# Multiple Inlet Approach to Reduce Water Requirements for Rice Production

E. D. Vories, P. L. Tacker, R. Hogan

**Abstract.** *Traditional flooded rice production utilizes a well or riser in the highest-elevation portion of the field and water spills into lower paddies as the upper paddies are filled. In an alternative method known as multiple-inlet irrigation, rather than discharging directly into the highest paddy, a pipe is connected and gates or holes water each paddy concurrently instead of each receiving overflow from a higher paddy. The objective of this research was to investigate whether a multiple-inlet approach would result in less water being pumped for rice production than conventional flooding, when applied on production-scale fields by the regular farm employees. On-farm water use studies were conducted during the 1999 through 2002 growing seasons. The studies consisted of 14 paired fields located close together, with the same cultivar, soil type, planting date, and management practices. One field was randomly assigned as a conventionally flooded field and the other was assigned as multiple-inlet rice irrigation. Flowmeters were installed in the inlets to both fields and the farmers provided yield data. The multiple-inlet method required 24% less irrigation water than conventional flooding and produced 3% more yield and 36% higher irrigation water use efficiency than conventional flooding. These findings can lead to easing the groundwater shortages being experienced in Arkansas and other rice-producing areas.*

**Keywords.** *Rice, Crop management, Water use, Water conservation, Irrigation, Surface irrigation, Water use efficiency, Water management, Crop production.*

Rice production is an important component of Arkansas' and other southern states' agriculture. In 2003, rice accounted for over $1.2 billion in total cash receipts, almost 10% of the state totals for all commodities for both Arkansas (9.7%) and Louisiana (8.3%) (USDA-ERS, 2004a). When combined with the rice processing, agricultural equipment, and other businesses supporting rice production, it is apparent that rice is also important to the overall economy and not just in the rice-producing states.

While rice is produced in some parts of the world in an upland, rainfed culture, almost all U.S.-produced rice is grown in a flooded culture. In the dry-seeding system commonly used in Arkansas, the crop is usually flooded at approximately the V-4 growth stage (Counce et al., 2000) and, unless a disease or fertility problem requires the field to be dried, a continuous flood is maintained until after heading. Tacker et al. (2001) reported typical values for the amount of irrigation water applied to rice on Arkansas soils ranged from 610 to 1220 mm. Even at the low end of the range (610 mm), rice production in Arkansas over the last five years (1998 through 2002), based on cropland hectares from Arkansas Agricultural Statistics Service (2003), required an average of at least 3.8 million $m^3$ of water applied per year.

The large amount of water applied to rice has resulted in two problems. The energy costs associated with pumping make up a significant portion of the rice production budget, and the cost is influenced by fluctuations in energy prices. In addition, groundwater shortages are being observed in parts of Arkansas and other rice-producing areas and similar problems with surface water sources have been encountered.

Reducing the water requirements for rice has been a goal of farmers and researchers for many years. One approach investigated producing rice in a row-crop culture with sprinkler or furrow irrigation rather than with continuous flood. Several studies have addressed sprinkler irrigation of rice; however, when compared with flooded production in Louisiana (Westcott and Vines, 1986) and Texas (McCauley, 1990), large yield reductions were reported. Similarly, Vories et al. (2002) reported consistent yield reductions associated with rice production using furrow irrigation. Producers will not readily abandon their practice of flooded production for an alternative system that produces lower yields. An alternative multiple inlet approach could require less water while not impacting yield.

Conventional flooded production utilizes a well or riser in the highest-elevation portion of the field (fig. 1a). Contour levees are constructed at approximately every 60 mm in elevation drop and adjustable spills are placed in the levees. When water is released from the well or riser, it fills the first paddy and then flows over the spills into lower paddies. Since the paddies must be overfilled to allow water to pass to the next lower paddy, there is quite a lot of skill and/or guesswork in knowing exactly how much water to pump so that all paddies are filled with little runoff from the lowest paddy.

Article was submitted for review in January 2005; approved for publication by the Soil & Water Division of ASAE in March 2005. Presented at the 2003 ASAE Annual Meeting as Paper No. 032014.

