PHOSPHORUS FERTILIZATION
Broadcast Banding and Starter
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INTRODUCTION

Growers in Washington State, particularly grain growers in eastern Washington, have customarily applied seed and fertilizers as two separate operations. With increased production costs many growers are taking a hard look at their overall management operation. Combining the fertilizer application-seeding operation is a convenient way to cut costs and many growers have adopted the practice as a management convenience.

The practice has sparked questions and controversy over proper application methods, particularly with respect to phosphorus application, although combination nitrogen-seeding, nitrogen-sulfur-seeding and complete fertilizer-seeding techniques are also under scrutiny. The questions asked are simple and straightforward. Will applications with the seed increase yields? Can fertilizer applications during seeding be harmful? The answer to both questions is yes. Awareness of plant growth characteristics, fertilizer chemistry, and good management practices are the keys to success.

Grower enthusiasm for something new or better for their production program is contagious. A new practice that is good will spread rapidly. However, a practice with good local adaptation often is used over a wide area of cropping systems and under soil conditions where it is not well suited. Since new equipment is expensive and not easily replaced, some growers continue to use a poor practice to justify the purchased equipment—even though it is not adapted to their conditions.

PHOSPHORUS CHEMISTRY

The fertilizer-soil chemistry surrounding phosphorus fertilization is relatively straightforward. Inorganic phosphorus is immobile in the soil system. It does not leach. Organic phosphorus has greater mobility in soils. Polyphosphate moves farther than other commonly used phosphate products; however, compared with nitrates and sulfates, polyphosphate movement is extremely limited. Efficient phosphorus uptake is dependent upon proper placement.

Applied phosphorus is removed from the soil primarily by plant uptake or soil erosion. Phosphorus removal will vary with different crops, but is in general related to the quantity of harvested crop removed. Phosphorus loss through erosion is directly related to the magnitude of soil loss.

Phosphorus immobilization occurs as a chemical reaction after fertilizers are applied to the soil. The phosphorus in fertilizers is in a chemical form that reacts readily
with calcium, iron, and aluminum—all abundant soil elements. In extremely acid (low pH) soils, iron and aluminum are more abundant than calcium, and applied phosphorus reacts to form iron and aluminum phosphates. In weakly acid to calcareous (high pH) soils, it forms calcium phosphates. In both situations the reaction occurs rapidly within a few millimeters of the application point. Phosphate in the reaction product from either acid or alkaline soils is available to plants as a nutrient but will have extremely low water solubility. Unused phosphorus that has reacted in this manner becomes less available to subsequent crops; however, in extremely acid soils the rate of release is so slow that, for practical purposes, unused phosphate is lost and should be ignored in intensive cropping situations.

**STARTER FERTILIZERS**

Starter or pop-up fertilizers are defined as a small amount of fertilizer applied with the seed at planting time. Equipment to apply starter fertilizers should place the materials near, but not in direct contact with, the seed.

**STARTER FERTILIZER APPLICATION EQUIPMENT**

Fertilizer boxes or attachments on seeding equipment for applying dry granular fertilizers are hardly a new concept. However, a large proportion of the fertilizer materials currently used are liquids, and attachments for applying liquid fertilizers during the seeding operation are becoming more widely used, particularly in reduced and no-tillage systems. The application for both dry and liquid materials is convenient and, with a proper set of management conditions, can appreciably improve fertilizer-seeding efficiency by reducing the number of field passes. On the other hand, increased complexity and time requirement of the seeding operation must also be considered. Although it is essential that growers use practices that are convenient and efficient, increased efficiency does not automatically mean increased yields.

