Northwest Columbia Plateau PM$_{10}$ Project

Objective 5: Wind Erosion and PM$_{10}$ Emission Control Methods

Title: Optimizing Seeding Rate and Phosphorus Fertility to Enhance the Yield of Recrop, Late-seeded Winter Wheat

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Abstract of Research Findings
Field studies were established in fall 2004 at five locations in the low to intermediate rainfall zones of eastern Washington. One location was abandoned due to poor stand establishment. Three of the remaining locations were recrop winter wheat while the fourth was winter wheat after a year of chemical fallow. Each study involved a factorial combination of two seeding rates (40 and 70 lb/acre) and five phosphorus rates (0, 20, 40, 60 and 80 lb P$_{2}$O$_{5}$/acre) applied as fluid ammonium polyphosphate in a deep band placed 2 to 3 inches below the seed row. Plant emergence, early season dry matter accumulation, final grain yield, grain yield components and straw and grain phosphorus uptake were determined. Under conditions of low seed zone moisture (e.g., September planting in chemical fallow), higher rates of phosphorus placed in a deep band reduced winter wheat stand density. Negative effects of phosphorus on stand density were not observed with late seeded wheat, presumably due to more favorable seed zone moisture conditions and a lower potential for fertilizer salt injury. There were linear relationships between phosphorus rate and vegetative-stage dry matter accumulation with late seeded wheat at two of the four locations, and a quadratic response at the early-seeded chemical fallow site. There was also a linear relationship between phosphorus rate and grain yield at two of the recrop locations, and a quadratic response to phosphorus rate at the chemical fallow location. Higher seeding rate resulted in higher grain yield at the chemical fallow location only. Samples for yield component and phosphorus analysis are still being processed. Preliminary results indicate that improved phosphorus nutrition can increase early season dry matter production and final grain yield of late-seeded winter wheat in recrop and chemical fallow situations. However, based on this one year of data the response to phosphorus may be relatively small and not economical in recrop situations due to the low overall yield potential.

Objectives
1. Assess the impact of seeding rate and phosphorus fertility on grain yield of direct-seeded, recrop winter wheat in low- and intermediate-rainfall zones of eastern Washington;
2. Evaluate the effects of seeding rate and phosphorus fertility on winter wheat grain yield components and straw production;
3. Evaluate economic returns from late seeded recrop winter wheat in comparison to recrop spring wheat or winter wheat-chemical fallow (to be addressed beginning in year
2);
4. Evaluate select seeding rate and phosphorus fertility treatments in on-farm tests conducted throughout the low rainfall area (to be addressed in year 3).

Methods and Materials
Objectives 1 and 2: Field studies were established in fall 2004 at five locations in eastern Washington (Walla Walla, Lind, Ritzville, Ralston, and Harrington) (Table 1). All locations except Ritzville were recrop winter wheat. Ritzville was winter wheat sown on a chemical fallow site. Each study involved a factorial combination of two seeding rates and five phosphorus rates. Seeding rates were 40 and 70 lb/acre at Lind, Ritzville, Ralston, and Harrington. Due to a higher rainfall and associated yield potential, seeding rates were 70 and 100 lb/acre at Walla Walla. All sites were seeded on 7.5 inch row spacing with 10 rows per plot. The soft white winter wheat variety Eltan was sown at all locations except Walla Walla, where Madsen was sown. At the Ritzville site both early and late seeding dates were included in the trial. Preplant soil test phosphorus and seeding dates for all locations are described in Table 1.

Fluid ammonium polyphosphate was applied at rates of 0, 20, 40, 60 and 80 lb P$_2$O$_5$/acre at each location. Phosphorus was placed in a deep band 2 to 3 inches below the seed row in combination with nitrogen at a rate of 50 lb N/acre at Lind, Ritzville, Ralston, and Harrington and 50 lb N/acre at Walla Walla. A Fabro no-till drill was used to deliver the phosphorus treatments and seed in a one-pass operation. The drill features two separate gangs of double disk openers, one for fertilizer application and one for seeding. Each treatment was replicated four times in a randomized complete block experiment design. Individual plot dimensions were seven feet wide by 50 (Walla Walla, Ritzville and Harrington) or 100 (Lind and Ralston) feet long.

Table 1. Location, seeding date, and average soil test phosphorus information.