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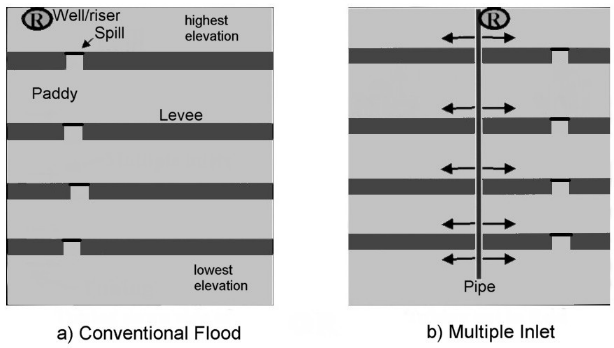


**Figure 1. Two methods of applying floodwater to rice fields: (a) conventional flood and (b) multiple inlet.**

An alternative method for applying flood water is known as side-inlet or multiple-inlet irrigation (fig. 1b). The name “side inlet” comes from the fact that a supply pipe is often installed on the side of the field; however, in many cases the pipe runs somewhere other than the side of the field, so multiple inlet is a more descriptive name. Rather than discharging directly from the well or riser into the paddy, the riser is connected to a pipe and gates or holes are placed in the pipe for each paddy. In this way, each paddy is watered concurrently, instead of receiving overflow from a higher paddy. By adjusting the gates, the operator can fill all paddies simultaneously. The spills are left in the levees to provide a spillway for rainwater. Tacker et al. (2001) provided additional information concerning the method and its application, as well as other potential benefits and disadvantages.

Since it is not necessary to overfill the paddies with multiple inlet irrigation, deep percolation and seepage through the outside levees should be reduced. In addition, since each paddy fills at the same time, it is possible to apply the exact amount of water needed without runoff. More efficient water management for rice will result in lower costs to the producers and allow more effective irrigation of other crops that share the water supply. It will also help relieve some of the water shortages being encountered in eastern Arkansas and other rice-producing areas.

The objective of this research was to investigate whether a multiple-inlet approach would result in less water being pumped for rice production than conventional flooding, when applied on production-scale fields by the regular farm employees; and if water use were affected, determine if it corresponded with a reduction in rice yield.

## METHODS

In order to study water requirements for rice on a production scale, on-farm water use studies were conducted during the 1999 through 2002 growing seasons. The studies consisted of paired fields located close together, with the same cultivar, soil type, planting date and management practices. One of the fields was randomly assigned as a conventionally flooded field (CONV) and the other was assigned as multiple-inlet rice irrigation (MIRI). Propeller-type flowmeters (McCrometer, Hemet, Calif.) were installed in the inlets to both fields and situated to ensure full-pipe flow. When the farmer was ready to begin the flood period, at approximately the V-4 growth stage, Extension personnel installed the flowmeters and assisted in setting up the MIRI field. Disposable, thin-walled, polyethylene irrigation tubing (e.g., Poly-Pipe, Armin Corp., Jersey City, N.J.) was connected to the well or riser and run over the tops of the levees through each paddy. Holes were punched or adjustable gates were installed within each paddy to allow the proper amount of water. The flow rate for each paddy was determined from the total flow rate multiplied by the ratio of individual paddy area to the total irrigated area.

Once the field was set up, the flow to the individual paddies could be adjusted so that all paddies filled simultaneously. During the flood period, Extension personnel periodically visited the fields to ensure that everything was working correctly. After the final draining of the fields, Extension personnel recorded the amount of water pumped on the fields. The farmer provided yield data for the fields from his farm records. The farm personnel managed the fields after the initial set up was completed. Thus, as an added benefit, the farmers and farm employees were able to provide input on the practicality of multiple-inlet irrigation and whether they would continue to use it after the study.

The overall economics of the methods will play a larger role in whether or not producers are willing to adopt a new system than will potential water savings alone. Bryant et al. (2001) estimated irrigation costs in Arkansas, and their findings would be similar to other southern states. They considered three irrigation systems commonly employed for rice production: a stationary relift system for surface water with 6-m maximum vertical pipe; “standard” well (i.e., < 37 m deep); and “deep” well (i.e., depths between 37 and 73 m). The standard and deep wells in the publication both referred to wells in the alluvial aquifer found in parts of Arkansas, Louisiana, Mississippi, Missouri, and Tennessee. In some areas of Arkansas, the alluvial aquifer no longer produces enough water to supply irrigation needs and some agricultural wells have been drilled into the deeper Sparta aquifer. Layne Arkansas Co. (Stuttgart, Ark.), a company that develops wells in the Sparta aquifer, provided the cost information needed to expand on Bryant et al. (2001) to include Sparta wells.

