming is the best way to correct Mo deficiency issues, as it will correct these related problems at the same time.

Molybdenum toxicities in livestock, or molybdenosis, can occur when Cu:Mo ratios in forage tissue are below 2:1. While uncommon, this problem can occur on fields low in Cu that receive excessive Mo applications. If you suspect Mo toxicities, monitor forage concentrations of Mo and Cu. To learn more, see Meyer, et al., 1999.

Appendix 1. Plant Growth Phase, Grazing Management, and Nutrient Management

Although growth rates are influenced by temperature, moisture, solar radiation, and overall soil fertility, grazing management has a profound impact on pasture production. Plant growth phases are used to describe pasture growth and the potential for forage production (Figure 7). Phase I (lag phase), Phase II (vegetative or log phase), and Phase III (maturity or senescence phase) describe the stages of growth and their impacts on grazing and forage production.

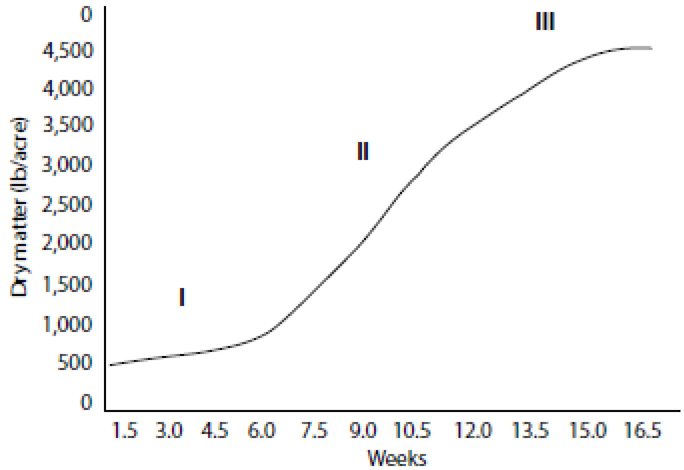


Figure 7. Example of orchardgrass growth phase response to time. Data collected at Monmouth, OR, March to July 1985. Data from G. Pirelli.

In **Phase I**, plants grow slowly because they lack sufficient leaf area for photosynthesis. In western Oregon and Washington, a pasture with less than 3 inches of plant height is considered to be in Phase I and should not be grazed until growth exceeds 3 inches. Keeping pasture plants in Phase I greatly reduces their response to nutrient application. It also can have negative effects on animals, such as grass tetany in the spring or weight loss due to low forage intake. If the pasture is constantly overgrazed throughout the growing season, it will not transition out of Phase I into more advanced growth phases.

Phase II (3 to 12 inches of growth) is desired in pastures. Plants grow most rapidly and efficiently in this stage. When grazing animals reduce pasture height to 3 inches, move the animals to another pasture with adequate growth. The resulting rest period will allow for regrowth in the first pasture. Managing pastures in this manner, referred to as a rotational grazing system, allows plants to develop sufficient leaf area for efficient use of sunlight. During hot weather, leaving 4 inches of growth will reduce soil temperatures as much as 10°F compared to an overgrazed pasture in Phase I.

It is important to maintain pastures in Phase II during the critical late-summer and early-fall period. Two major plant activities occur during this period: root regeneration and formation of shoots (growing points) for the following year. Overgrazing or excessive forage harvest inhibits root system rebuilding and the formation of shoots for spring growth, resulting in reduced forage production during the next growing season. Allowing plants to store carbohydrates in the fall is also essential for long-term pasture production. Finally, the insulation from taller forage keeps plants growing later in the fall and helps start growth earlier in the spring.

Do not graze plants below 3 inches in late summer and fall, even if the plants are dry and dormant. Grazing below this height will reduce forage response to a T-Sum 200 N application the next year.

Phase III (greater than 12 inches, varying by species and variety) is the reproductive phase. During this phase, plant growth slows, the lower leaves become shaded and die, and the seedhead emerges. Grazing efficiency is reduced due to trampling, the response to nutrient application is reduced, and animal performance suffers.