<table>
<thead>
<tr>
<th>Location</th>
<th>Cooperator</th>
<th>Seeding date</th>
<th>Soil test phosphorus method (mg/kg soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bicarbonate</td>
</tr>
<tr>
<td>Harrington</td>
<td>Jim Els</td>
<td>10/25/04</td>
<td>24.5</td>
</tr>
<tr>
<td>Lind</td>
<td>WSU Station</td>
<td>10/27/04</td>
<td>18.3</td>
</tr>
<tr>
<td>Ralston</td>
<td>Jerry Snyder</td>
<td>10/27/04</td>
<td>13.0</td>
</tr>
<tr>
<td>Ritzville</td>
<td>Rob Dewald</td>
<td>09/17/04 (early)</td>
<td>18.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10/25/04 (late)</td>
<td></td>
</tr>
<tr>
<td>Walla Walla</td>
<td>Alan Harwood</td>
<td>10/20/04</td>
<td>13.2</td>
</tr>
</tbody>
</table>

Early dry matter production was assessed by harvesting six linear feet of plant row from each treatment on late May 24, 2005. Grain yield was measured by harvesting an area five feet (8 rows) in width by 40 to 90 feet in length from the center of each plot with a small plot combine. Samples were collected for yield component (plants per area, spikes per area, kernels per spike and weight per kernel) analysis before grain harvest. Yield components samples consisted of six linear feet of sample row hand-harvested at ground level from each treatment. Yield
components and harvest index will be determined from these samples. Grain and straw fractions will be also analyzed for total phosphorus concentration and used together with yield to calculate total phosphorus uptake. Neither yield component nor tissue phosphorus data are available at this time.

These studies were repeated with seeding occurring in fall 2005 at the Lind, Ritzville and Ralston locations only. As in 2004, each location featured a factorial combination of seeding rates (40 and 70 lb/acre) and phosphorus rates. Phosphorus rates were altered to 0, 10, 20, 40 and 60 lb P$_2$O$_5$ acre$^{-1}$. Seeding occurred in early October 2005.

**Objective 3:** Marginal revenue and marginal costs will be determined and used to calculate economically optimum phosphorus rates. This objective will commence when additional yield data are available in 2006 and 2007.

**Objective 4:** On-farm tests will be used to evaluate select treatments in the context of larger plot sizes and rotations characteristic of the low rainfall areas. It is expected that this phase of the research will commence in year 3 of the study, and may involve evaluations of wind erosion from treatments established on larger plots.

**Results and Discussion**
Due to stand establishment problems the Walla Walla site was abandoned in May 2005. A late-season sawfly infestation at the Harrington site resulted in highly variable yield and yield component data at this location.

**Stand establishment:** At Lind there was a significant effect of seeding rate on stand counts (Fig. 1). There was no significant effect of phosphorus rate or interaction between seeding and phosphorus rate on stand counts. Overall, 83.5% of the seeds sown at the 40 lb/ac rate survived to produce countable plants; 72.5% of the seeds sown at the 70 lb/ac rate survived. At Harrington there was a significant effect of seeding rate on stand count (Fig. 1). As with Lind, there was no significant effect of phosphorus rate or interaction between seeding and phosphorus rate on stand counts at Harrington. Overall, 79.5% of the seeds sown at the 40 lb/ac rate survived to produce countable plants; 78.5% of the seeds sown at the 70 lb/ac rate survived. At Ralston there was a significant interaction between seeding rate and phosphorus rate. Phosphorus did not affect stand counts at the 40 lb/ac seeding rate, and an average of 83% of seeds sown at this rate survived to produce countable plants (Fig. 1). There was a trend toward higher stand densities with increasing phosphorus rate at the 70 lb/ac seeding rate (Fig. 1). An average of 58 to 71% of seeds sown at the 70 lb/ac rate survived to produce countable plants. At Ritzville there were three statistically significant two-way interactions between: 1) seeding rate and phosphorus rate; 2) seeding date and seeding rate; and 3) seeding date and phosphorus rate. Higher phosphorus rates reduced stand counts at the higher seeding rate and in early seeded treatments (Fig. 1). There were no effects of phosphorus on late seeded wheat stand counts. At the 70 lb/ac rate, late seeded wheat had higher stand counts than early seeded wheat; effects of seeding data on stand counts were less pronounced with the 40 lb/ac seeding rate (Fig. 1).
Fig. 1. The effect of seeding rate, phosphorus rate and seeding date (Ritzville only) on stand establishment in 2005.