To investigate the economics of multiple inlet rice irrigation, costs were calculated for each of the study fields for water from each of the four sources (i.e., stationary relift − RELIFT; standard well − STANDARD; deep well − DEEP; and Sparta well − SPARTA). Each of the systems was assumed to have a diesel power unit and the cost of diesel was assumed to be a constant $0.264/L. Revenue was determined from the rice yield provided by the farmer and a constant price of $0.143/kg, the federal loan price for the period of the study (USDA-ERS, 2004b). The case of rented farmland was also considered, with the landlord receiving 25% of the crop as rent payment and not sharing in the expenses. To determine the effect of assuming constant diesel cost and commodity prices, sensitivity analyses were conducted for these variables. Finally, because the fields were managed identically except for water, a partial-budgeting approach was used and no other costs were considered in the economic comparisons.

The data were analyzed using the MIXED procedure of SAS (Statistical Analysis System Release 8.02; SAS Institute Inc., Cary, N.C.), with years, farm(years), and years*irrigation method as random effects, and least square means rather than arithmetic means were reported.

## Results and Discussion

During the four-year study period (1999-2002), data for comparisons were collected from 14 pairs of fields ranging in size from 12.5 to 32.4 ha (table 1). The farms represented the northern, central, and southern portions of the rice-growing region in Arkansas, and the range of soil types used for rice production. All of the values observed for CONV in each of the years were within the range of values reported by Tacker and Slaton (1992) for measurements from 42 Arkansas rice fields during the years 1983 through 1990 (380 to 1710 mm).

The MIRI method required 24% less irrigation water application than conventional flooding, with 930 and 703 mm for CONV and MIRI, respectively (table 2). In addition, the MIRI field used numerically less water for each of the 14 farms, ranging from 10% less for the Crittenden County farm in 2002 to 42% less for the Poinsett County farm in 2002. The reduction in irrigation water applied to the MIRI fields is important to rice farmers for more than just water savings. Rice fields often share a water supply with other crops. The ability to adequately irrigate the other crops is usually dependent on first being able to adequately irrigate the rice crop. Therefore, a 24% water savings on the rice crop should correspond to more income on other crops. If the well is not shared, less pumping for rice should result in less overall demand on aquifers that are experiencing declining water levels.

Yields in the study were similar to the state average yields (Arkansas Agricultural Statistics Service, 2003) in each of the years with one exception. In Crittenden County in 2002 yields were 5.04 and 5.30 Mg/ha for CONV and MIRI, respectively, versus a state average yield of 7.22. The fields had been precision graded the previous year, which is often associated with reduced yields, and there were indications of straighthead, a yield-reducing disease affecting rice. Since both methods were similarly affected, the data were included in the analyses.

**Table 1. Fields used in the study comparing multiple-inlet rice irrigation with conventional flooding in Arkansas during the 1999 through 2002 growing seasons.**

| Year | Farm | Arkansas County | Soil Type | Field Size (ha) Irrigation Method[a] CONV | MIRI |
|---|---|---|---|---|---|
| 1999 | 1 | Lincoln | Sandy loam | 12.5 | 15.0 |
| 1999 | 2 | Lee | Sandy loam | 17.4 | 16.2 |
| 1999 | 3 | Desha | Clay | 15.0 | 15.0 |
| 2000 | 1 | Ashley | Silt loam | 21.9 | 28.7 |
| 2000 | 2 | Crittenden | Clay | 15.4 | 15.4 |
| 2000 | 3 | Crittenden | Clay | 16.2 | 16.2 |
| 2001 | 1 | Crittenden | Clay | 25.9 | 28.7 |
| 2001 | 2 | Crittenden | Silt loam | 29.9 | 29.1 |
| 2001 | 3 | Cross | Silt loam | 24.7 | 27.5 |
| 2001 | 4 | Chicot | Clay | 30.4 | 32.4 |
| 2001 | 5 | Arkansas | Silt loam | 20.2 | 20.2 |
| 2002 | 1 | Desha | Silt loam | 23.1 | 29.1 |
| 2002 | 2 | Poinsett | Clay | 15.0 | 29.9 |
| 2002 | 3 | Crittenden | Sandy loam | 17.4 | 16.2 |

[a] CONV = conventionally flooded; MIRI = multiple-inlet rice irrigation.