The most efficient use of Phase III pasture is as conserved forage, such as hay or silage. With the major perennial grass and legume pasture species grown on the westside, regrowth will emerge following a hay or silage harvest, assuming nutrients and water are adequate. Plants will again progress through Phase I and Phase II if conditions allow. The ability to manage pasture species strictly as pasture or in combination with one or more hay or silage harvests is one of the greatest attributes of westside pastures.

Appendix 2. Realistic Yield Estimations

By estimating a pasture's realistic yield, you can determine the amount of N needed to support optimal forage quality and yield. Yield potential is influenced by soil texture, soil depth, drainage, forage type, precipitation, temperature, weed pressure, manure application history, and irrigation practices. Realistic yield estimates are based on the estimated average yield from a 3- to 5-year period.

Estimating forage yield is more challenging in grazed systems than in row crop systems because the forage is not collected at a single harvest event. A variety of methods can be used to estimate forage yield in a grazed pasture. One simple method uses a combination of animal units and bale yield estimates.

The number of animal units can help you estimate the amount of pasture dry matter consumed by grazing animals, based on the amount needed to maintain their body weight. Most grazing animals will digest approximately 2.5 percent of their body weight as feed on a daily basis. In a grazed forage system, grazed yield (dry weight basis) is estimated using the following calculation. (Grey-shaded areas represent required producer inputs.)

$$\frac{\text{no. animals}}{\text{acre}} \cdot \text{animal wt (lb)} \cdot \text{days in field} \cdot 0.025 \cdot \frac{1 \text{ ton}}{2{,}000 \text{ lb}}$$

$$= \text{grazed forage yield (ton/acre)}$$

Table 6 shows examples of estimated grazed yield, based on animal type and typical grazing periods in western Oregon and western Washington.

In addition to grazed forage yield, pastures may also be baled for hay during peak growth seasons when forage production exceeds the amount consumed by the animals. Baled yield should be added to grazed yield to determine a pasture's total realistic yield. Baled yield (dry weight basis) can be estimated using the following calculation. (Grey-shaded areas represent required producer inputs.)

$$\frac{\text{no. bales}}{\text{acre}} \cdot \text{bale wt (lb)} \cdot \frac{100 - \text{moisture content (\%)}}{100} \cdot \frac{1 \text{ ton}}{2{,}000 \text{ lb}}$$

$$= \text{baled forage yield (ton/acre)}$$

Table 7 lists examples of estimated baled yield, based on bale size and number of bales harvested per acre.

Other methods of estimating yield include the clipping method, the rising plate method, and the pasture ruler method. These methods are based on relatively direct measurements of plant growth or biomass content over the production season. Therefore, they are more labor intensive but potentially more accurate than the animal yield/baled yield calculations described above. To learn more about these methods, see Hall, 2007.

Table 7. Estimated baled yield (dry matter) in a pasture system that is baled for hay, based on number of bales harvested and bale weight.[1]

	Bale weight (lb/a)		
	70	**110**	**1,400**
Number of bales/a	**Dry matter yield (ton/a)**		
5	0.1	0.2	3.0
10	0.3	0.5	6.0
20	0.6	0.9	—
40	1.2	1.9	—
60	1.8	2.8	—
80	2.4	3.7	—

[1]Moisture content of forage tissue in the bales is assumed to be 15 percent.

Table 6. Estimated grazed yield (dry matter) in a grazed pasture, based on animal type, number of animals in the field, and number of days on the field.[1]

			Days on pasture field			
	Animal type		**15**	**30**	**45**	**60**
200-lb sheep	**1,000-lb beef cattle (animals/a)**	**1,300-lb beef cattle**	**Grazed yield (ton dry matter/a/yr)**			
5	1	—	0.2	0.4	0.6	0.8
10	2	1	0.4	0.8	1.1	1.5
15	3	2	0.6	1.1	1.7	2.3
20	4	3	0.8	1.5	2.3	3.0
25	5	4	0.9	1.9	2.8	3.8

[1]Intake per day is assumed to be 2.5 percent of the animal's body weight.

