A Self-Learning Resource From MSU Extension

MONTANA STATE UNIVERSITY EXTENSION

MontGuide

Developing Fertilizer Recommendations for Agriculture

by Courtney Pariera Dinkins, Research Associate, and Clain Jones, Extension Soil Fertility Specialist/Assistant Professor, Department of Land Resources and Environmental Services

Developing fertilizer rates specific to your soil and crops should improve crop yield and profit.

MT200703AG New 7/07

THE PURPOSE OF THIS GUIDE IS TO PROVIDE producers, Extension agents and crop advisers with the tools to more accurately determine fertilizer rates to optimize crop yield and reduce loss of nutrients to the environment, thereby increasing profit.

FERTILIZER RECOMMENDATIONS AND GUIDELINES

Soil test results typically include a fertilizer recommendation that is based upon your previous crop, the crop to be grown and your yield goals (just for nitrogen (N)). However, recommended fertilizer rates may be adjusted based on climate and soil properties at your specific location due to the high degree of variability throughout the state of Montana and between soil testing labs. In addition, out-of-state labs often do not use Montana guidelines, so you may need to determine fertilizer rates yourself, or at least check the recommended rates. If you are unfamiliar with soil test reports, developing yield goals or fertilizer calculations, please first see Interpretation of Soil Test Reports for Agriculture (MT200702AG). See "Extension Materials" at the back of this publication for web address and ordering information.

Crop advisers and agricultural Extension agents generally know regional differences in nutrient needs, so if you are a producer, they may be the best source for specific recommendations. However, if you wish to determine approximate fertilizer rates based on Montana State University guidelines (EB161), this guide is designed to enable you to do this. Keep in mind that these guidelines are considered the best averages for the entire state, and may not represent your local soil and climate conditions.

SOIL ANALYSIS CONVERSION

Laboratories report some nutrients in parts per million (ppm), and, generally, will convert results from ppm to pounds per acre (lb/acre) for mobile nutrients, such as N. However, if your soil sampling depth was not provided, this conversion cannot be made. To determine N application rates, results in ppm will need to be converted to lb/acre (see Soil Analysis Conversion sidebar).

SOIL ANALYSIS CONVERSION (ppm to lb/acre)

Calculation: N (lb/acre) = Nitrate-N (NO_3-N) Concentration (ppm) x 2 x Soil Sample Thickness (in.)/6 in.
(Assuming: 2 million pounds of dry soil in upper 6 in./acre)

Example:	Depth	NO_3-N (nitrate expressed as N in ppm)
	0 – 6 inch	8 ppm
	6 – 24 inch	4 ppm

N in 0 – 6 inch increment = 8 x 2 x 6 in./6 in. = 16 lb N/acre
N in 6 – 24 inch increment = 4 x 2 x 18 in./6 in. = 24 lb N/acre
N total in 0 – 24 inch profile = 40 lb N/acre

FERTILIZER RECOMMENDATIONS

Nitrogen

Standard Rate

To calculate a standard (or approximate) N fertilizer rate, you only need 1) your soil nitrate-N (nitrate expressed as N) level, 2) your yield goal, generally based on recent averages, and 3) the crop to be seeded. MSU guidelines are based on the general N requirements to attain a desired yield (i.e. N required per bushel or weight of crop). For example, these guidelines suggest 3.3 pounds of N per bushel (lb N/bu) of spring wheat, 2.6 lb N/bu of winter wheat, 1.2 lb N/bu of malt barley and 25 lb N/ton of grass. After the total available N needed is either calculated, or found in Tables 1-17 of

EB 161 (see Table 1 for an example), the amount of soil available N is subtracted from the total available N needed to determine fertilizer N need. The result will be in pounds per acre (lb/acre), also referred to as 'units of N'. See Calculation Box 1 for an example (on crop-fallow). You can also use the fertilizer calculator provided at http://www.sarc.montana.edu/calculators.

