FERTILIZER guide

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Winter Wheat in Continuous Cropping Systems

(Intermediate precipitation zone)

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Recommendations in this fertilizer guide apply to winter wheat grown after a winter or spring cereal; peas, lentils, or garbanzo beans; canola or mustard; or sunflower or safflower. This guide is one of a set of publications that address the nutritional requirements of nonirrigated cereal crops in north-central and eastern Oregon (Table 1).

Recommendations for nitrogen, phosphorus, potassium, sulfur, chloride, and zinc are covered in this guide. Soils in the region supply sufficient amounts of other nutrients for optimum production of high-quality grain.

Nitrogen

To calculate the nitrogen (N) application rate, determine crop demand and adjust for soil test nitrogen and previous crop history. Evaluate application rates by reviewing the protein content of harvested grain. A detailed explanation is provided on pages 2–5.

Growing conditions

Annual precipitation: 12 to 18 inches

Soil: Silt loam

Soil organic matter content: 1 to 3 percent

Expected yield

40 to 80 bu/acre

Table 1.—Fertilizer guides for nonirrigated cereal production in low, intermediate, and high precipitation zones of Oregon.*

Publication #	Title	Precipitation zone
FG 80	Winter Wheat in Summer-Fallow Systems	Low
FG 81	Winter Wheat and Spring Grains in Continuous Cropping Systems	Low
FG 82	Winter Wheat in Summer-Fallow Systems	Intermediate
FG 83	Winter Wheat in Continuous Cropping Systems	Intermediate
FG 84	Winter Wheat in Continuous Cropping Systems	High

*This set of publications replaces FG 54, *Winter Wheat, Non-irrigated, Columbia Plateau.* Precipitation zones are based on average annual precipitation and are defined as follows: Low = less than 12 inches; Intermediate = 12 to 18 inches; High = more than 18 inches.

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Crop demand for nitrogen

Multiply expected yield by the nitrogen requirement to get crop demand for nitrogen. The nitrogen requirement, *which is the amount of nitrogen required to produce 1 bushel of wheat,* is based on a grain protein goal (Table 2).

Expected yield

Wheat yield depends on soil water recharge over winter, spring growing season precipitation, and previous crop effects. Effects of the previous crop are the result of water use and/or disease suppression.

Water use: Relative water use by the previous crop is as follows.

Water use

↑
Winter wheat, winter canola
Sunflower, safflower, garbanzo bean
Spring cereal, spring mustard or canola
Lentils
Peas

Disease suppression: Disease suppression is a "rotational effect" from an alternative crop grown during the previous year. Reduced disease pressure may increase the attainable yield of a subsequent wheat crop. Legumes, canola, and mustard provide the most benefit. The rotational effect will not be significant if wheat yield (or yield of the alternative crop) is limited by unfavorable growing conditions.

Table 2.—Grain protein goal and corresponding nitrogen requirements (per bushel) for wheat.

Grain protein goal (%)	Nitrogen requirement	
	Average (lb N/bu)	Range (lb N/bu)
9	2.2	2.0–2.4
10	2.4	2.2–2.6
11	2.7	2.4–2.9
12	3.0	2.6–3.2
13	3.3	2.8–3.5

Nitrogen requirement

Average nitrogen requirements are suitable for most situations. The ranges given in Table 2 can be used to compensate for growing conditions, rotational effects, or varieties that are genetically predisposed to having lower or higher grain protein content.

A grain protein content of 10 percent is optimum for soft white wheat. Desired grain protein concentrations for hard wheat range from 11 to 13 percent. Nitrogen requirements for high-protein hard wheat are greater than those for low-protein soft wheat. The extra protein in hard wheat accumulates in grain when plant uptake of nitrogen exceeds that required for maximum yield (Figure 1).