**Table 2. Findings from the study comparing multiple-inlet rice irrigation with conventional flooding in Arkansas during the 1999 through 2002 growing seasons.**

| Parameter | Least Square Mean Value, Irrigation Method[a]: CONV | MIRI | Significance Level |
|---|---|---|---|
| Irrigation water applied (mm) | 930 | 703 | 0.017 |
| Yield (Mg/ha @ 12% MC) | 7.41 | 7.66 | 0.077 |
| Irrigation water use efficiency (kg/ha-mm) | 8.74 | 11.89 | 0.006 |

[a] CONV = conventionally flooded; MIRI = multiple-inlet rice irrigation.

Rice grain yields averaged 3.4% greater for MIRI, with 7.41 and 7.66 Mg/ha for CONV and MIRI, respectively (table 2). Although the significance level (0.077) is slightly greater than the value of 0.05 commonly used to denote significant differences, it should be noted that yield for the CONV field was numerically greater than that of the MIRI field on only two (Crittenden County farm 2 in 2000, Crittenden County farm 2 in 2001) of the 14 farms in the study (fig. 2). Since those two were in different years and on different soil types, nothing can be concluded about what situations, if any, will lead to a yield loss. Differences ranged from 13% greater for MIRI on a Chicot County farm in 2001 to 3% greater for CONV on a Crittenden County farm (2) in 2001.

No yield differences were expected, since neither irrigation method allowed the crop to become water stressed or affected weed control. Factors that could have resulted in higher yields include a shallower depth of water, reduced “cold water” effect, and improved nitrogen efficiency. Zeng et al. (2003) reported that grain yield for flood depths < 10 cm was generally greater than for depths >10 cm. Even if the spills were set the same in both systems, the water is deeper in the CONV fields during pumping, since the water level has to be higher than the spills. The cold water effect observed for conventional flooding with groundwater refers to the area around the well or riser that is typically later maturing and lower yielding than the rest of the field. Although the name implies it is solely a function of water temperature on the plants, it is also affected by the calcium in the groundwater that precipitates out when the water is exposed to the air and warmed. Introducing the water at several points in the field appears to reduce the cold water effect, but no data are available to verify the observations. With yield monitors and GIS yield mapping in widespread use, it will be possible to study the cold water effect and how multiple-inlet irrigation impacts it in greater detail. Finally, Wilson et al. (2001) recommended completing the initial flood within five days of nitrogen application to minimize losses. Often with conventional flooding that time is exceeded; however, most cooperators have reported requiring less time for the initial flood with multiple-inlet irrigation.

Since both the irrigation water applied and yield favored MIRI, it follows that the irrigation water use efficiency (WUE) (i.e., the ratio of yield to irrigation water applied or the yield produced per unit of irrigation water applied) favored MIRI. In fact, an average 36% increase was

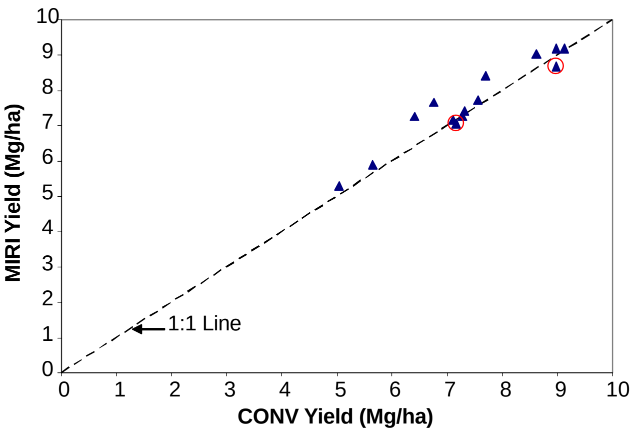


**Figure 2. Grain yields from each farm for the study comparing multiple-inlet rice irrigation with conventional flooding in Arkansas during the 1999 through 2002 growing seasons. Circled points represent cases where CONV yield was numerically greater than MIRI yield.**

associated with MIRI, with 8.74 and 11.89 kg/ha-mm for CONV and MIRI, respectively (table 2). Differences ranged from 15% greater for MIRI for a Crittenden County farm (2) in 2000 to 81% greater for MIRI on a Poinsett County farm in 2002. Irrigation WUE values for MIRI in this study were comparable to the average value of 10.67 kg/ha-mm for a water-saving treatment for furrow-irrigated rice reported by Vories et al. (2002); however, their treatment experienced lower yields than conventional flooding.

