Rice Grain Yield as Influenced by Various Water Management Practices


ABSTRACT

Increasing concerns over the water use associated with rice production in the Delta has led producers to consider alternative water management practices in an effort to preserve water resources and lower input costs. This trial was initiated to determine the influence of cultivar and water management strategy on rice grain yield at the University of Arkansas System Division of Agriculture’s Rice Research and Extension Center (RREC) near Stuttgart, Ark. Water management treatments included a conventional flood (CF), fields drained according to recommendations from the Degree-Day 50 (DD50) computer program, intermittent flood (IF), and flush (FL) irrigation treatments. The cultivars were chosen to represent commonly produced cultivars in the Delta region and included Presidio, CL151, Jupiter, Cheniere, Clearfield (CL) XL729, and CLXL745. A simple one-way analysis of variance (ANOVA) was used to compare cultivars within a water management treatment as well as how a cultivar performed across the various water management treatments. The two Rice Tec hybrids (CLXL729 and CLXL745), CL151, and Jupiter were among the highest-yielding cultivars across all water management treatments. However, Presidio was the lowest-yielding cultivar in all of the water treatments. The highest yield obtained in this trial was for the hybrid CLXL745 at 251 bu/acre and was achieved in both the CF and IF water management treatments. The lowest overall yield in the trial was Presidio in the FL treatment which only yielded 164 bu/acre. Data presented in this paper indicates that cultivar is an important consideration when implementing alternative water management practices as there is a significant influence on rice grain yield.
INTRODUCTION

Water management and availability is becoming an increasingly important issue for rice farmers in the Delta region of Arkansas. A recent report by the Arkansas Natural Resource Commission indicated that current groundwater supplies in the alluvial aquifer, where most of the groundwater used for agricultural production in Arkansas is obtained, is only 59% sustainable (Arkansas Natural Resources Commission, 2012). Knowing that the quantity of groundwater currently available is not sustainable at current usage rates, the desire to look at alternative water management strategies for rice production is coming to the forefront. Direct-seeded, delayed-flood production practices are the most commonly used technique in Arkansas and it is estimated that ~99% of the acreage is produced using a conventional flood irrigation practice (Hardke, 2014). Currently less than 1% of the total rice acreage in Arkansas is produced with alternative irrigation practices including furrow or sprinkler irrigation. In addition to the flood practices currently used, it is estimated that roughly 78% of the land devoted to rice production in Arkansas relies on groundwater for the primary irrigation water source (Hardke, 2014). Irrigation costs represent a significant portion of the input costs associated with rice production and rank second only behind fertilization (Flanders et al., 2014). Increasing concern associated with the unsustainable use of groundwater for rice production, coupled with the relatively high cost of irrigation, has placed more emphasis on researching alternative irrigation strategies that reduce water use.

Previous research conducted in Arkansas focused on the influence of alternative water management practices on rice grain yield and greenhouse gas emissions (Anders et al., 2013). This research indicated that rice can maintain relatively high grain yields with alternative water management practices, but was limited in scope as it only included hybrid rice cultivars. In order to assess the viability of these alternative water management practices and help producers make informed decisions concerning cultivar selection, more work needs to be done. Therefore this research was established to look at the influence of cultivar and water management practice on rice grain yield.

METHODS AND MATERIALS

Field experiments were established at the University of Arkansas System Division of Agriculture’s Rice Research and Extension Center (RREC) near Stuttgart, Ark., on 24 April 2014. Six commonly produced cultivars were chosen for this trial to represent planting practices across the Mid-south. Pure-line varieties were planted at a seeding rate of ~68 lb seed/acre and hybrids were planted at ~27 lb seed/acre. Emergence date for this trial was 10 May 2014 and the plots were flooded on 6 June 2014. Prior to flooding, 120 lb N/acre was applied as a single preflood application and the water management treatments were established within 48 h following urea fertilizer application. The water management treatments implemented included a conventional flood (CF), DD50 drain (DD50), intermittent flood (IF), and flush (FL) irrigation treatments. In the CF treatment, water was maintained throughout the season at a 3- to 4-inch level following best management practices for direct-seeded, delayed-flood rice production.
Water management in the DD50 treatment was similar to the CF except that the flood was drained until the soil cracked based on the median DD50 straightahead drain date provided for each cultivar. The IF treatment involved the establishment of a 3- to 4-inch flood that was allowed to drop until soil moisture sensors indicated the need to reapply water at which time another 3- to 4-inch flood was applied. Similar to the IF treatment, the FL treatment was flushed (water applied for several hours and then drained off) when soil moisture level dropped to a predetermined level. Soil moisture sensors were installed prior to flooding and used to initiate irrigation in the IF and FL treatments when the soil moisture level dropped to ~20 centibars. The soil moisture level selected to trigger water application in the IF and FL treatments was such that the soil remained moist and the rice plants should not have experienced drought conditions. During this trial the DD50 bay was drained on 24 June 2014 and reflooded on 1 July 2014. The IF treatment received water to reestablish a flood on 7 July 2014 and 28 July 2014, and flushed on 2 September 2014 prior to draining. The FL irrigation treatment received irrigation 20 times throughout the course of the season and the application dates were as follows: 6 June, 20 June, 23 June, 27 June, 1 July, 3 July, 7 July, 9 July, 11 July, 14 July, 21 July, 25 July, 28 July, 4 August, 8 August, 11 August, 15 August, 10 August, 22 August, and 2 September.

