Soil Fertility Recommendations for Small Grains

Fact Sheet FS1188







Cooperative Extension

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Small grains (wheat, rye, oats, and barley) are valuable crops to have in a farm rotation. Careful varietal selection and crop management, and fertile soil can produce profitable yields of grain and straw.

With the exception of spring planted oats in the piedmont and mountain regions, small grain crops are all fall-seeded in New Jersey. Spring-seeded wheat, barley, and rye are not recommended.

Well drained loamy soils are best for small grain production. Rye has better tolerance for less ideal soil conditions. For best crop performance the soil pH should be near 6.5 and soil fertility well balanced. When small grains are grown in rotation with legumes, the focus should be on maintaining the desired soil pH level for the legume. For alfalfa, the target soil pH range is 6.8 to 7.0.

Soil fertility recommendations for small grains should be based on a recent soil test and a realistic crop yield goal. The recommendations given in this fact sheet are derived from soil fertility research in New Jersey and surrounding states.

Recommendations for phosphorus (P) and potassium (K) vary depending on the soil fertility test level. Soil fertility levels are based on the Mehlich-3 soil test and are defined for general crops as soil test levels: below optimum (low, medium) optimum (high) or above optimum (very high) in Rutgers Cooperative Extension Fact Sheet 719, "Soil Fertility Test Interpretation." The soil fertility levels described as optimum in this fact sheet are specific for each type of small grain crop. Farmers should not set unrealistic yield goals on soils that test low in P or K. Before above average yields may be achieved on such soils, soil fertility levels should be improved over a period of years.

Nitrogen (N)

Small grain crops are susceptible to lodging and harvest losses when provided with excessive amounts of N from manures, legumes, or fertilizers. On fields with a recent history of manure application, N fertilizer rates should be reduced or eliminated. Small grains grown after legumes usually need lower rates of topdress N fertilizer. A balanced N management program is crucial to achieving economic yield, avoiding lodging, and protecting water quality.

Fall seeded small grain crops usually need 15 to 25 lbs N/acre broadcast and disked in prior to establishment, or preferably drilled with a grain drill at planting time. In some instances, such as where manures have been applied or where significant residual N remains in soil from the previous legume crop, small grains may be established without fall applied N. A soil test for nitrate-N in the 0-6 inch depth prior to planting can be used to determine if N fertilizer is needed. When the soil test finds 25 ppm nitrate-N present, no N fertilizer is recommended for fall establishment. When soil nitrate-N test levels are less than 10 ppm, apply 25 lbs N/acre at time of establishment.

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Small grains are usually topdressed with N (30 to 60 lbs N/acre for wheat or barley) late winter or early spring. In southern New Jersey, the topdress N should be applied early March, in the central region in middle March, and in the northern region in late March or early April. In the case of spring seeded oats, 30 to 40 lbs N/acre is usually broadcast at time of seeding.

For wheat growers interested in a more intensive production strategy, they may split the spring N application. Split applications, especially on sandier soils, often produce higher grain yields. This management system, based on research conducted in Virginia, is adaptable for wheat production in New Jersey. The original detailed Virginia recommendations are described on the web at pubs.ext.vt.edu/424/424-026/424-026.html.

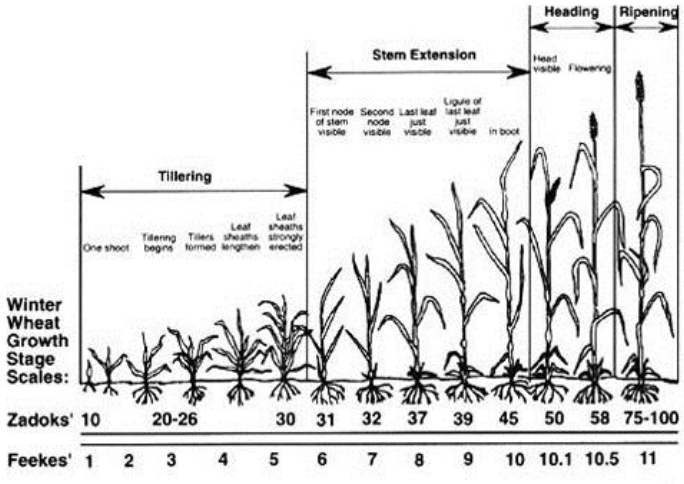


Figure 2. Growth stages of wheat according to the Zadoks and Feekes scales.