Table 1. Winter wheat nitrogen guidelines based on soil analysis. (Table 17 of EB 161: http://www.montana.edu/wwwpb/pubs/eb161.pdf)

Yield Potential (bu/acre)[a]	Available N (lb/acre)[b]
30	78
40	104
50	130
60	156
70	182
80	208
90	234

[a]Attainable yield with all growth factors optimized
[b]Fertilizer N = Available N - soil NO_3-N

Adjustments to Standard Rate

To adjust the standard N rate based on your specific conditions, it is useful to know the organic matter (O.M.) content, soil sampling date, sampling depth (if more than 2 feet), the previous crop and the amount of straw residue remaining on the surface in continuously cropped fields. Adjustments based on these five factors follow.

1. The level of O.M. in your field should relate directly to how much N is released during the growing season. MSU guidelines assume a typical O.M. content of 2%. If the O.M. content is 1% or lower, 15 to 20 lb N/acre should be added to your standard rate because less N will likely be released from the O.M. present. Conversely, if the O.M. is 3% or higher, you can subtract 15 to 20 lb N/acre from your standard rate.

2. If the previous crop was a legume, N rates can be decreased because some N from these high N containing crops will likely be released during the growing season. For example, MSU guidelines suggest decreasing the N rate by 40 lb N/acre if the previous crop was alfalfa. This is termed as an N 'credit'. The N credit for annual legumes ranges from 0 to 20 lb N/acre. It is recommended that a smaller credit (<10 lb N/acre) be used on fields that have only had one year with an annual legume, whereas a larger credit (10-20 lb N/acre) be used when annual legumes have been grown at least 3 years.

3. If fertilizer N will be surface applied to small grain stubble that remains on the surface from the previous year, some N will generally be tied up ('immobilized'). Add 10 lb N/acre to your standard N rate for each 1000 lb stubble per acre that remains on the surface, up to 40 lb N/acre. Subtract any amount of stubble removed as baled straw from the stubble weight to determine the amount of stubble remaining. Stubble to grain ratios for barley, spring wheat and winter wheat are approximately 1.13, 1.33 and 1.67 lb stubble/lb grain, respectively. See Calculation Box 2 for N adjustments based on remaining grain stubble.

4. Sampling time is important because MSU guidelines assume that sampling occurred in the spring. Soil testing in the fall does not always capture the true amount of N that will be available at spring seeding because some O.M. decomposition occurs during the winter months, releasing plant-available N in a process called "mineralization". Fall nitrate-N levels will be similar to spring nitrate-N levels if the fall and winter are cold and dry because these conditions decrease N mineralization. In three Montana soils with an average of 1.8% O.M., soil nitrate-N levels were about 25 lb N/acre higher in the spring than late summer/early fall based on a study by Miller et al. (2006). Therefore, if soil is tested in the late summer or early fall, your

Calculation Box 1. Fertilizer nitrogen rate for spring wheat after fallow.

Spring wheat N fertilizer guidelines for a 50 bu/acre yield potential = 165 lb N/acre[a]
Soil NO_3-N (from soil test report) = 40 lb N/acre
Fraction of N in Urea Fertilizer (46–0–0) = 46% = 0.46 lb N/lb urea
Calculations:
Fallow-Spring Wheat
Recommended Fertilizer N = Recommended N – Soil NO_3-N
= 165 lb/acre – 40 lb/acre = **125 lb/acre**
Fertilizer (Urea) Needed = Recommended Fertilizer N ÷ Fraction of N in Fertilizer
= (125 lb N/acre) ÷ (0.46 lb N/lb urea) = **272 lb urea/acre**

[a]Table 17 from EB 161

Calculation Box 2. Worksheet to determine nitrogen adjustments for remaining stubble.

Grain Weight:
Grain Weight = Last Year's Yield (bu/acre) x Test Weight[a] (lb grain/bu)
= _____bu/acre x _____lb/bu
= _____lb grain/acre

Stubble Weight:
Stubble Weight = Grain Weight x Stubble/Grain Ratio[b]
= _____lb grain/acre x _____lb stubble/lb grain
= _____lb stubble/acre

Stubble Remaining Calculation:
Stubble Remaining = Stubble Weight (lb stubble/acre) - Stubble Baled/Removed (lb stubble/acre)
= _____lb/acre – _____lb/acre
= _____lb/acre

Nitrogen Adjustment for Stubble Remaining Calculation:
N adjustment for stubble remaining = 10 lb N/1000 lb x Stubble Remaining (lb/acre)
= 10 lb N/1000 lb x _____lb/acre
= **_____lb N/acre (add this to N rate, up to 40 lb N/acre[c])**

[a]Table 21 from EB 161 or measured at grain elevator [b]Stubble/Grain Ratio: 1.13 for barley, 1.33 for spring wheat and 1.67 for winter wheat [c]Montana research indicates that additional N is not needed

fertilizer N rate in the spring of the following year can be decreased by about 25 lb N/acre. This adjustment is dependent upon the previous crop, O.M. content and fall/winter weather conditions. In very wet winters, spring nitrate-N levels can be lower than in the fall (Chen, unpub. data) likely due to leaching, so fertilizer N rates should be somewhat increased in very wet winters.