**COLD SOILS**

The increased early growth from using phosphorus is frequently obtained in cold soils where phosphorus soil test readings are high and normally a phosphorus application would not be considered. Root growth and soil exploration for a supply of available phosphorus in cold soils can be limited to a few millimeters per day compared with a warm, moist soil at midseason, where root growth will be 1 1/2 to 2 inches per day. A response to a readily available supply of phosphorus applied as a starter fertilizer in soils containing high phosphorus levels is often obtained during the cool portion of the growing season, as with late fall or early spring seedings, when the soil volume explored by roots is small. This effect is more pronounced when the soil phosphorus level is low or marginal. When soils are warm and root exploration is rapid, the response is usually negligible except in soils with low phosphorus levels.

**SMALL GRAINS**

Root development patterns and rate of root growth determine the relative agronomic advantages of starter fertilizers on different crops. Tillering crops, such as small grains (Figures 1 and 2), form a crown just below the soil surface and develop a complete root system for each new tiller.

The advantage of phosphorus placement near the seed with these crops is short-lived,
particularly so if the soil is warm and plant development is rapid. Starter fertilizers (Figure 1) aid plant development most during the period of time when only the primary root system supports the plant. During this period of time, the initial two weeks of growth, phosphorus placed some distance away from the seed is not available to the young seedling. Following tillering and development of new root systems (Figure 2) phosphorus in either position is equally available. Phosphorus promotes tiller development and head number per area in small grains.

**Figure 1. Fertilizer placement with respect to primary root system development and small grains.**

**Figure 2. Fertilizer placement and secondary root system development in small grains following tillering.**

**CORN**

Starter fertilizer applied to corn in cold soils is utilized much the same as it is on small grains. Corn, instead of tillering, develops a secondary root system from nodes developed between the seed and the ground surface. As the soil warms and secondary root development increases, the relative advantage of fertilizer placed near the seed diminishes.

**PEAS AND LENTILS**

Peas and lentils, important crops for Pacific Northwest growers, do not produce a secondary root system. Root development, as is shown in Figure 3, is from the seed downward. No roots develop above the seed. Hence, the position of fertilizer placement with respect to the seed is considerably more important. Ideally, to be of greatest advantage to the crop, fertilizers on peas, lentils, and beans would be placed directly below the seed, as shown in Figure 3. Fertilizers placed to one side and below the seed are available to the crop as plant roots grow out and down.

Although pea and lentil root systems do expand laterally, few roots in a dryland cropping system grow upward to the soil surface. Normally, rainfall following seeding is limited and the soil surface dries rapidly, prohibiting root growth or nutrient uptake from phosphorus placed above the seeding depth.
Where heavy rates are to be used, it is frequently most efficient to broadcast phosphorus on the ground surface prior to plowing or following plowing but before seedbed preparation.

Two schools of thought prevail toward plow down applications. Both are applicable in Washington State: (a) add nutrients at a level to obtain maximum yield for a given crop. (b) add fertilizers at a rate to correct soil nutrient deficiencies for all crops in a cropping sequence. The latter amounts to fertilizing the soil rather than fertilizing a crop. Both are agronomically sound and can be used to fulfill management needs in today's farming operations.

In dryland cropping systems, the surface soil layer often dries out during later stages of crop development, rendering surface layer P unavailable for uptake. The crop is then reliant on subsoil P availability which can be limiting, particularly in eroded soils. Current research is being conducted to determine methods for enhancing deep P availability and the potential benefits from these practices.

Broadcast applications of phosphorus on established crops should be applied judiciously in Washington. Phosphorus lying on top of the ground can only be used by feeder roots growing near the soil surface. A feeder root system will develop at the soil surface only when the soil is moist. The roots die back as soon as the soil dries. Hence, the amount of phosphorus uptake and response to broadcast applications on growing crops hinge on: (a) a moist soil surface that promotes development of shallow feeder roots and (b) time.

Uptake of phosphorus from broadcast applications on established crops is limited to the period of time when the soil surface is moist. These two phenomena function regardless of the crop species or crop management situation.

Alfalfa or alfalfa-grass mixtures and certain row crops under irrigation respond well to broadcast applications. Dryland alfalfa and legume-grass mixtures, on the other hand, seldom respond well in eastern Washington because the soil surface dries rapidly and uptake is limited to a brief period in the spring.