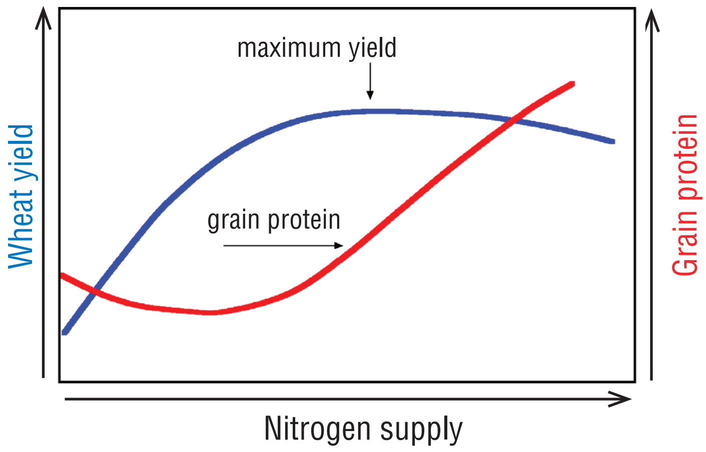

Figure 1.—Generalized relationship of wheat grain yield and grain protein to nitrogen supply.

Adjust for soil test nitrogen and previous crop history

Subtract soil test nitrogen

Laboratory methods are used to test soil samples for plant-available nitrogen (soil test nitrogen). Collect samples from the effective root zone (usually 4 feet) in 1-foot increments and have them analyzed for nitrate nitrogen (NO_3-N). Samples from the surface foot also should be analyzed for ammonium nitrogen (NH_4-N). Add reported values for all depths to get total soil test nitrogen (Table 3).

Table 3.—Soil test nitrogen for samples collected in 1-foot increments. Values are used for application rate calculations in Examples 1–4 (pages 4–5).

Soil depth (inches)	Ammonium nitrogen (NH$_4$-N) (lb/acre)	Nitrate nitrogen (NO$_3$-N) (lb/acre)	Total soil test nitrogen (NH$_4$-N + NO$_3$-N) (lb/acre)	Amount to subtract (lb/acre)
0–12	11	27	38	38
13–24	—	15	15	15
25–36	—	13	13	13
37–48	—	4	4	4
Profile*	**11**	**59**	**70**	**70**
49–60**	—	12	12	—
61–72**	—	10	10	—

* Calculation of the nitrogen application rate should be based on soil test results from the top 4 feet or the effective root zone.

** Nitrogen in the fifth and sixth foot usually does not contribute to yield, but may increase grain protein.

Periodic assessment of nitrate concentration in the fifth and sixth foot can be used to fine-tune nitrogen management. If nitrate concentrations are high or increase over time, consider adjusting the application rate or the time of application. Split applications may improve nitrogen use efficiency.

Subtract for a previous legume crop

The benefit of a previous legume crop is a cumulative effect of: (1) nitrogen released from decomposing residue, (2) reduced N immobilization, and (3) a healthier root system in the subsequent wheat crop. A healthier root system will utilize soil nitrogen or applied nitrogen more efficiently.

Recommended nitrogen credits (Table 4) are based on the assumption that the legume crop produced an average or near-average seed yield. Reduce the credit by 10 lb N/acre if vegetation is removed from the field (e.g., pea vines for hay).

Table 4.—Nitrogen credit for a previous legume crop.

Previous crop (average yield)	Credit (lb N/acre)
Dry peas	25–35
Lentils	10–20
Garbanzo beans	10–20

Add nitrogen for excessive straw from a previous cereal crop

Nitrogen “tie-up” in crop residue (immobilization) temporarily reduces the amount of available nitrogen in the soil; immobilization can be a problem when greater-than-average quantities of straw are present in the field.

Grain yield can be used to estimate the quantity of straw. Increase the nitrogen application rate as shown in Table 5 if grain yield from the previous wheat crop exceeded the **long-term field average** by 10 bu/acre or more. Adjustments for greater-than-average barley or oat yield (straw production) are listed in Table 6 (page 4).

Adjustment is not required if the previous crop was peas, lentils, garbanzo beans, canola, mustard, safflower, or sunflower.

Table 5.—Nitrogen application rate adjustments to compensate for **wheat** yield *(straw production)* that is greater than the long-term field average.