5. MSU fertilizer guidelines are based on soil tests from the top 2 feet of soil because the best correlations between N uptake and soil N come from this sampling depth. However, substantial amounts of nitrate-N can be present below 2 feet, especially in crop-fallow systems when yield goals have not been met in recent years. Therefore, some crop advisers sample nitrate-N to deeper depths and the amount of nitrate-N (in lb/acre) in the entire sampled profile (up to 4 feet) can be used to calculate fertilizer N amounts. However, if there are dry layers that would prevent roots from penetrating to this depth, substantial leaching is probable or shallow rooted crops are being grown; it is likely that not all of this nitrate-N will be available. In these cases, it is recommended to only assume a fraction of the nitrate-N in these lower depths will be accessed. Although there is no hard and fast rule, a rough guideline would be to use 50% of the nitrate-N at depths from 2 to 4 feet in calculating fertilizer N needs. See Calculation Box 3 to adjust N rates for your situation.

Nitrogen rates can be further adjusted for your fields based on yields and quality from previous years. To determine if past yields have been maximized based on protein for spring wheat and winter wheat, see Fertilizer Facts No. 11 and 26, respectively. See "Extension Materials" at the back of this publication for web address.

Calculation Box 3. Fertilizer nitrogen rate.

	Example	Your Values
Previous Crop	*Legume*	
Standard N Rate	130[a]	
O.M. Correction	+20[b]	
Legume N Credit	-10	
Stubble Correction	+0[c]	
Sampling Time Correction	-25[d]	
50% of Soil Test Nitrate-N below 2 ft	-22[e]	
Fertilizer N Rate	**93 lb/acre**	

[a]Based on a 50 bu/acre spring wheat yield potential (Table 1) [b] < 1% O.M [c]Legume stubble does not require additional N [d]Sampled in fall [e]Soil test value nitrate-N below 2 ft = 44 lb N/acre

Phosphorus and Potassium

Unlike N, phosphorus (P) and potassium (K) are largely immobile in Montana soils, making them less plant available, with P being much more immobile than K. Due largely to these differences, P and K fertilizer requirements are not based on yield goals and soluble nutrient levels, but instead are based on separate soil tests designed to estimate plant availability.

There are three basic approaches to fertilizing plants with P and K: sufficiency, maintenance and build. The sufficiency approach recommends applying the minimum amount of fertilizer necessary to maximize yield in the current year. The maintenance approach recommends replacing the nutrients removed at harvest, and is generally used when soil test levels are high (above 'critical levels'). Critical levels are nutrient levels above which it often does not pay to fertilize. The build approach recommends applying fertilizer to increase nutrient availability over time and save on fertilizer in future years.

To use the sufficiency approach, use Tables 2 and 3 for P and K, respectively. If using the sufficiency approach and P is broadcast rather than banded, it is recommended that rates be doubled for soils with Olsen P levels between 8 and 12 ppm and tripled for soils with Olsen P levels less than 8 ppm. To use the maintenance approach, use Table 4. To use the build approach, add the values from the sufficiency and maintenance approaches. For examples of sufficiency, maintenance and build fertilization strategies, refer to Calculation Box 4.

If a sufficiency approach is used, and P or K soil test levels are above 'critical levels', it is still recommended to use a small amount of starter fertilizer with or near the seed (~10-20 lb nutrient/acre). Starter fertilizer is often useful in Montana because it can help overcome slow movement of native P and K in cool soils common at seeding time. See Calculation Box 5 for calculating P fertilizer needs. Note that the amount of P and K in fertilizer is always expressed as P_2O_5 and K_2O.