In the early spring, at growth stage 25 (GS25), count the number of tillers to decide how much N to apply for the first application. Tiller density is measured by counting all of the tillers along a 3-foot length of row. These counts are taken from at least 5 locations in the field. Tiller density is calculated using this equation: Tiller Density (tillers/sq ft) = Average Tiller Count X 4 / Row Width in inches.

If the tiller density is less than 50 per sq. ft., apply 60 lbs N/acre immediately to encourage tiller development.

However, if the tiller density is greater than 100 per sq. ft., no fertilizer N is need at this time. For a tiller density in the range of 80 to 90, apply 20 lbs N/acre, and for or a tiller density in the range of 60 to 70, apply 40 lbs N/acre.

A decision about how to follow through with the other half of the split application should be based on plant tissue analysis. For a reliable assessment of crop N status, the plant tissue samples must be taken at growth stage 30 (GS30). Wheat plants at GS30 exhibit leaf sheaths that are strongly erect. When plants at GS30 are cut open, the length of the hollow internode should measure about ½ inch. Since changes are rapidly occurring in the crop, tissue sampling at this specific growth stage is critical to obtaining meaningful information on N status.

Rutgers New Jersey Agriculture Experiment Station field trials have demonstrated that if N fertilizer is needed, highest grain yields are achieved with split applications. However, additional costs of dual N applications must be considered.

To obtain a representative tissue sample, avoid unusual areas of the field or decide to sample separately large areas with apparent differences separately. Collect green wheat tissue by cutting plants at ½ inch above the soil surface. Cut tissue from about 25 representative areas in the field. Be careful to avoid getting any soil particles in the sample. Also, remove dead leaf tissue from the sample. Mix the sample and place three handfuls of plant tissue in a paper bag or sample bag provided by the laboratory. Do not place fresh tissue samples in plastic containers.

Immediately submit the tissue to an agricultural testing lab for analysis of total N concentration. The results should be used to determine recommendations at this final window of opportunity to apply topdress N. If the tissue N concentration is near 5.0%, no fertilizer N is recommended. If the tissue N concentration is in the range of 4.5 to 4.0%, apply 20 to 40 lbs N/acre. If the tissue N concentration is in the range of 3.5 to 3.0%, apply 40 to 60 lbs N/acre. If the tissue N concentration is below 3.0%, the application should not exceed 80 lbs N/acre so as to avoid risk of over application that could cause lodging.

Besides N, wheat plants samples may also be analyzed at the same lab for other nutrients. At GS30, a nutrient concentration in wheat tissue considered sufficient is 0.25% phosphorus, 2.0% potassium, 0.10% magnesium, 3 ppm boron, 12 ppm zinc, 20 ppm manganese, and 3 ppm copper. Sulfur, however, is evaluated based on a nutrient concentration ratio. An N/S ratio below 15 indicates a sufficient level of sulfur in relation to nitrogen. If the N/S ratio is about 15, use sulfur containing fertilizers, such as ammonium sulfate, when applying topdress N.

Phosphorus (P)

Many soils have very high or above optimum levels of phosphorus due to years of fertilizer and manure application. No P fertilizer is recommended for small grains grown on such soils.

Soils that test high have optimum phosphorus levels for small grains. The amount of P2O5 recommended is enough to replace the phosphorus removed by the crop. Wheat or rye typically remove 1.0 pound of P2O5 per bushel of grain. Thus, for soils that test high for P, the recommendation for a 50 bu/acre grain yield is 50 lbs P2O5 /acre. The typical removal value for oats is 0.9 pound of P2O5 per bushel and for barley 0.6 pound of P2O5 per bushel of grain.