Greater-than-average wheat yield (previous crop) (bu/acre)	Corresponding increase in straw production (lb/acre)	Increase application rate by (lb N/acre)
+10	1,000	15
+20	2,000	25
+30	3,000	35

Table 6.—Nitrogen application rate adjustments to compensate for **barley or oat** yield *(straw production)* that is greater than the long-term field average.

Greater-than-average grain yield (previous crop) (ton/acre)	Corresponding increase in straw production (lb/acre)	Increase application rate by (lb N/acre)
+0.5	1,500	20
+1.0	3,000	35
+1.5	4,500	50

Combining the pieces

Nitrogen application rates are based on expected yield, a grain protein goal, soil test nitrogen, and residual effects of the previous crop. The effect of a previous crop on expected yield is a consequence of water use and/or disease suppression. A nitrogen credit is justified when the previous crop was garbanzo beans, lentils, or peas. Adjustment for excessive straw is warranted if the previous crop was wheat, barley, or oats and if grain yield significantly exceeded the long-term field average.

The process of putting all this information together is summarized in Table 7. Each row of the table is one possible field situation for continuous cropping systems in the intermediate precipitation zone. Nitrogen application rate calculation examples are provided for the first four rows.

Example 1 (Table 7, row 1). A nitrogen application rate calculation for soft white common and club-type winter wheat (10% protein).

Assumptions include:

- A previous crop of winter wheat
- Expected yield of 60 bu/acre
- Soil test nitrogen = 70 lb N/acre

	(lb N/acre)
Crop demand for nitrogen[*]	
(Expected yield) x (per-bushel N requirement) at desired protein	
(60 bu/acre) x (2.4 lb N/bu) @ 10% protein	**145**
Subtract soil test nitrogen	
0–12"	38
13–24"	15
25–36"	13
37–48"	4
Total soil test nitrogen	**70**
Nitrogen application rate	**75**

[*] Crop demand for nitrogen rounded to nearest 5 lb.

Table 7.—Summary of the process used to calculate a nitrogen application rate. Each row of the table is one example of a possible field situation.

Example	Previous crop	Crop to be grown[*]	Expected yield (bu/acre)	Protein goal (%)	Nitrogen required (lb/bu)	Crop demand[**] (lb N/acre)	Soil test nitrogen (–) (lb N/acre)	Legume credit (–) (lb N/acre)	Excessive straw (+) (lb N/acre)	Nitrogen application rate (lb N/acre)
1	Winter wheat	SWWW	60	10	2.4	145	70	0	0	75
2	Winter wheat[***]	SWWW	60	10	2.4	145	70	0	25	100
3	Winter wheat	HRWW	60	12	3.0	180	70	0	0	110
4	Dry peas	SWWW	70	10	2.4	170	70	30	0	70
5	Spring cereal	SWWW	65	10	2.4	155	70	0	0	85
6	Winter canola	SWWW	65	10	2.4	155	70	0	0	85
7	Spring mustard	SWWW	65	10	2.4	155	70	0	0	85
8	Garbanzo beans	SWWW	60	10	2.4	145	70	15	0	60
9	Safflower	SWWW	60	10	2.4	145	70	0	0	75
10	Sunflower	SWWW	60	10	2.4	145	70	0	0	75

[*] SWWW = Soft white winter wheat; HRWW = Hard red winter wheat

[**] Crop demand for nitrogen rounded to the nearest 5 lb.

[***] Grain yield of this crop was 20 bu/acre greater than the long-term field average.

Example 2 (Table 7, row 2). A nitrogen application rate calculation for soft white common and club-type winter wheat (10% protein).

Assumptions include:

- A previous crop of winter wheat—yield was 20 bu/ac greater than the long-term field average (Table 5)
- Expected yield of 60 bu/acre
- Soil test nitrogen = 70 lb N/acre

	(lb N/acre)
Crop demand for nitrogen[*]	
(Expected yield) x (per-bushel N requirement) at desired protein	
(60 bu/acre) x (2.4 lb N/bu) @ 10% protein	**145**
Subtract soil test nitrogen	
0–12"	38
13–24"	15
25–36"	13
37–48"	4
Total soil test nitrogen	**70**
Add nitrogen for excessive straw	**25**
Nitrogen application rate	**100**

[*] Crop demand for nitrogen rounded to nearest 5 lb.