Costs were estimated for the two irrigation methods with water from each of the four different irrigation systems (table 3). Bryant et al. (2001) considered fixed or ownership costs independent of the amount of water pumped annually, while repairs and maintenance, labor, and fuel were functions of the amount of water. An additional $14/ha was added for MIRI for the cost of the disposable, thin-walled, polyethylene irrigation tubing. No charge was included for adjustable discharge gates because they are not a requirement for the method and they are reusable. Because labor costs were calculated based on the amount of water applied, the MIRI method resulted in $2/ha less labor cost. While there is an additional labor requirement for setup of the MIRI field, cooperators almost always report less labor required after setup; therefore, no adjustments were made to the labor values reported by Bryant et al. (2001). Not surprisingly, the largest component of variable costs was diesel fuel. A fairly low, constant fuel cost ($0.264/L) was used for the analysis, and the relative contribution of diesel fuel would increase during times of high oil prices.

Based on the grain yields (table 2) and estimated costs (table 3), total and net revenues (above irrigation costs) were calculated for the two irrigation methods with water from each of the four different irrigation systems (table 4). Revenues were based on a constant grain price of $0.143/kg, the federal loan price for the period of the study, with separate comparisons for owned land (no land rent payment) and leased farmland with a 25% crop share rent. Naturally, net revenue decreased as water-associated costs increased for the different irrigation systems. Similarly the significance level decreased, with the value for RELIFT (0.074) slightly greater than the value of 0.05 commonly used to denote significant differences. The SPARTA system with crop share rent had a $115 increase in net revenues for MIRI ($117 and $232 for

**Table 3. Irrigation costs[a] associated with multiple-inlet rice irrigation and conventional flooding in Arkansas during the 1999 through 2002 growing seasons.**

| Irrigation System[b] | Cost Component | Least Square Mean Cost ($/ha) Irrigation Method[c] CONV | MIRI |
|---|---|---|---|
| RELIFT | Diesel fuel | 45 | 34 |
| | Irrigation tubing | 0 | 14 |
| | Labor | 9 | 7 |
| | Repair & maintenance | 18 | 14 |
| | Total variable cost | 72 | 69 |
| | Fixed cost | 41 | 41 |
| | Total irrigation cost | 113 | 110 |
| STANDARD | Diesel fuel | 90 | 68 |
| | Irrigation tubing | 0 | 14 |
| | Labor | 9 | 7 |
| | Repair & maintenance | 19 | 15 |
| | Total variable cost | 119 | 104 |
| | Fixed cost | 40 | 40 |
| | Total irrigation cost | 159 | 144 |
| DEEP | Diesel fuel | 136 | 103 |
| | Irrigation tubing | 0 | 14 |
| | Labor | 9 | 7 |
| | Repair & maintenance | 28 | 21 |
| | Total variable cost | 173 | 145 |
| | Fixed cost | 60 | 60 |
| | Total irrigation cost | 233 | 205 |
| SPARTA | Diesel fuel | 317 | 239 |
| | Irrigation tubing | 0 | 14 |
| | Labor | 9 | 7 |
| | Repair & maintenance | 98 | 74 |
| | Total variable cost | 424 | 334 |
| | Fixed cost | 258 | 258 |
| | Total irrigation cost | 682 | 592 |

[a] Costs are from Bryant et al. (2001), with additional information provided by Layne Arkansas Co. (Stuttgart, Ark.).
[b] RELIFT = stationary relift with 6-m maximum vertical pipe; STANDARD = alluvial aquifer well < 37 m; DEEP = 37 m < alluvial aquifer well < 73 m; SPARTA = Sparta aquifer well.
[c] CONV = conventionally flooded; MIRI = multiple-inlet rice irrigation.