Table 2. Selected phosphorus fertilizer guidelines based on soil analysis (Jacobsen et al., 2005). For other crops, see Table 18 of EB 161: http://www.montana.edu/wwwpb/pubs/eb161.pdf.

	Olsen P Soil Test Level (ppm)				
	0	4	8	12	16[a]
	P Fertilizer Rate (lb P_2O_5/acre)				
Alfalfa-Grass	55	50	40	25	10
Barley-Feed/Malt	50	40	30	20	10
Winter Wheat	55	50	45	40	35

[a]For soil analysis levels > 16 ppm, consider using crop removal rates listed in Table 4.

Table 3. Selected potassium fertilizer guidelines based on soil analysis (Jacobsen et al., 2005). For other crops, see Table 19 of EB 161: http://www.montana.edu/wwwpb/pubs/eb161.pdf.

	K Soil Test Level (ppm)					
	0	50	100	150	200	250
	K Fertilizer Rate (lb K_2O/acre)					
Alfalfa-Grass	80	70	60	50	40	25
Barley-Feed	75	65	55	45	30	20
Barley-Malt	90	80	65	50	35	25
Wheat	135	115	90	70	40	10

Calculation Box 4. Example of phosphorus and potassium fertilization strategies.

Winter Wheat Grain Yield Potential = 60 bu/acre
Expected Straw Removal = 1.5 ton/acre

Phosphorus: Assume Olsen P = 8 ppm

Banding Application:

Sufficiency Approach (Table 2):
Recommended P fertilizer rate = **45 lb P_2O_5/acre**

Maintenance Approach (Table 4):
Recommended P fertilizer rate = (0.62 lb P_2O_5/bu x 60 bu/acre) + (3.6 lb/ton x 1.5 ton/acre) = **42 lb P_2O_5/acre**

Build Approach:
Recommended P fertilizer rate = 45 lb P_2O_5/acre + 42 lb P_2O_5/acre = **87 lb P_2O_5/acre**

Broadcast Application:

Sufficiency Approach (Table 2):
Recommended P fertilizer rate = 45 lb P_2O_5/acre x 2[a] = **90 lb P_2O_5/acre**

Maintenance Approach (Table 4):
Recommended P fertilizer rate = **42 lb P_2O_5/acre** (same as for banding)

Build Approach:
Recommended P fertilizer rate = 90 lb P_2O_5/acre + 42 lb P_2O_5/acre = **132 lb P_2O_5/acre**

Potassium: Assume soil test K = 100 ppm

Sufficiency Approach (Table 3):
Recommended K fertilizer rate = **90 lb K_2O/acre**

Maintenance Approach (Table 4):
Recommended K fertilizer rate = (0.38 lb K_2O/bu x 60 bu/acre) + (25 lb K_2O/ton x 1.5 ton/acre) = **60 lb K_2O/acre**

Build Approach:
Recommended K fertilizer rate = 90 lb K_2O/acre + 60 lb K_2O/acre = **150 lb K_2O/acre**

[a]Adjustment for broadcast application at an Olsen P between 8 and 12 ppm.

Table 4. Nutrient removal amounts from harvested portions of crops (Jacobsen et al., 2005). For other crops, see Table 21 of EB 161: http://www.montana.edu/wwwpb/pubs/eb161.pdf.

Crop	Unit	Test Weight	N	P_2O_5	K_2O	Ca	Mg	S	Fe	Zn	Mn	Cu	B
		(lb/bu)	lb										
Alfalfa	ton	NA	48	11	53	28	5	5.5	0.38	0.11	0.11	0.02	0.02
Barley-grain	bu	48	0.87	0.36	0.25	0.025	0.05	0.08	NA	0.002	0.001	0.001	0.001
Barley-straw	ton	NA	14	4.1	30	7.6	2	3.8	NA	0.045	0.3	0.01	NA
Wheat-grain	bu	60	1.25	0.62	0.38	0.025	0.15	0.08	NA	0.004	0.002	0.001	0.001
Wheat-straw	ton	NA	14.5	3.6	25	4.4	2.2	3.7	NA	0.03	0.11	0.007	NA

Calculation Box 5. Calculating P fertilizer need.