Dryland peas and lentils in eastern Washington seldom respond well to surface placement on peas, lentil, or beans.
broadcast applications. Typically, rains cease and the ground surface dries shortly after seedling establishment. Surface uptake is further hampered in these crops because the root growth pattern develops from the portion of the plant that develops below the seed as shown in Figure 3. Although pea and lentil roots will grow laterally or, when soil moisture-temperature conditions are right, upward, it is advantageous to place phosphorus below and to the side of seed.

**IRRIGATED CROPS**

The manner of phosphorus application on irrigated crops is less critical than applications on dryland crops. However, the application equipment available and other management conveniences are such that the methods of application under irrigation are frequently identical with methods used for dryland production.

**BAND APPLICATIONS OF PHOSPHORUS**

The use of fertilizer bands less than 12 inches apart and at least 5-6 inches deep is the preferred method for applying all phosphorus materials.

Band applications of phosphorus are often more effective than broadcast applications. They concentrate the phosphorus that is applied so that soil chemical reactions are confined to the outside edge of the fertilizer band. This is particularly important for low phosphorus soils with high P fixation capacity.

Banding phosphorus fertilizer at low rates is more beneficial for immediate cropping needs than a broadcast and plow down application. Optimum response can be obtained with lower rates of fertilizer with banding. This is an especially important fact to consider in times of limited supplies and high prices of fertilizer. Plow down applications depend on complete root exploration for uptake. A single plant root that finds a fertilizer band is capable of supplying complete plant phosphorus needs.

In a program to fertilize the soil to correct a nutrient deficiency of phosphorus for all crops, relatively high rates are often required. Under these conditions banding can be expected to have a greater cost of application than broadcasting because of higher power requirements. Eventually, however, banded applications are mixed by tillage operations and crop responses can be expected to be comparable from either method of application.

**GERMINATION DAMAGE**

Fertilizer salt damage to germinating seed can occur any time high concentrations of materials are placed near the seed. Although damage may occur at low application rates with some plant nutrients, all fertilizer products are capable of damaging seed. The data in Table 1 show the rates at which germination damage occurs when various fertilizer materials are applied as a band placement in wet soil.

<table>
<thead>
<tr>
<th>Material</th>
<th>Grade</th>
<th>Nutrient</th>
<th>7 (lb./A)</th>
<th>12 (lb./A)</th>
<th>18 (lb./A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treble super</td>
<td>(0-46-0)</td>
<td>Phosphorus</td>
<td>892</td>
<td>520</td>
<td>347</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>N</td>
<td>P</td>
<td>K</td>
<td></td>
<td></td>
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<td>----------------------------</td>
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<td></td>
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<tr>
<td>Ammonium nitrate</td>
<td>128</td>
<td>75</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muriate of potash</td>
<td>120</td>
<td>70</td>
<td>47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium phosphate (16-20-0)</td>
<td>124</td>
<td>72</td>
<td>48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium sulfate</td>
<td>82</td>
<td>48</td>
<td>32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium phosphate** (18-46-0)</td>
<td>70</td>
<td>41</td>
<td>27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid ammonium phosphate**</td>
<td>70</td>
<td>41</td>
<td>27</td>
<td></td>
<td></td>
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<tr>
<td>Anhydrous ammonia</td>
<td>32</td>
<td>18</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urea</td>
<td>8</td>
<td>5</td>
<td>3</td>
<td></td>
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</tr>
</tbody>
</table>

*Recalculated data from D.G. Cummings and W.L. Parks, 1961. Soil Science Society Proceedings, Vol. 25, pp. 47-49. Calculations are based on placing seed with the fertilizer material in a one-inch fertilizer band at the indicated row spacings.