Appendix 3. Calculating T-Sum in Oregon from Weather Data

T-Sum 200 is an accumulation of heat units (in degrees C) for consecutive days beginning January 1, until a total of 200 is reached. Research shows that certain plants such as cool-season grasses initiate growth at or near this time. A heat unit, or growing degree day (GDD), is the average of the high and low temperature for the day, in degrees Celsius. If the temperature is below 0°C, the heat unit is 0. The formula for calculating a T-Sum heat unit is:

$$\frac{\text{maximum °C} + \text{minimum °C}}{2}$$

For example, if the high for January 1 is 11.7°C and the low is 4.4°C, the number of heat units for that day is 8.1 (11.7 + 4.4 ÷ 2 = 8.1).

T-Sum calculations are available online from OSU Integrated Plant Protection Center (http://uspest.org). You can see degree day accumulation on a regional map or estimate T-Sum for a specific weather station using an online degree day model.

When using an online calculator, specify the following:

- Lower temperature threshold for degree day accumulation (biofix) = 0°C
- Start date: January 1
- Calculation method: Simple average growing degree days

Some online degree day calculators use degrees F; in this case, T-Sum 200 occurs when 360 degrees F have accumulated (1°C = 1.8°F).

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Attachment 5
Dr. Dan Sullivan Email Correspondence

From: KENNEDY Paul
To: NOMURA Ranei
Subject: FW: Soil tests Newport biosolids sites
Date: Thursday, September 5, 2019 3:45:15 PM
Attachments: Soil test Newport Sent back to Kennedy May 27 2019.xlsx

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From: Sullivan, Dan [mailto:dan.sullivan@oregonstate.edu]
Sent: Wednesday, May 29, 2019 6:09 PM
To: KENNEDY Paul <KENNEDY.Paul@deq.state.or.us>
Subject: Soil tests Newport biosolids sites

Paul
I highlighted soil tests of interest in grass pasture production. Lime stabilized biosolids are great for liming to increase pH, supplying P and most other nutrients.
Recommend that pasture managers apply mineral (inorganic) K fertilizers at biosolids application sites, because soil test K is low. Soil test Mg is marginal, so would also recommend some Mg application from inorganic fertilizer, like Sul-po-Mag or K-Mag.
Soil test recommendations from OSU pasture guide are pasted into the worksheet as picture on right side.
N recommendations based on how grass is managed. Better pasture management = more biomass, so more N required for grass production.
Dan

Oregon State University
Central Analytical Laboratory
Crop and Soil Science Department 3079 Ag-Life Sciences Bldg Corvallis, OR 97331 541-737-2187

Producer's Soil Nutrient Analysis Report

Name:	Paul Kennedy
Organization:	DEQ
Contact for results:	kennedy.paul@deq.state.or.us
Date submitted:	4/25/2019
Date delivered:	5/16/2019
Group number:	219274

Really = sum of cations

Sample ID		%	%			ratio	ppm		pH		dS/m			ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	meq/100g	meq/100g	meq/100g
Cust ID	Lab ID	rocks	C	N	OM	C:N	NH4-N	NO_3-N	pH	BpH	EC	Cust ID	Lab ID	P	K	Mn	Cu	Zn	Fe	SO4-S	B	Ca	Mg	CEC
Wyscaver 0-12	1	0.5	6.14	0.53	12.29	11.6	16.9	8.2	6.09	5.44	0.105	/yscaver 0-1	1	10.8	133	17.3	1.0	1.8	87	7.8	0.6	7.6	3.0	10.9
Wyscaver 12-24	2	0.2	3.82	0.32	7.65	12.0	7.2	3.3	6.06	5.93	0.035	yscaver 12-2	2	4.0	76	6.3	0.7	0.1	74	14.6	0.3	5.5	2.1	7.9
Hughes 0 - 12	3	1.2	7.41	0.63	14.81	11.7	16.4	4.9	5.75	5.19	0.049	Hughes 0 - 1	3	21.2	21	9.5	1.4	1.6	119	14.5	0.4	4.0	0.4	4.5
Hughes 12-24	4	1.8	4.71	0.41	9.42	11.5	12.3	2.9	5.80	6.00	0.026	Hughes 12-2	4	4.1	9	5.4	0.3	0.0	60	55.6	0.2	1.8	0.0	1.9
Airport Control 0 - 12	5	15.6	3.41	0.19	6.82	17.9	8.0	15.1	5.33	4.98	0.051	ort Control 0	5	3.4	84	1.7	0.6	1.2	130	10.8	0.5	3.3	2.7	6.2
Airport Control 12-24	6	6.8	3.64	0.19	7.28	19.7	7.8	1.6	5.11	5.02	0.046	ort Control 12	6	2.3	52	0.9	0.4	0.3	184	12.2	0.4	0.8	1.1	2.0
Wyscaver Control 0 - 12	7	0.6	7.72	0.58	15.43	13.4	25.7	5.8	5.95	5.27	0.029	aver Control	7	13.1	219	14.9	8.8	7.7	152	11.2	0.6	12.4	2.0	14.9
Wyscaver Control 12-24	8	0.0	3.33	0.28	6.66	12.1	9.0	2.4	6.26	6.03	0.294	aver Control	8	3.5	69	9.5	1.4	0.3	136	16.3	0.3	10.3	2.0	12.5
Airport 0 - 12 Biosolids	9	0.6	8.18	0.52		15.7	7.4	33.3	7.59	7.21	0.341	rt 0 - 12 Bios	9	88.5	198	6.9	5.4	14.9	125	15.7	0.8	78.2	1.6	80.2
Airport 12-24 Biosolids	10	0.2	5.87	0.32		18.3	4.8	20.3	7.32	7.20	0.119	rt 12-24 Bios	10	39.1	147	5.2	2.3	5.1	92	49.5	0.5	41.0	1.0	42.4