CONV and MIRI, respectively). The increase ($115) almost equaled the net revenue for the conventional system ($117). The RELIFT system with no rent had a $39 increase ($950 and $989 for CONV and MIRI, respectively).

Finally, the preceding economic analyses do not consider fluctuations in either price paid for diesel fuel or price received for grain. Fuel price paid and rough rice price received by producers are not constant from year to year, but are determined by economic forces. In the real world these prices change continuously. For the sensitivity analyses, these values were not allowed to change simultaneously, so effects of one variable changing would not be masked by changes in the second variable. Only the case of no land rent payments (i.e., producer owned land) was considered in the sensitivity analyses.

Ad hoc minimum and maximum diesel prices were chosen for the sensitivity analysis as $0.10/L and $0.40/L, respectively. Net revenues for each irrigation system were calculated at the minimum and maximum price while holding rough rice price constant at $0.143/kg (table 5). Although net

**Table 4. Economic findings from the study comparing multiple-inlet rice irrigation with conventional flooding in Arkansas during the 1999 through 2002 growing seasons.**

| Economic Parameter | Irrigation System[a] | Least Square Mean Value: No Land Rent Payment, Irrigation Method[b] CONV | MIRI | Sig. Level | Least Square Mean Value: 25% Crop Share Land Rent, Irrigation Method CONV | MIRI | Sig. Level |
|---|---|---|---|---|---|---|---|
| Total revenue[c] ($/ha) | | 1060 | 1100 | | 796 | 823 | |
| Net revenue[d] ($/ha) | RELIFT | 950 | 989 | 0.074 | 685 | 715 | 0.074 |
| | STANDARD | 905 | 955 | 0.046 | 640 | 681 | 0.043 |
| | DEEP | 832 | 895 | 0.032 | 567 | 621 | 0.028 |
| | SPARTA | 384 | 508 | 0.016 | 117 | 232 | 0.016 |

[a] RELIFT = stationary relift with 6-m maximum vertical pipe; STANDARD = alluvial aquifer well < 37 m; DEEP = 37 m < alluvial aquifer well < 73 m; SPARTA = Sparta aquifer well.
[b] CONV = conventionally flooded; MIRI = multiple-inlet rice irrigation.
[c] Based on grain price of $0.143/kg.
[d] Net revenue = total revenue − total irrigation costs; other costs not different between irrigation methods.

revenue was always higher for MIRI, it was more profoundly affected by an increase in diesel fuel prices as energy requirements increased (RELIFT<STANDARD<DEEP <SPARTA), making the potential for savings with MIRI more valuable. In fact, for the SPARTA irrigation system, the positive net revenue may be insufficient to cover other variable operating costs when diesel costs are high, making any increase in net revenue essential.

Sensitivity analysis with respect to rice price was a two-step process. Rather than selecting minimum and maximum rice prices ad hoc, it was desirable to base the values on the actual variation in observed prices. To achieve this, the Simetar© (Simulation for Excel To Analyze Risk) add-in for Microsoft Excel (Richardson, 2004) was used to produce theoretical replications of historical rough rice prices by stochastic simulation. In stochastic simulation models, future risk is assumed to mimic historical risk, so past variability is used to estimate parameters for the probability distributions of risky variables in a model.

Eleven years of Arkansas farm level rough rice data, 1993 through 2003, were obtained from USDA-NASS (2004). The statistical mean and deviations of each observation from the mean were computed and the deviations were converted to a percent of the mean and sorted to create an empirical distribution. Simulated rice prices were calculated using the equation:

$$\tilde{x}_i = \bar{x} \times \{1 + f[F(x), usd_i]\} \quad (1)$$

where $\tilde{x}_i$ is the i[th] simulated rice price, $\bar{x}$ is the statistical mean, F(x) is the ordered empirical distribution, and $usd_i$ is the i[th] uniform random number in the range (0, 1). The simulation engine of Simetar© used equation 1 to generate 100 rough rice prices and determined the minimum and maximum values as $0.104/kg and $0.217/kg, respectively. Minimum and maximum net revenues corresponding to these rice prices are shown in table 6 for each of the irrigation systems. Similar to the diesel cost analysis, net revenue was always higher for MIRI. For a producer with a SPARTA irrigation system, the positive net revenue may be insufficient to cover other variable operating costs when grain prices are low, making any increase in net revenue essential. Of course, any land rental payments not considered in these analyses would exacerbate the problems of low net revenue.