On below optimum testing soils, the recommended P2O5 rate exceeds crop removal to build the soil test level into the optimum range (Table 1).

Potassium (K)

An adequate supply of potassium for economic yield is a concern for producing small grains on many New Jersey soils. Applying adequate amounts of this nutrient to soils that test below optimum for potassium helps to ensure maximum economic yield. Sandy soils have a more limited capacity to supply potassium than loamy soils and are thus more prone to potassium deficiency.

Small grains take up potassium in large amounts. On soils that test optimum for potassium, it is important to apply enough potassium to maintain this optimum level of fertility. Wheat or rye typically removes 1.8 lbs of K2O per bushel of grain. A 50 bu/acre wheat crop harvested for grain would remove about 90 lbs of K2O in the grain. The typical removal value for oats or barley is 1.5 pound of K2O per bushel of grain.

Potassium is not recommended for soils that test above optimum. On below optimum testing soils, the recommended K2O rate exceeds crop removal to build the soil test level into the optimum range (Table 2).

The total recommended potassium application should generally be broadcast. However, if some of the potassium is applied with the grain drill; do not apply more than 20 pounds of K2O per acre in the row with the seed.

Potassium chloride, also called muriate of potash, or 0-0-60, is the most commonly used source of potassium fertilizer. Potassium sulfate may be used instead when there is a need for sulfur.

Liming Practice: Calcium (Ca), Magnesium (Mg), and Silicon (Si)

Calcium and magnesium are supplied along with the regular liming program to maintain soil pH. Select the appropriate liming material based on its calcium and magnesium concentrations and the relative soil test levels for these nutrients. The goal of the liming program is to maintain the soil fertility levels for calcium and magnesium in the optimum range (about 65 to 70% Ca and 10 to 20% Mg saturation of the soil cation exchange capacity) and to maintain the desired soil pH level for crop rotation.

The most commonly used liming material is limestone. Depending on purity or the concentrations of calcium and magnesium in the mineral, a particular limestone is commonly referred to as calcite (calcium carbonate) or dolomite (calcium magnesium carbonate).

Calcium silicate is another type liming material that maybe used instead. An advantage of applying calcium silicate is that it supplies plant available silicon which has been shown, from research conducted in New Jersey, to suppress powdery mildew disease on wheat.

On the finer textured soils of the piedmont region of New Jersey, a soil pH range of 6.2 to 6.5 is optimum but on the course textured soils of the coastal plain the optimum range is pH 6.0 to 6.2. A lower soil pH range is recommended for the coastal plain soils to reduce the risk for manganese deficiency. Plant nutrient uptake is more efficient within these pH ranges. However, where small grains are grown in rotation with alfalfa, maintain soil pH between 6.5 and 7.0. Soil testing should be performed at a minimum of every 2 to 3 years to evaluate the need for lime. On strongly acid soils, limestone should be broadcast well in advance of planting small grains. Rutgers Cooperative Extension Fact Sheets 903 “Liming New Jersey Soils for Field and Forage Crops” and 905 “Agricultural Liming Materials” provides additional information about liming.

Sulfur (S)

Sulfur-deficient plants have yellow leaves. Sulfur fertilization is generally not based on soil testing. Soil tests for available S are helpful but the required sampling of the subsoil to a depth of 24 inches discourages widespread testing for this nutrient. The need for S fertilization is usually based on soil type, field history, and plant tissue analysis.

Sandy, highly leached, low organic matter content soils are the soils most likely to need S fertilization. Soils high in organic matter content or fields that have a recent history of manure application generally supply adequate amounts of S for small grains. Crop rotations that remove large amounts of crop residues from the field increase the need for S fertilization.

In wheat, S tissue status can be evaluated based on a nutrient concentration ratio when sampled at GS 30. An N/S ratio below 15 indicates a sufficient level of S in relation to N. If the N/S ratio is about 15, S fertilizer is recommended.