Dan rough guide on when nutrient application may provide long-term benefit on grass pasture biosolids sites

Sample ID		ppm = mg nutrient/kg soil								meq/100g		
Cust ID	Lab ID	P	K	Mn	Cu	Zn	Fe	SO4-S	B	Ca	Mg	CEC
Wyscaver 0-12	1	10.8	133	17.3	1.0	1.8	87	7.8	0.6	7.6	3.0	10.9
Wyscaver 12-24	2	4.0	76	6.3	0.7	0.1	74	14.6	0.3	5.5	2.1	7.9
Hughes 0 - 12	3	21.2	21	9.5	1.4	1.6	119	14.5	0.4	4.0	0.4	4.5
Hughes 12-24	4	4.1	9	5.4	0.3	0.0	60	55.6	0.2	1.8	0.0	1.9
Airport Control 0 - 12	5	3.4	84	1.7	0.6	1.2	130	10.8	0.5	3.3	2.7	6.2
Airport Control 12-24	6	2.3	52	0.9	0.4	0.3	184	12.2	0.4	0.8	1.1	2.0
Wyscaver Control 0 - 12	7	13.1	219	14.9	8.8	7.7	152	11.2	0.6	12.4	2.0	14.9
Wyscaver Control 12-24	8	3.5	69	9.5	1.4	0.3	136	16.3	0.3	10.3	2.0	12.5
Airport 0 - 12 Biosolids	9	88.5	198	6.9	5.4	14.9	125	15.7	0.8	78.2	1.6	80.2
Airport 12-24 Biosolids	10	39.1	147	5.2	2.3	5.1	92	49.5	0.5	41.0	1.0	42.4

soil pH< 6.5; Buffer pH<6.1
P<50 ppm
K<200 ppm
Sulfate-S<20 ppm
Boron<1 ppm
Calcium< 5 meq/100g
Magnesium<1 meq/100g

Primary goal on grass pastures is to increase pH, P, K to adequate levels.
City of Newport lime stabilized biosolids will increase pH and provide P and most other nutrients (but does not add K)
Will need to apply mineral K fertilizer for sure, and adding Mg fertilizer likely needed at some fields. Sul-po-mag supplies both K and Mg.
Increased potential for Mg and K deficiency expected when lime added.

Rocks	% by mass of mineral matter that would not pass a 2mm sieve
Moisture	Gravimetric moisture of the sample at the time of submission
C, N	Dry combustion with direct measure of total nitrogen, carbon and sulfur by Elementar Macro Cube
OM	Total organic matter, calculated by multiplying total C by 2 for samples with pH < 7
NO_3-N	Extracted with 2M KCl. Sulfanilamide and NEDD colorimetric reaction measured on spectrophotometer
NH4-N	Extracted with 2M KCl. Salicylate colorimetric reaction measured on Lachat FIA
pH + EC	Soil shaken in 1:1 ratio with water for 15 minutes prior to measurement on Hanna benchtop meter
BpH	After pH measurement Sikora buffer added, shaken for 15 minutes and measured on Hanna benchtop meter
Nutrients	Extracted with Mehlich 3 solution. Quantified on Agilent 5110 ICP-OES
B	Extracted using dilute hot calcium chloride solution. Quantified on Agilent 5110 ICP-OES
SO4-S	Extracted using calcium phosphate soluion. Quantified on Agilent 5110 ICP-OES
	All values reported on a dry soil basis