Example 3 (Table 7, row 3). A nitrogen application rate calculation for hard red winter wheat (12% protein).

Assumptions include:

- A previous crop of winter wheat
- Expected yield of 60 bu/acre
- Soil test nitrogen = 70 lb N/acre

	(lb N/acre)
Crop demand for nitrogen	
(Expected yield) x (per-bushel N requirement) at desired protein	
(60 bu/acre) x (3.0 lb N/bu) @ 12% protein	**180**
Subtract soil test nitrogen	
0–12"	38
13–24"	15
25–36"	13
37–48"	4
Total soil test nitrogen	**70**
Nitrogen application rate	**110**

Example 4 (Table 7, row 4). A nitrogen application rate calculation for soft white common and club-type winter wheat (10% protein).

Assumptions include:

- A previous crop of dry peas
- Expected yield of 70 bu/acre
- Soil test nitrogen = 70 lb N/acre

	(lb N/acre)
Crop demand for nitrogen[*]	
(Expected yield) x (per-bushel N requirement) at desired protein	
(70 bu/acre) x (2.4 lb N/bu) @ 10% protein	170
Subtract soil test nitrogen	
0–12"	38
13–24"	15
25–36"	13
37–48"	4
Total soil test nitrogen	**70**
Subtract for a previous crop of peas	**30**
Nitrogen application rate	**70**

[*] Crop demand for nitrogen rounded to nearest 5 lb.

Review protein content of harvested grain

A postharvest review of grain protein can be a good way to evaluate application rates. Higher-than-desired protein indicates overfertilization—if growing conditions were normal or about average. High protein also can be caused by unusually dry conditions or nitrogen that is positioned deep in the soil profile.

Lower-than-desired protein may be due to an insufficient application rate. Low protein also can be a problem when late-season rainfall results in an above-average yield or when nitrogen losses occur during or after application. Examples of nitrogen losses include “escape” of anhydrous ammonia from dry soil or an unsealed soil surface, volatilization of surface-applied urea, and nitrate leaching below the root zone.

Phosphorus

Application of 25 to 35 lb P_2O_5/acre should increase yield if soil test phosphorus (P) levels are 5 ppm or less (Table 8). A phosphorus application is not recommended when soil test values are greater than 15 ppm.

Phosphorus response in fields with soil test values of 6 to 15 ppm is highly variable. Yield increases from phosphorus fertilization seem to be associated with: (1) high yield potentials, (2) late seeding dates, or (3) root diseases that limit plant growth and development. In fields with soil test levels between 6 and 15 ppm, effects of fertilization are best evaluated through on-farm experiments.

Optimum efficiency is achieved by banding phosphorus. Placement of either liquid or dry material with the seed, below the seed, or below and to the side of seed is recommended. Subsurface shank applications also are effective. Broadcast applications are not recommended.

Table 8.—Recommended phosphorus fertilizer application rates for a range of soil test values.

Soil test phosphorus (P) (ppm)*	Plant-available index	Amount of phosphate (P_2O_5) to apply (lb/acre)**
0–5	Very low	25–35
6–10* **	**Low**	**15–25**
11–15* **	**Moderate**	**5–15**
Over 15	High	0

* Plant-available index is correlated to sodium bicarbonate-extractable phosphorus only and does not apply to other test methods.

** Recommended application rates apply to banded or subsurface shank applications.

***** Phosphorus response in fields with soil test values between 6 and 15 ppm is highly variable.**

Soil sampling for phosphorus

Collect soil samples for phosphorus testing from the surface foot. Reported values are best thought of as an index of availability. The test cannot be used to calculate the pounds of plant-available P_2O_5 per acre.

Potassium

Soil potassium (K) concentrations in regional soils generally are high or very high (>100 ppm extractable K). Fertilizer applications are not recommended.