**Table 5. Effect on net revenue from varying diesel costs with a constant grain price, from the study comparing multiple-inlet rice irrigation with conventional flooding in Arkansas during the 1999 through 2002 growing seasons.**

| Irrigation System[a] | Net Revenue[b] ($/ha): $0.10/L Diesel Cost, Irrigation Method[c] CONV | MIRI | $0.40/L Diesel Cost, Irrigation Method CONV | MIRI |
|---|---|---|---|---|
| RELIFT | 977 | 1,010 | 927 | 972 |
| STANDARD | 960 | 997 | 860 | 921 |
| DEEP | 915 | 958 | 765 | 845 |
| SPARTA | 581 | 658 | 231 | 393 |

[a] RELIFT = stationary relift with 6-m maximum vertical pipe; STANDARD = alluvial aquifer well < 37 m; DEEP = 37 m < alluvial aquifer well < 73 m; SPARTA = Sparta aquifer well.
[b] Total revenue based on grain price of $0.143/kg and no rent payment − total irrigation costs; other costs not different between irrigation methods.
[c] CONV = conventionally flooded; MIRI = multiple-inlet rice irrigation.

**Table 6. Effect on net revenue from varying grain price with a constant diesel cost, from the study comparing multiple-inlet rice irrigation with conventional flooding in Arkansas during the 1999 through 2002 growing seasons.**

| Irrigation System[a] | Net Revenue[b] ($/ha): $0.104/kg Grain Price, Irrigation Method[c] CONV | MIRI | $0.217/kg Grain Price, Irrigation Method CONV | MIRI |
|---|---|---|---|---|
| RELIFT | 662 | 691 | 1496 | 1554 |
| STANDARD | 617 | 658 | 1451 | 1521 |
| DEEP | 544 | 598 | 1379 | 1461 |
| SPARTA | 101 | 215 | 935 | 1078 |

[a] RELIFT = stationary relift with 6-m maximum vertical pipe; STANDARD = alluvial aquifer well < 37 m; DEEP = 37 m < alluvial aquifer well < 73 m; SPARTA = Sparta aquifer well.
[b] Total revenue based on diesel price of $0.264/L and no rent payment − total irrigation costs; other costs not different between irrigation methods.
[c] CONV = conventionally flooded; MIRI = multiple-inlet rice irrigation.

## CONCLUSION

The multiple-inlet method required 24% less irrigation water than conventional flooding, with 930 and 703 mm for conventional flooding and multiple-inlet irrigation, respectively. Grain yields also favored the multiple-inlet method, with 7.41 and 7.66 Mg/ha for conventional flooding and multiple-inlet irrigation, respectively. Yield differences were not an expected benefit of the method and the cause of the differences is not known. Possible causes include shallower water depth, reduced cold water effect, and improved nitrogen efficiency. Future research with yield monitoring/ mapping may help explain the differences. A 36% increase in irrigation water use efficiency was associated with multiple-inlet irrigation, with 8.74 and 11.89 kg/ha-mm for conventional flooding and multiple-inlet irrigation, respectively. Based on estimated costs from four different irrigation systems and two land-rent arrangements, and considering only irrigation costs, net revenues increased by $115 for multiple-inlet irrigation for a well in the Sparta aquifer in Arkansas with crop share rent ($117 and $232 for conventional flooding and multiple-inlet irrigation, respectively). The increase ($115) almost equaled the net revenue for the conventional system ($117). Producers with irrigation systems in the Sparta aquifer appeared particularly at risk of insufficient revenues due to variations in diesel costs and grain prices. The research is continuing with emphasis on runoff quantity and quality, which will provide data on the potential environmental benefits of a multiple-inlet rice irrigation system over conventional flooding.

### ACKNOWLEDGEMENTS

Funding for these studies was provided by the Arkansas Rice Research and Promotion Board. The authors would also like to express their appreciation for the assistance provided by the farmers and their staffs, County Extension Agents, Extension Technicians, and Dr. Ron McNew.

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