Summary

Before planting

Lime	When soil pH is below 5.5, broadcast lime according to Table 2. See page 4.
Nitrogen (N)	Broadcast or band 20 to 25 lb N/acre. See page 5.
Phosphorus (P)	When soil test P is below 30 ppm, broadcast or band P according to Table 4. See page 10.
Potassium (K)	When soil test K is below 200 ppm, broadcast K according to Table 5. Banding K is permitted at less than 60 lb K_2O/acre. See page 10.
Sulfur (S)	Sulfate-S may be broadcast or band applied to new fields at a rate of 15 to 25 lb S/acre. See page 10.
Magnesium (Mg)	When soil test Mg is below 0.8 meq/100 g or 100 ppm, replace 1 ton lime/acre of the lime requirement with 1 ton dolomite/acre. See page 5.
Calcium (Ca)	When soil test Ca is below 5 meq/100 g or 1,000 ppm, apply 1 ton lime/acre. See page 4.
Boron (B)	For clover pastures, 2 to 3 lb B/acre is recommended when soil test B is below 0.7 ppm. Use a broadcast application; do not band B. See page 11.

Established stands

Lime	For stand age under 5 years, top-dress lime if pH in the top 6 to 8 inches is below 5.5. For stand age over 5 years, top-dress lime if pH in the top 2 inches is below 5.5. Follow Table 2, page 4.
Nitrogen (N)	Top-dress N when grass is actively growing in early spring and early fall. On irrigated pastures, apply additional N in the summer. See Table 3, Figure 4, and pages 6–9.
Phosphorus (P)	When soil test P is below 30 ppm, top-dress P in either the fall or spring. See Table 4 and page 10.
Potassium (K)	When soil test K is below 200 ppm, top-dress K in either the fall or spring. See Table 5 and page 10.
Sulfur (S)	Top-dress sulfate-S in the spring or fall at a rate of 20 to 30 lb S/acre every year or 40 to 50 lb S/acre every other year. See page 10.
Magnesium (Mg)	When soil test Mg is below 0.8 meq/100 g or 100 ppm, apply either 1 ton dolomite/acre (if pH $<$ 5.5) or 500 lb K-Mag/acre (if pH $>$ 5.5). See page 5.
Calcium (Ca)	When soil test Ca is below 5.0 meq/100 g or 1,000 ppm, apply 1 ton lime/acre. See page 4.
Boron (B)	For clover pastures, broadcast application of 2 to 3 lb B/acre is recommended when soil test B is below 0.7 ppm. See page 11.
Selenium (Se)	Refer to *Selenium Supplementation Strategies for Livestock in Oregon* (EM 9094) to determine whether you should consider correcting Se deficiencies in grazing animals via fertilizer applications. See page 11.
Molybdenum (Mo)	For clover pastures, Mo deficiencies can be corrected by following lime recommendations in this guide. See page 11.

2

Table 2. Lime application rates for grass or grass/white clover pastures.[1]

	At seeding	Established field
If the SMP buffer test for lime is[2]	Apply this amount of lime and incorporate (t/a)	Top-dress this amount of lime (t/a)
Below 5.5	4 to 5	2
5.5 to 5.8	3 to 4	2
5.8 to 6.1	2 to 3	2
6.1 to 6.5	1 to 2	1 to 2
Above 6.5	0 to 1	0 to 1

[1]Liming rate is based on 100-score lime, which is an index of calcium carbonate content, moisture, and fineness. For more information about lime materials and lime score, see EM 9057, *Applying Lime to Raise Soil pH for Crop Production (Western Oregon).*
[2]OSU lime recommendations are calibrated specifically for the SMP buffer. Recommendations have not been established for Sikora or other buffer pH methods.