Sulfur may be broadcast or drilled at planting. Typical S recommendations range from 20 to 30 lbs S/acre broadcast. When nitrogen fertilizer is topdressed on small grains as ammonium sulfate, the crop can be expected to be well supplied with sulfur. Ammonium sulfate contains 24% sulfur. Other sulfur fertilizers (magnesium sulfate, 14%S; potassium sulfate, 18%S; potassium magnesium sulfate, 23%S; calcium sulfate, 24%S, or gypsum, 19%S) that supply sulfur as sulfate are also effective when surface applied or incorporated. Consider the soil test K, Mg, and Ca fertility levels to select the most appropriate S fertilizer.

Manganese (Mn)

Manganese is often deficient in coarse-textured soils of southern New Jersey but is seldom found deficient in fine-textured soils of northern New Jersey. Sandy soils are very susceptible to Mn deficiency if too much limestone is applied. As soil pH increases, plant availability of soil Mn decreases. Deficiency of Mn on wheat is exhibited yellowing of leaves. On oats, Mn deficiency is described as "gray-speck" where there are whitish-gray spots, flecks, or strips on the leaves. Manganese deficiency is often a persistent and reoccurring problem in certain fields.

Take-all disease on wheat is often associated with Mn deficiency. Application of Mn fertilizer is an effective treatment for reducing the incidence of take-all disease.

On these fields with a history of Mn deficiency, be prepared to apply Mn fertilizer as a foliar spray as soon as the symptoms appear. Manganese fertilizers can be applied as a tank mix with topdress N fertilizer. In severe cases of deficiency, it may be necessary to reapply the Mn sprays during later vegetative growth stages. Apply the Mn at the rate of 0.5 to 1.0 lbs of Mn per acre for each foliar treatment. Manganese sulfate or chelated forms of Mn are equally effective as foliar fertilizers.

Manganese fertilizer may also be applied to the soil, but there is very little long term benefit from soil applied Mn fertilizer. If Mn is soil applied, a typical recommendation is 10 lbs Mn/acre broadcast or 5 lbs Mn/acre drilled. Chelated forms of Mn are not recommended for soil application. Refer to Rutgers Cooperative Extension Fact Sheet FS973 "Manganese Needs of Soil and Crops in New Jersey" for additional information about Mn nutrition, soil test interpretation, and correction of this deficiency.

Iron (Fe)

Iron deficiency is uncommon in wheat grown on New Jersey soils. Refer to Rutgers Cooperative Extension Fact Sheet FS971 "Iron Needs of Soils and Crops in New Jersey" for further information on iron.

Boron (B)

Some crops grown on New Jersey soils require B fertilization. Small grains, however, seldom benefit from boron fertilization. Legume forage crops that may be seeded into small grains are more likely to benefit from B fertilizer. Sandy coastal plain soils are the most susceptible to B deficiency. Soils with less than 0.5 ppm B (by hot water extract or by Mehlich-3 soil test) are considered B deficient. On B deficient soils, broadcast 0.25 to 0.50 lbs B/acre before planting. Because excessive B can cause harm to crops, be careful not to exceed the recommended rates. When small grains are grown as a nurse crop for forage legumes, base the B fertilizer rates on the needs of the forage legume. There are several fertilizer B formulations available for pre-plant broadcast application. Refer to Rutgers Cooperative Extension Fact Sheet FS873 "Boron Needs of Soils and Crops in New Jersey" for additional information.

Zinc (Zn)

Zinc deficiency is not a common occurrence on small grain crops grown on New Jersey soils. When Zn deficiency occurs, it is more likely on soils with pH values greater than 6.5 and on soils testing very high for P. Recommendations for Zn should be based on soil testing. Soils with less than 1.0 ppm Zn (by Mehlich-3 soil test) are considered Zn deficient. On Zn deficient soils, broadcast before planting 10 lbs Zn/acre on coarse-textured soils and 20 lbs Zn/acre on fine-textured soils. Broadcast applications should correct a Zn deficient soil for at least 3 to 5 years. Zinc sulfate, which contains 35% zinc, is the most commonly used zinc fertilizer. For additional information on Zn refer to

Rutgers Cooperative Extension fact sheet FS721 "Zinc Needs of Soils and Crops in New Jersey."

