**BACKGROUND INFORMATION AND RESEARCH PROBLEM**

United States wheat (*Triticum aestivum* L.) owes a significant portion of its production to the mid-South, namely, Mississippi, Louisiana, and Arkansas. Approximately 450,000 acres of soft red winter wheat were harvested in Arkansas in 2012, and acreage increased to 615,000 in 2013 (National Agricultural Statistics Service, 2014). Although wheat is best suited for well-drained soils, a significant amount of wheat is produced on Arkansas’ poorly drained loamy and clayey-textured soils. Without adequate drainage, increased concentrations of aluminum and manganese can lead to toxicity and reduce wheat yields (Carver and Ownby, 1995). Compensation for these challenges is achieved by planting wheat on raised beds or incorporating drainage ditches to prevent extended periods of surface ponding.

Nitrogen (N) is one of the most limiting nutrients in cereal crop production and must be applied to most fields in order to maximize yield. Consequently, N fertilizer is one of the greatest input costs associated with Arkansas wheat production. Nitrogen fertilizer costs producers approximately $0.68/lb or $81.60/acre (120 lb N/acre is the current recommendation for the majority of the wheat production acreage), which accounts for 31% of total input costs associated with Arkansas wheat production (University of Arkansas Cooperative Extension Service, 2012).

Overapplication of N fertilizer can lead to yield decreases and profit losses by both increased cost and yield losses due to lodging and increased disease pressure. Current N fertilizer recommendations for Arkansas wheat grain production range from 90 to 120 lb N/acre on loamy-textured soils following crops other than fallow (less N) or rice (more N). Producers participating in the program were applying approximately 120 lb N/acre, which accounts for 31% of total input costs associated with Arkansas wheat production (University of Arkansas Cooperative Extension Service, 2012).

PROCEDURES

Two field experiments, one in 2012 and one in 2013 were conducted to evaluate the responsiveness of wheat to N fertilizer. Trials took place at the Pine Tree Research Station near Colt, Ark., on a Calloway silt loam (fine-silty, mixed, active, thermic Aquic Fraglossudalfs) in 2012 and a Calhoun silt loam (fine-silty, mixed, active, thermic Typic Glossaqualfs) in 2013. Soil series and classification were defined using the Web Soil Survey, by the Natural Resources Conservation Service (Soil Survey Staff, 2010). The Calloway and Calhoun soil series are both classified as poorly drained soils and representative of the standard production setting for wheat produced on poorly drained silt loam soils in the Eastern Arkansas Delta Region.

Soil samples were collected to a 4-inch depth prior to planting and submitted to the University of Arkansas Diagnostic Lab (Fayetteville, Ark.). Samples were subjected to Mehlich-3 extractable nutrients analysis (Helmke and Sparks, 1996) to ensure P, K, S, and other micronutrients were not limiting wheat growth (Table 1). Prior to planting, 50 lb P₂O₅ and 60 lb K₂O/acre were broadcast and incorporated at each location.

Weeds, insects, and diseases were controlled using best management practices according to University of Arkansas wheat production recommendations. Wheat cultivar Ricochet was drill-seeded at a rate of 100 lb/acre and recommended management practices were followed (Johnson, 1992).

Three different N-fertilizer application times for each rate were carried out as follows: Early-single (Feekes stage 3), Late-single (Feekes stage 6), and Split application (one-half of the N applied at Feekes stage 3 followed by one-half of the N applied at Feekes stage 6). The yield study was conducted in 16-ft long by 5.7-ft wide plots that received six different N-fertilizer rates ranging from 0 to 200 lb N/acre using urea (46% N) as the N-fertilizer source. Fertilizer treatments were applied by hand, and fertilizer was treated with the urease inhibitor n-(n-butyl) thiophosphoric triamide, trade name Agrotain® Ultra (Koch Fertilizer LLC, Wichita, Kansas), at a rate of 3 qt/ton in order to reduce ammonia volatilization.

Analysis of variance (ANOVA) was carried out using JMP PRO 9.0 (SAS Institute, Inc., Cary, N.C.). Each experiment was a randomized complete block design with a three by six factorial treatment structure. Each treatment was replicated four times and year was included in the model statement as a random effect. Means were separated using the least significant difference (LSD) test, assessing significance at \( P < 0.05 \).
RESULTS AND DISCUSSION

The ANOVA indicated that there was a significant N application time by rate interaction \( (P = 0.0058) \). Overall, the minimum yield-maximizing N rate and application method was 120 lb N/acre applied as an Early-single or Split application (Table 2). Yield tended to increase as N rate increased within the Split-application treatments until N rate reached 120 lb N/acre at which time grain yield reached a plateau and declined when N rate exceeded 160 lb N/acre. Wheat receiving N as the Split application had similar yields as the equivalent amount of N applied as an Early-single, but the Late-single N application produced yields that were numerically and sometimes statistically lower for each N rate >40 lb N/acre. Overfertilization with N can have an adverse effect on grain yield due to increased lodging, delayed maturity, and increased disease (Wells et al., 1995). Split application of N rates greater than 160 lb N/acre reduced wheat yield. For the Early-single application, yield tended to increase as N rate increased until yield reached a plateau at rates of 120 to 200 lb N/acre. Although this study indicated that the Early-single N application timing could produce similar yields to the Split application at rates of 80 to 160 lb N/acre, N from the Early-single application could suffer substantial loss in years with greater rainfall increasing the risk associated with applying all the N prior to the Feekes 3 growth stage.