Overall, higher seeding rates tended to produce more plants per unit area. Higher phosphorus rates reduced stand density at the higher seeding rate and particularly with early seeding at Ritzville. The negative effect of higher phosphorus rates at Ritzville may be related to dry seed zone conditions associated with the early planting and an apparent salt effect on the seedlings. Interestingly, higher phosphorus rates resulted in higher stand density with the 70 lb/acre seeding rate at Ralston. This can not be explained at this time.

**Early dry matter accumulation:** There was no significant effect of phosphorus or seeding rate on early dry matter accumulation at Lind (data not presented). At Harrington, the 40 lb/ac seeding rate produced significantly (p < 0.10) less dry matter (1557 lb/ac) than the 70 lb/ac seeding rate (1742 lb/ac). At Ralston, early season dry matter production increased nearly 90% with the 20 lb P2O5/ac rate compared to the control (Fig. 2). Overall there was a significant (P < 0.001) linear relationship between phosphorus rate and dry matter production at Ralston. At Ritzville there was a significant interaction between phosphorus rate and seeding date. For the early seeding date there was a significant quadratic relationship between phosphorus rate and dry matter production, whereas the relationship was linear for the late seeding date (Fig. 2). The quadratic response to phosphorus rate for the early seeded wheat at Ritzville may be related to the reductions in stand density with the higher phosphorus rates at this site (Fig. 1).
Fig. 2. The effect of phosphorus rate (Ralston) and phosphorus rate and seeding date (Ritzville) on early dry matter accumulation by winter wheat.

**Grain yield:** Grain yield was influenced by a phosphorus rate main effect at three of the four locations (Fig. 3). Yield increased linearly with phosphorus rate at the Lind and Ralston locations. At Lind the slope of the line relating grain yield to phosphorus rate indicated a yield increase of 1.6 lb per lb P$_2$O$_5$ applied. At Ralston the slope indicated 3.6 lb grain per lb P$_2$O$_5$ applied. At Ritzville the application of 20 lb P$_2$O$_5$/acre resulted in 580 lb/acre more grain (9.7...
bushels/acre) than the 0 lb P$_2$O$_5$ rate. Overall the relationship between grain yield and phosphorus rate was quadratic at Ritzville.

There was no interaction between phosphorus rate and either seeding rate at any location, or seeding date at Ritzville. There were main effects of seeding date and seeding rate on grain yield at the Ritzville location only. At Ritzville, early seeding resulted in 259 lb/ac higher grain yield than late seeding. The higher seeding rate resulted in 193 lb/ac higher grain yield than the lower seeding rate.

![Graph showing the effect of phosphorus rate on grain yield at maturity.](image)

**Fig. 3. The effect of phosphorus rate on grain yield at maturity.**

**Yield components:** We are completing sample processing for yield component analysis.

**Tissue phosphorus content:** We are completing sample processing for tissue analysis.

Preliminary results indicate that improved phosphorus nutrition can increase early season dry matter production and final grain yield of late-seeded winter wheat. This is similar to results reported by others (Knapp and Knapp, 1978; Blue et al., 1990). Grain yield increases at the recrop sites are relatively small and likely not economical. The response to phosphorus at the chemical fallow location may be economical. Further analysis will be conducted when more data are available.
Preliminary results suggest that at least part of the mechanism responsible for increasing yield may be related to increases in plant dry matter production. Further analysis of harvest index and yield component data will clarify the impacts of phosphorus on yield. Interestingly, seeding rate influenced early season dry matter at only one location, and grain yield only at the Ritzville location. This is in contrast to results reported by Donaldson et al. (2001) which showed increased seeding rate produced a relatively small but significant increases in straw production and grain yield. This latter research, while conducted at Lind, was on a traditional crop-fallow system where moisture availability and yield potential are higher.

Responses to phosphorus were obtained at locations with soil test levels near or above adequate (Table 1). This suggests either historical soil test databases are outdated and not able to accurately predict a response to phosphorus fertilizer in these cropping systems. Additional studies were initiated at two conventional fallow sites to further explore the relationship between soil test phosphorus, fertilizer rate and yield.

References

Publications and Presentations
None