Chlorine (Cl)

Chlorine is a nutrient used by plants in the ionic form as chloride. Wheat and barley crops grown on soils in the Great Plains often benefit from chloride fertilization. The need chloride fertilizer has not been established for small grain crops production in New Jersey. Potassium chloride fertilizers and other amendments used in small grain production often provide considerable amounts chloride to prevent the possibility for chloride deficiency.

Copper (Cu)

Copper deficiency in small grains grown on New Jersey soils is uncommon. For further information on Cu refer to Rutgers Cooperative Extension Fact Sheet FS720 "Copper Needs of Soils and Crops in New Jersey."

Molybdenum (Mo)

Nitrogen fixing bacteria require Mo. New Jersey soils generally contain sufficient Mo, but its availability is strongly influenced by soil pH. Liming acid soils to the proper soil pH (6.0 to 7.0) for wheat production will greatly improve Mo availability. Molybdenum may be applied along with the seed inoculation treatment to forage legume seeds planted along with small grains. Apply 2 ounces Mo per bushel of legume seed. For additional information on Mo refer to Rutgers Cooperative Extension Fact Sheet FS972 "Molybdenum Needs of Soils and Crops in New Jersey."

Organic Soil Fertility Management

The soil fertility management for production of organic small grains should be considered within the context of the overall organic crop rotation cycle or farming system. When transitioning farmland to the organic system, legumes are a better choice to begin the crop rotation cycle than non-legumes because soils under organic transition are usually nitrogen deficient. Nitrogen fertility can be provided for production of small grains from following a good crop rotation system, application of compost, or manures. Be careful to avoid oversupply of N from these sources because excessive N increases the susceptibility to lodging and harvest loss. The soil and plant tests as described above in the section on nitrogen can be helpful diagnostic tools to monitor if an organic N fertility is on target.

On organic farms that include livestock, manure is an important source of fertility, but if supplemental phosphorus or potassium is needed only raw, mined, unprocessed fertilizer sources are approved for organic production. As a source of phosphorus, rock phosphate may be used. If potassium is needed there are three commercial K fertilizers, langbeinite, potassium sulfate, and sylvinite, which may sometimes be used with certain restrictions in organic farming. When micronutrient deficiencies occur, they can be corrected as necessary for organic crop production using many of the same fertilizer materials and application practices as used in conventional agriculture. In organic farming, however, micronutrient fertilizer products cannot be routinely applied without prior soil or plant diagnostics to confirm the specific micronutrient deficiency. Always check with the organic certifier to be sure a particular product is approved for use in organic farming.

Table 1. Recommended phosphorus applications based on Mehlich-3 soil test P for wheat or rye.

Soil Test Category	Mehlich-3 Soil Test P[1]		Yield Goal (bu/acre)				
	(lbs/acre P)	(ppm P)	50	60	70	80	90
			Phosphorus Recommendation (lbs P_2O_5/acre)				
Below Optimum	0	0	110	120	130	140	150
	10	5	100	110	120	130	140
	20	10	90	100	110	120	130
	30	15	80	90	100	110	120
	40	20	70	80	90	100	110
	50	25	60	70	80	90	100
Optimum Range	60	30	50	60	70	80	90
	70	35	40	50	50	60	70
	80	40	30	30	40	40	50
	90	45	10	20	20	20	20
	100	50	0	0	0	0	0

[1]**Optimum soil test P: 60-100lbs/A or 30-50 ppm (Note: ppm x 2 = lbs/acre)**

Table 2. Recommended phosphorus applications based on Mehlich-3 soil text P for oats.