Using monoammonium phosphate (MAP) which has a grade of 11-52-0:
Nutrient Fractions = 11% N (0.11 lb N/lb fertilizer), 52% P_2O_5 (0.52 lb P_2O_5/lb fertilizer) and 0% K_2O

Fertilizer Calculation:
Fertilizer Needed = Nutrient Needed ÷ Nutrient Fraction

Application Amount:
To apply 10 lb P_2O_5/acre using MAP
MAP needed = (10 lb P_2O_5/acre) ÷ (0.52 lb P_2O_5/lb MAP) = **19.5 lb MAP/acre**

Q&A Box

Question: Once I have figured how much N, P_2O_5 and K_2O I need, how do I determine a blend of, for example, urea (46-0-0), MAP (11-52-0), and potash (0-0-61)?

Answer: Fertilizer dealers should have blending programs, but if you would like to calculate a blend yourself, use the following approach:

1. Calculate the amount of MAP needed (see Calculation Box 5).
2. Calculate the amount of N in the MAP (0.11 lb N/lb MAP) x (lb MAP/acre)
3. Subtract the amount of N from 2 above from your N recommendation (from soil test report or your calculated N rate) to get a urea N rate.
4. Calculate urea need from your new urea N rate (see Calculation Box 1).
5. Calculate the amount of potash using same approach as for MAP.
6. Add the three fertilizer amounts to get the pounds of fertilizer to apply per acre.
7. Divide each individual fertilizer amount by the total to get the fraction of urea, MAP and potash you will need in your blend.

Sulfur

Unfortunately, responses to sulfur (S) fertilizer are much less consistent than for P and K, partly because concentrations of available S below typical sampling depths can be very high due to high levels of gypsum (calcium sulfate). In addition, soil tests for S often do not accurately reflect S availability. Due to these inconsistencies, MSU fertilizer guidelines do not contain S guidelines.

The highest likelihood of an S response occurs on coarse, shallow soils as these soils generally do not contain much gypsum and have trouble retaining the S that is present. The best way to determine if S applications will result in positive responses is to test your field for increases in grain protein and/or yield after applying soluble S fertilizer in strips. If S is needed, it is often recommended that 15 to 20 lb of S/acre be applied, particularly for canola.

Table 5. Micronutrient fertilizer guidelines based on soil analysis.

Soil Test[a] (ppm)	Fertilizer Rate (lb/acre)
Boron	
0-0.5	2
0.5-1.0[b]	1
Copper	
0-0.5[b]	2
Iron	
0-2.5	4
2.5-5.0[b]	2
Manganese	
0-0.5	20
0.5-1.0[b]	10
Zinc	
0-0.25	10
0.25-0.5[b]	5

[a]0-6 inch sample depth [b]At higher concentrations, no fertilizer is recommended

Micronutrients

Mineral micronutrients are naturally present in soil, yet are required by plants in lower quantities than macronutrients, but are no less important. They include boron (B), chloride (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni) and zinc (Zn). In general, Mo and Ni are present in Montana soils in quantities well above the necessary levels and will not be discussed further. Because micronutrient deficiencies are uncommon, there has been little work in Montana to determine crop-specific micronutrient requirements. Therefore, Montana's micronutrient fertilizer guidelines (for B, Cu, Fe, Mn and Zn) are independent of crop (Table 5). Banding or foliar applications of metal micronutrients (Cu, Fe, Mn, Zn) is recommended over broadcast applications, because metals are very immobile in soil.

The only micronutrient with confirmed deficiencies in Montana that does not have a critical level, or a fertilizer guideline, is Cl, because not enough research has been conducted on this nutrient. Chloride deficiencies occur in Montana due to both low concentrations of Cl in rainwater and infrequent or low potash (KCl) use in some areas due to generally high K levels. Deficiencies of Cl have only been documented in wheat. For example, soil near Poplar, Montana, with 7 lb Cl/acre in the upper 3 feet, was fertilized with 0 and 40 lb Cl/acre (as KCl) and planted with durum wheat. The Cl fertilizer decreased flag leaf spot severity (caused by low Cl) from 87% in the control to 6% in the treated plants and increased yield by 22%. A study on winter wheat found that grain yield increased 16% when 20 lb Cl/acre was applied to soil containing 12 lb Cl/acre in the upper 2 feet of soil. It is recommended to apply about 20 lb Cl/acre to wheat if a Cl deficiency is suspected based on symptoms or soil test levels near, or below, levels observed in these two studies. If you are applying more than 50 lb/acre of potash (KCl) to meet K needs, you will be applying at least 20 lb Cl/acre, which should meet your crop's Cl needs.