**Data supplied by the authors with the assumption that the nitrogen present in 18-46-0 behaves in a similar manner.

The original data of Cummings and Parks have been reworked and tabulated in a manner that assumes all of the fertilizer was placed in a one-inch square band containing the seed. Seeding situations where these data apply are frequently found on spring-seeded crops in wet, cold soils of eastern Washington. Large-seeded legumes, such as peas, lentils, and beans are more susceptible to damage than are small grains. The data are not applicable to fall-seeded dryland wheat because wheat is seeded into much dryer soil.

See EB1426, *Estimate of Salinity Level Produced by Broadcast and Band-Applied Fertilizer* (1989), for a detailed discussion and data applicable to planting fall-seeded wheat into soils of different moisture content, row spacings, and with fertilizer broadcast or banded 3 inches below the seed or 3 inches to the side and 3 inches below the seed.

Fertilizer salts have an affinity for water. In soil systems, water attracted to the fertilizer reduces the amount available for plant growth or, as in the case with seed placement, increases moisture stress on germinating seed. The combined or additive effect of increased fertilizer salt levels and soil drying is shown in Figure 4.

Germinating seed does not differentiate between added tension on the soil water from drying or increased salt levels. The effect of increased tension from either source acting singly or in combination is to restrict the amount of water available to the seed.

A wet soil that has had time to drain following rain will hold water against about .3 atmosphere of pressure. Soil at the wilting point for most plants will retain water against about 15 atmospheres of pressure. Water held between these two tension levels, the field capacity and the wilting point, is the water available for plant growth.
Although, as noted earlier, there are differences in salt tolerance among kinds of plant seed, most crops germinate and emerge normally until the combined moisture drying-salt level moisture tension reaches about 8 atmospheres (Figure 4). At tension greater than 8 atmospheres, seedling emergence drops rapidly. Eight atmospheres of tension can be reached independently by soil drying or by adding fertilizer salts that have an affinity for water, or by a combination of both. The effect in each case is increased tension on water available for plant growth.

Although a drop in the total number of seed that germinate or emerge isn't experienced until tension on soil water is greater than about 8 atmospheres, the time required for germination to occur may be increased. Delayed germination in a drying seedbed, a direct result of moisture stress, is common in fall-seeded wheat on fallow ground all across the Pacific Northwest. Fertilizer materials placed near the seed intensifies the problems by increasing the tension on water at a time when the germinating seed is already in stress.

Fertilizer salt damage is difficult to distinguish from moisture stress in seedling plants. However, there are identifying factors that will aid in distinguishing between the two. The example in Figure 5 can be used as a guide.

Seed germination in the presence of excess salts is slow. Frequently, germination may be delayed 10 days with subsequent reduction in germination percentage as is indicated in Figure 4. Further, seed that does germinate in the presence of excess salt or comes in contact with excess salt after germination, grows slowly. Root growth is limited, and root tip burn is frequently found where roots come in contact with fertilizer bands. The retarded growth rate reduces seedling vigor and the seedling frequently lacks energy to push through to the soil surface. Hence, salt-damaged seedlings that have not emerged will often be found to have misshapen coleoptile tips.

As is common with moisture stress, germinating seeds that survive the rigors of high salt levels and emerge through the soil surface frequently recover, develop a normal root system, and grow to maturity in a normal manner.

Fertilizer salt damage is less likely to occur on spring-seeded crops in the Pacific Northwest because of wet seeding conditions and slow soil-drying conditions. Damage or lack of damage, particularly on fall-seeded crops, will hinge on the moisture level in the seedbed. Under normal fall seeding conditions, any fertilizer product applied with the seed that contains more than 10-15 lbs/A nitrogen may retard germination.

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1The pressure necessary to remove water from soil and the tension soil exerts to water are used interchangeably. Measurement in atmospheres is based on normal air pressures, 14.7 lbs. square inch, exerted on all exposed surfaces at sea level.
Figure 4. Effect of soil drying and fertilizer salts on germination.

Figure 5. Salt damage symptoms on seedlings.

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