Soil Test Category	Mehlich-3 Soil Test P[1]		Yield Goal (bu/acre)				
	(lbs/acre P)	(ppm P)	70	80	90	100	120
			Phosphorus Recommendation (lbs P_2O_5/acre)				
Below Optimum	0	0	100	110	120	130	150
	10	5	90	100	110	120	140
	20	10	90	100	110	120	140
	30	15	80	90	100	110	120
	40	20	80	80	90	100	120
	50	25	70	80	90	100	120
Optimum Range	60	30	60	70	80	90	110
	70	35	50	50	60	70	80
	80	40	30	40	40	50	50
	90	45	20	20	20	20	20
	100	50	0	0	0	0	0

[1]**Optimum soil test P: 60-100lbs/A or 30-50 ppm (Note: ppm x 2 = lbs/acre)**

Table 3. Recommended phosphorus applications based on Mehlich-3 soil test P for barley.

Soil Test Category	Mehlich-3 Soil Test P[1]		Yield Goal (bu/acre)				
	(lbs/acre P)	(ppm P)	60	70	80	90	100
			Phosphorus Recommendation (lbs P_2O_5/acre)				
Below Optimum	0	0	110	120	130	140	150
	10	5	100	110	120	130	140
	20	10	90	90	100	110	120
	30	15	70	80	90	100	110
	40	20	60	70	80	80	90
	50	25	50	60	60	70	80
Optimum Range	60	30	40	40	50	50	60
	70	35	30	30	40	40	50
	80	40	20	20	20	30	30
	90	45	10	10	10	10	20
	100	50	0	0	0	0	0

[1]**Optimum soil test P: 60-100lbs/A or 30-50 ppm (Note: ppm x 2 = lbs/acre)**

Table 4. Recommended potassium applications based on Mehlich-3 soil text K for wheat or rye.

	Mehlich-3 Soil Test K[1]		Yield Goal (bu/acre)				
	(lbs/acre)	(ppm)	50	60	70	80	90
			Potassium Recommendation (lbs K_2O/acre)				
Below Optimum	0	0	120	140	160	180	200
	20	10	120	140	160	180	200
	40	20	110	130	150	170	190
	60	30	110	130	150	170	190
	80	40	110	130	150	170	180
	100	50	110	120	140	160	180
	120	60	100	120	140	160	180
	140	70	100	120	140	150	170
	160	80	100	110	130	150	170
	180	90	90	110	130	150	170
Optimum Range	200	100	90	110	130	140	160
	220	110	70	90	100	120	130
	240	120	50	60	80	90	100
	260	130	40	40	50	60	60
	280	140	20	20	30	30	30
	300	150	0	0	0	0	0

[1]**Optimum soil test K: 200-300lbs/A or 100-150 ppm (Note: ppm x 2 = lbs/acre)**

Table 5. Recommended potassium applications based on Mehlich-3 soil text K for oats.

	Mehlich-3 Soil Test K[1]		Yield Goal (bu/acre)				
	(lbs/acre)	(ppm)	70	80	90	100	120
			Potassium Recommendation (lbs K_2O/acre)				
Below Optimum	0	0	140	150	160	170	200
	20	10	140	150	160	170	200
	40	20	130	140	160	170	200
	60	30	130	140	150	160	190
	80	40	130	140	150	160	190
	100	50	120	140	150	160	190
	120	60	120	130	150	160	190
	140	70	120	130	140	160	190
	160	80	110	130	140	150	180
	180	90	110	120	140	150	180

[1]**Optimum soil test K: 200-300lbs/A or 100-150 ppm (Note: ppm x 2 = lbs/acre)**

Table 6. Recommended potassium applications based on Mehlich-3 soil text K for barley.

	Mehlich-3 Soil Test K[1]		Yield Goal (bu/acre)				
	(lbs/acre)	(ppm)	60	70	80	90	100
			Potassium Recommendation (lbs K_2O/acre)				
Below Optimum	0	0	160	170	180	190	200
	20	10	150	160	170	180	200
	40	20	150	160	170	180	190
	60	30	140	150	160	170	190
	80	40	130	140	160	170	180
	100	50	130	140	150	160	180
	120	60	120	130	140	160	170
	140	70	110	120	140	150	170
	160	80	100	120	130	150	160
	180	90	100	110	130	140	160

[1]**Optimum soil test K: 200-300lbs/A or 100-150 ppm (Note: ppm x 2 = lbs/acre)**

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