Following maturity, the center five rows of each plot were harvested, the moisture content and weight of the grain were determined, and yields were calculated as bu/acre at 12% moisture. A bushel of rice weighs 45 pounds (lb). During harvest, the FL irrigation treatment was harvested with a different combine, but all yield values were similar. A simple one-way analysis of variance was used to compare cultivars within a water management treatment as well as a single cultivar across water management treatments, and means were separated using Fishers protected least significant difference test at $P = 0.05$ level. All statistical analyses were carried out using JMP 11.0 (SAS Institute, Inc., Cary, N.C.).

**RESULTS AND DISCUSSION**

Rice grain yields were significantly influenced by cultivar and water management strategy. Therefore, for the purposes of this paper a discussion of rice grain yields within each water management practice will be presented. The CF treatment is the current standard by which all other practices will be compared. A direct-seeded, delayed-flood production system has some of the highest nitrogen use efficiencies in the world and is very efficient in terms of rice produced per unit area of land. In this trial within the CF irrigation management treatments, the highest numerical yields were seen for Presidio, Cheniere, CLXL745, and CLXL729, with yields of 181, 211, 249, and 251 bu/acre, respectively (Table 1). Although the yields of Jupiter and CL151 in the CF treatment were not the highest numerical yields, they were not statistically different than the highest yielding water management treatments for these two cultivars. Overall the yields for all cultivars within the CF treatment were exceptional.

The DD50 drain treatment is designed to mimic a traditional drain that would be conducted based on the DD50 program to reduce the potential of straightahead for
susceptible cultivars. Although a continuous flood is maintained for the majority of the growing season, there is still a 7 to 10 day period where no water is being pumped on the field, which can reduce total water usage and pumping costs. In theory, there should be no yield loss associated with a DD50 drain when properly executed. However in this trial, Presidio had a significant yield loss when this treatment was compared to the CF treatment, suggesting that Presidio is not as drought tolerant as the other cultivars used in this trial. Presidio was the only cultivar that exhibited a significant yield loss in the DD50 treatment compared to the CF; and for all other cultivars, the yield difference between these two treatments was <7 bu/acre.

Intermittent flooding is a way for producers to reduce total water usage and pumping costs, but lower the risk associated with something like flush-, furrow-, or sprinkler-irrigated rice. When IF is implemented, the water is pumped to a 3- to 4-inch depth and allowed to evaporate or soak in until the soil moisture level requires more irrigation to prevent yield loss. The IF treatment in this trial would dry to the point that you could walk on the soil and leave footprints, but never really track mud. For all cultivars used in this trial, the IF yields were not statistically different than those obtained using the CF irrigation practice. The highest numerical yields for Jupiter, CL151 and CLXL745 were all obtained within the IF treatment. Although high yields were achieved with the IF irrigation treatment, it should be pointed out that blast was not noted in any of the plots, which could have severely limited yields if it had been present. Intermittent flooding can be a viable alternative to CF irrigation when diseases such as rice blast are not present.

Flush or furrow-irrigated rice has the greatest potential for water savings and can significantly increase water use efficiency of rice. In this trial, the FL treatment produced the statistically lowest yields of all the irrigation treatments. Yield losses using the FL treatment ranged from 16% for CL151 to 34% for CLXL745 when compared to the highest-yielding irrigation treatment for those respective cultivars. The yield reductions for hybrid rice seen here are similar to what was reported by Anders et al. (2013), but are counterintuitive to what one might expect. Traditionally we think of hybrids being more drought resistant, but in this particular trial they took more of a yield penalty in the FL irrigation treatment (on a percent yield reduction basis) than did the pure-line cultivars.

**SIGNIFICANCE OF FINDINGS**

The results presented here indicate that alternative water management practices can be implemented to reduce total water usage and input costs associated with irrigation while maintaining relatively high yield potentials. Although water usage was not recorded in this trial, IF has been shown to have lower total water use and in this trial there was no significant difference in rice yield for each cultivar when compared to CF irrigation practices. However during the 2014 growing season at RREC, rice blast was not present in this trial, which could have had a significant impact on rice yield in the IF and FL irrigation treatments where a permanent flood is not maintained throughout the growing season. Pure-line cultivars also performed well in the IF which indicates that they may be viable options in these alternative irrigation management practices.
ACKNOWLEDGMENTS

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LITERATURE CITED


Table 1. Influence of cultivar and water management on rice grain yield at the Rice Research and Extension Center (RREC) near Stuttgart, Ark., during 2014.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Water Management</th>
<th>Yield (bu/acre)</th>
<th>LSD (_{0.05}) (^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flood</td>
<td>DD-50 Drain</td>
<td>Intermittent</td>
</tr>
<tr>
<td>Jupiter</td>
<td>233</td>
<td>236</td>
<td>243</td>
</tr>
<tr>
<td>Presidio</td>
<td>181</td>
<td>162</td>
<td>180</td>
</tr>
<tr>
<td>CL 151</td>
<td>220</td>
<td>221</td>
<td>221</td>
</tr>
<tr>
<td>Cheniere</td>
<td>211</td>
<td>205</td>
<td>204</td>
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<tr>
<td>RT CLXL729</td>
<td>249</td>
<td>246</td>
<td>246</td>
</tr>
<tr>
<td>RT CLXL745</td>
<td>251</td>
<td>244</td>
<td>251</td>
</tr>
<tr>
<td>LSD (_{0.05}) (^b)</td>
<td>16.6</td>
<td>12.5</td>
<td>13.6</td>
</tr>
</tbody>
</table>

\(^a\) LSD \(_{0.05}\) to compare cultivars across water management treatments.

\(^b\) LSD \(_{0.05}\) to compare cultivars within a water management treatment.