For the Late-single application, the soil inorganic-N content was too low to produce significant tillering before fertilizer N was applied, and the N fertilizer was applied late enough that the wheat could not regain all of the yield potential exhibited by the treatments that received at least a portion of the N prior to the Feekes 6 growth stage. Except for the 40 and 80 lb N/acre rates, wheat yields for the Late-single application were statistically lower within a N rate than wheat yields from either the Early-single or Split-application. The greatest yields for the Late-single application were not achieved until 160 lb N/acre was applied, and even then grain yield was ~12 bu/acre lower than the maximum yields attained with the Early-single and Split treatments. However, it is surprising that the Late-single applications were able to provide sufficient N to achieve the yields that they did. Previous work on a silty clay soil has shown that N fertilizer applied as late as Feekes stage 10 can significantly increase wheat yield (Mascagni et al., 1990). In light of these findings, it might be deduced that wheat yield is less affected by tillering than other yield components (number of spikes per square ft., number of kernels per spike, and kernel weight).

PRACTICAL APPLICATION

Wheat grain yields were maximized by application of 120 to 160 lb N/acre as an Early-single or Split application. The Early-single N fertilizer application method is perhaps a less economically sound decision due to the potential for significant N loss in one or multiple events following application of all of the N fertilizer. The Late-single N fertilizer application method does not provide enough N to optimize early plant development on N-deficient soils. Although the results averaged across two years of research do not show clear differences between the Early-single and Split application N-fertilization methods, applying the total N rate in two splits may increase N recovery and reduce N loss compared to an Early-single application with little or no additional costs if N is applied by airplane. The results also support previous research, which suggests that the initial N fertilizer application should be applied no later than Feekes stage 5.

ACKNOWLEDGMENTS

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LITERATURE CITED


Table 1. Selected soil chemical property means from 0 to 4-inch deep soil samples (n = 4) collected from N-fertilization trials located at the Pine Tree Research Station, near Colt, Ark., during 2012 and 2013.

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Soil OM (%)</th>
<th>Soil pH</th>
<th>P (ppm)</th>
<th>K (ppm)</th>
<th>Ca (ppm)</th>
<th>Mg (ppm)</th>
<th>S (ppm)</th>
<th>Fe (ppm)</th>
<th>Mn (ppm)</th>
<th>Zn (ppm)</th>
<th>Cu (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calloway</td>
<td>2.8</td>
<td>7.7</td>
<td>35</td>
<td>112</td>
<td>1801</td>
<td>350</td>
<td>7</td>
<td>290</td>
<td>222</td>
<td>4.7</td>
<td>1.2</td>
</tr>
<tr>
<td>Calhoun</td>
<td>2.6</td>
<td>7.1</td>
<td>29</td>
<td>133</td>
<td>2077</td>
<td>363</td>
<td>6</td>
<td>240</td>
<td>267</td>
<td>2.4</td>
<td>1.2</td>
</tr>
</tbody>
</table>

* OM = organic matter.

Table 2. Winter wheat yield means, averaged across years, as influenced by N-fertilizer rate and application time at the Pine Tree Research Station, near Colt, Ark., during the 2011-2012 and 2012-2013 growing seasons.

<table>
<thead>
<tr>
<th>Application time*</th>
<th>N rate (lb N/acre)</th>
<th>Early-single</th>
<th>Late-single</th>
<th>Split</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(bu/acre)</td>
<td>(bu/acre)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>46b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>56</td>
<td>56</td>
<td>65</td>
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</tr>
<tr>
<td>80</td>
<td>73</td>
<td>71</td>
<td>73</td>
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<tr>
<td>120</td>
<td>92</td>
<td>76</td>
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<tr>
<td>160</td>
<td>90</td>
<td>86</td>
<td>97</td>
<td></td>
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<tr>
<td>200</td>
<td>98</td>
<td>83</td>
<td>87</td>
<td></td>
</tr>
</tbody>
</table>

LSD$_{0.05}$ = 9.3 bu/acre

* Early-single applied at Feekes stage 3; Late-single applied at Feekes stage 6; and Split involved applying one-half of the N at Feekes stage 3 followed by one-half of the N applied at Feekes stage 6.
* The 0 lb N/acre treatment yields reported as an average across all applications.