Calculation Box 6. Cost per pound of nitrogen and cost per acre of urea.

Example: Urea (Grade = 46-0-0)
Urea Nutrient Fraction = 46% N (0.46 lb N/lb urea)
Cost of Urea = $400/ton (example cost)
Urea application rate = 50 lb N/acre

Calculation:

Cost/lb N
Cost/lb N = Price of Fertilizer per Ton ÷ (2000 lb x Nutrient Fraction)
= $400 ÷ (2000 lb x 0.46 lb N/lb urea)
= **$0.43/lb N (Note: not per lb of Fertilizer)**

Cost of Urea/acre
Cost/acre = (Cost/lb N) x Application Rate
= $0.43/lb N x 50 lb N/acre
= **$22 of Urea/acre**

DETERMINATION OF FERTILIZER COST

Because fertilizers do not contain 100% of any one nutrient, caution must be used in calculating fertilizer costs per ton or per acre. Make certain to consider grade in making these calculations. See Calculation Box 6 for an example showing how to calculate cost per lb of N and cost per acre for urea.

CONCLUSION

By using this guide, accurate fertilizer application rates based on your soil test report can be made. This allows you to check a laboratory's recommendations or develop your own, especially if using an out-of-state laboratory. If you still have questions regarding how much fertilizer to apply based upon your soil test report, please contact your local Extension agent or crop adviser.

REFERENCES

Chen, C. Assistant Professor. Western Triangle Agricultural Research Center. Conrad, MT.

Jacobsen, J., G. Jackson and C. Jones. 2005. *Fertilizer Guidelines for Montana Crops*. Montana State University Extension Service Publication EB 161. http://www.montana.edu/wwwpb/pubs/eb161.pdf

Miller, P.R., R.E. Engel and J.A. Holmes. 2006. *Cropping sequence effect of pea and pea management on spring wheat in the Northern Great Plains*. Agronomy Journal. 98: 1610-1619.

ACKNOWLEDGEMENTS

We would like to extend our utmost appreciation to the following volunteer reviewers of this document:

Dr. Rick Engel, Associate Professor, Montana State University, Bozeman, MT

Mr. Jeff Farkell, Certified Crop Adviser and Senior Agronomist, Centrol Ag Consulting, Brady, MT

Dr. Grant Jackson, Professor, Montana State University, Western Triangle Agricultural Research Center, Conrad, MT

Ms. Virginia Knerr, Broadwater County Extension Agent, Montana State University, Townsend, MT

Dr. Richard Koenig, Associate Soil Scientist/Extension Soil Fertility Specialist, Washington State University, Pullman, WA

Dr. Kent McVay, Extension Cropping Systems Specialist, Montana State University, Southern Agricultural Research Center, Huntley, MT

Mr. Mark Peterson, Producer, Havre, MT

EXTENSION MATERIALS

Fertilizer Facts. Free. Online at: http://landresources.montana.edu/FertilizerFacts/Default.htm

Fertilizer Guidelines for Montana Crops (EB161), single copy free. Online at: http://www.montana.edu/wwwpb/pubs/eb161.html

Interpretation of Soil Test Reports for Agriculture (MT200702AG). Free. Online at: http://www.montana.edu/wwwpb/pubs/mt200702AG.pdf.

Nutrient Management Modules (#4449-1 to 4449-15). Free. Online at: http://landresources.montana.edu/nm

Soil, Plant, and Water Analytical Laboratories for Montana Agriculture (EB150), single copy free.

Obtain Extension publications (will need to add between $1.95 to $2.95 for shipping and handling depending on the number and the publication) from:

MSU Extension Publications
P.O. Box 172040
Bozeman, MT 59717-2040
(406) 994-3273
email: orderpubs@montana.edu
online: http://www.montana.edu/publications

http://www.montana.edu/wwwpb/pubs/mt200703AG.pdf

MONTANA STATE UNIVERSITY EXTENSION

File under: Soil Resource Management

J-1 (Fertilizer)

New July 2007
700-707SA