Sulfur

Sulfur (S) is one of the most limiting nutrients for wheat production—second only to nitrogen in importance. The sulfur requirement of the wheat plant is about one-tenth the nitrogen requirement. Sulfur is necessary for optimum yield and high-quality baking flour.

Sulfur deficiencies in wheat are fairly common in the spring after a wet winter. Above-average precipitation moves sulfate-sulfur (SO_4-S), *the form of sulfur available to plants*, below the root zone. Deficiency symptoms often disappear later in the season as root growth extends to deeper layers of the soil profile.

The soil sulfur (SO_4-S) test is not definitive. Low or moderate soil test values (Table 9) are a first indication that fertilization might be warranted. Other factors need to be considered. Yield responses are more likely if one or more of the following situations apply: (1) winter wheat is seeded late in the fall, (2) more than 5 years have passed since the last application of sulfur, and/or (3) greater-than-average quantities of straw are present in the field. Field experience, observation, and on-farm experimentation provide valuable information about the need for sulfur.

Table 9.—Plant-available sulfate-sulfur and recommended fertilizer application rates for a range of soil test values.

Soil test sulfate-sulfur (SO_4-S) (ppm)	Plant-available index	Amount of sulfur (S) to apply (lb/acre)*
0–5	Low	15–20
6–10	Moderate	10
Over 10	High	0

*Sulfur may be beneficial if SO_4-S soil test values are low or moderate and if: (1) winter wheat is seeded late in the fall, (2) more than 5 years have passed since the last application of sulfur, and/or (3) greater-than-average quantities of straw are present in the field.

Soil sampling for sulfur

Collect soil samples for sulfur (SO_4-S) testing from the surface foot. The test is not definitive, and reported values are best thought of as an index of availability. Field experience, observation, and on-farm experimentation provide valuable information about the need for sulfur.

Optimum efficiency is achieved by banding sulfur. Placement of either liquid or dry material with the seed, below the seed, or below and to the side of seed is recommended. Subsurface shank applications also are effective.

Ammonium thiosulfate liquid (Thiosul, 12-0-0-26) is an effective source of sulfur, but it can injure or kill seedlings when placed with the seed. Avoid this problem by placing the product below or below and to the side of seed.

Elemental sulfur should be used with caution because it is not immediately plant-available. Microorganisms will oxidize elemental sulfur to plant-available sulfate, but the process is a slow reaction that sometimes takes place over several growing seasons. Rates of 100 lb elemental S/acre may be necessary to ensure that adequate sulfate is available during the first growing season.

Chloride

Research shows that application of chloride (Cl) may increase grain yield, test weight, and/or kernel size. It is important to note, however, that these responses occur only some of the time.

Chloride applications are known to increase yield of winter wheat suffering from "Take-all" root rot, and they reduce the severity of physiological leaf spot. Yield responses in the absence of disease also have been observed and may be a consequence of improved plant–water relations.

Consider applying chloride if soil test concentrations in the surface foot are less than 10 ppm. The recommended application rate for chloride is 10 to 30 lb/acre. Benefits from fertilization may last for several years.

Yield increases, when they occur, usually range from 2 to 5 bu/acre. Responses are most often associated with above-average yield. Growers are advised to experiment with chloride on small acreages.

Do not apply chloride with the seed; it is a soluble salt that can delay germination or injure or kill germinating seeds. Rain is required after application to move surface-broadcast chloride into the root zone.

Potassium chloride (KCl) is the most readily available source of chloride.

Zinc

Zinc (Zn) fertilization of dryland wheat has not been economical in research trials. On-farm experiments with fertilization should be limited to small acreages. A zinc application rate of 5 lb/acre is appropriate. A 10 lb/acre application should last for several years.

The potential for a grain yield response increases when DTPA-extractable soil test zinc values (surface foot) are less than 0.3 ppm, soil phosphorus levels are moderate to high, the soil pH is greater than 7.5, and yield potential exceeds 50 bu/acre.

For more information

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*Oregon State University and Pacific Northwest Extension publications

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