

# 8 – Efficient Use of Fertilizer

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## Nitrogen Fertilizer Rates

Rice varieties differ in the amount of nitrogen (N) fertilizer required to produce optimum grain yields. Nitrogen rates listed in Table 8-1 are for a) rice grown in rotation after soybeans, b) rice grown on silt loam or sandy loam soil, c) optimum stand density and d) land that has been in cultivation for longer than five years. If all four listed criteria have not been met, an adjustment of the early N rate is required.

Adjustments in the early N rate will be needed for the following situations and are additive if more than one applies:

1. Increase early N by 30 pounds per acre if:
  - rice is grown on clay soils
2. Increase early N rate by 20 pounds per acre if:
  - rice follows RICE in rotation
  - rice follows COTTON in rotation
  - stand density is < 10 plants per square foot (6 plants per row-foot with 7-inch drill row spacing)
3. Increase early N rate 10 pounds per acre if:
  - rice follows GRAIN SORGHUM in rotation
  - rice follows WHEAT in rotation (doublecrop)
  - rice follows CORN in rotation
4. Decrease early N rate 10 pounds per acre if:
  - rice follows SET-ASIDE or FALLOW that is not continuously tilled in rotation
5. Omit early N if :
  - rice follows FISH, LONG-TERM PASTURE or FIRST YEAR AFTER CLEARING in rotation. Use the plant area measurement made with the Rice Gauge to evaluate vegetative plant growth at midseason to adjust N rate (see No. 6).

Table 8-1. Recommended Nitrogen Rates and Distribution for Varieties Grown in Arkansas

Variety	Nitrogen Distribution			
	Optimum (Single) Preflood N <sup>†</sup> (lbs/A)	2 or 3-Way Split Application		
		Total N <sup>†</sup> (lbs/A)	Early N <sup>‡</sup> Preflood (lbs/A)	Midseason Nitrogen Internode Elongation (IE) <sup>§</sup> N Rate (lbs/A)
Adair	NR	120	60	60
Alan	105	135	75	60
Bengal	120	150	90	60
Cocodrie	120	150	90	60
Cypress	120	150	90	60
Della	NR	110	50	60
Drew	105	135	75	60
Jackson	105	135	75	60
Jasmine 85	NR	120	60	60
Jefferson	120	150	90	60
Jodon	105	135	75	60
Katy	NR	135	75	60
Kaybonnet	105	135	75	60
Lacassine	120	150	90	60
Lafitte	120	150	90	60
LaGrue	105	135	75	60
Lemont	150	180	120	60
Litton	105	135	75	60
L202	105	135	75	60
Madison	150	180	120	60
Mars	NR	110	50	60
Maybelle	105	135	75	60
Millie	105	135	75	60
Newbonnet	105	135	75	60
Priscilla	120	150	90	60
Wells	120	150	90	60

<sup>†</sup>Nitrogen rate for rice on silt loam soils following soybean in rotation. Rates may need to be adjusted for soil factors, thin stands and other rotational crops. NR means that the optimum preflood N method is “not recommended” for this variety.

<sup>‡</sup>Early nitrogen should be applied preflood or a portion of the early N can be flushed in.

<sup>§</sup>Midseason N may be applied in a single application between beginning internode elongation and 1/2 inch internode elongation.

6. Use the Rice Gauge plant area measurement to evaluate plant growth at the beginning internode elongation (panicle initiation) growth stage as indicated on the DD50 printout (Table 8-2) when adjusting mid-season N applications. Refer to the RICEPA computer program and FSA 2122, *Rice Plant Area*, for additional information.

**NOTE:** Use the N rate adjustment rules for both **optimum pre flood** (formerly referred to as single pre flood) and **split** application methods.

**Table 8-2. Rice Gauge Measurement Thresholds and N Recommendations Based on Plant Area (Size) at Midseason†**

Variety	Midseason Plant Area	Midseason N Time/Rate‡	
		BIE to 1/2" IE§	7 days after BIE to 1/2" IE
	cm <sup>2</sup>	lbs N/A	
Alan Drew Jackson	> 900	0	0
Katy Kaybonnet Millie	800 - 900	30	0
Newbonnet	600- 800	60	0
	< 600	45	45
Bengal Cocodrie†	> 750	0	0
Cypress Jefferson†	650 - 750	30	0
Lacassine LaGrue Lemont	550 - 650	60	0
Madison† Priscilla† Wells†	< 550	45	45

†Note: Rice Gauge area thresholds for these varieties are tentative and may change due to limited data available at time of publication.

‡Midseason N can be applied in one or two applications.

§BIE: beginning internode elongation.  
1/2" IE: 1/2" internode elongation.

## Maximizing N Utilization

Management of N fertilizer for maximum uptake efficiency by the rice crop varies with the cultural system, variety, soil texture, soil moisture and several other factors. These factors are discussed in more detail in the following text.

## Dry Seeding

Two options are available for applying N fertilizer to rice: the standard 3-way split method, which may be simplified to a 2-way split by combining the two midseason N applications, or a single optimum pre flood (formerly referred to as single pre flood) N application. Several options are available for managing the N in a dry-seeded cultural system, and all options are viable if performed using the defined guidelines. However, correct management of the pre flood N is critical since a rice crop's potential grain yield is determined by the early N.

A single **optimum pre flood** N application followed by monitoring the plant N status at midseason with the Rice Gauge (plant area board) is recommended for most conditions (Table 8-2). (For more information on the Rice Gauge, see FSA2122, *Rice Plant Area*.) Research has consistently shown over the past ten years that a single application of an optimum amount of N before flooding results in equal or better yields than the traditional 3-way split application method and usually requires less total N to achieve maximum yields. The pre flood N is critical for determining potential grain yield regardless of whether split or single applications are used. The number of panicles (heads) and the number of grains per panicle are determined by the pre flood N application. New stiff-strawed, early-maturing varieties do not respond to midseason N applications like their taller, longer-season predecessors. Because yield potential is determined prior to midseason, yield cannot be completely recovered with midseason N applications if the pre flood N application was insufficient. Milling yield (percent head rice) also benefits from proper N fertilization. In general, the percent head rice is highest when maximum grain yield is produced. Table 8-1 provides rates for both the split and optimum pre flood N application methods as well as the varieties that are suited for the larger optimum pre flood N application method. An "NR" in the optimum pre flood column indicates that the optimum pre flood method is not recommended for this variety, generally because of potential lodging problems. Where management practices allow, use the optimum pre flood N application since this method has consistently produced the highest grain and milling yields in replicated research.

A **split application** can still be used effectively as long as the pre flood N application is managed correctly. Less yield benefit is obtained from midseason N, so less dependence should be placed

on the yield gained from midseason N applications. Research data indicate that when the pre-flood N is improperly managed, resulting in poor plant growth, midseason N applications are not capable of recovering all of the lost yield potential. There is a greater chance of this happening with the lower pre-flood N rate applied in the split application method than with the larger pre-flood N rate used in the optimum pre-flood N method. Nitrogen is stored in the plant stem and leaf tissue during vegetative growth following the pre-flood N application. This stored N is transported and used within the plant later in the season during periods of peak N needs, such as during grain fill. If the pre-flood N is mismanaged and adequate plant growth does not occur, crop yield potential suffers. As a general rule, when more than 60 pounds N per acre is needed at midseason, yield potential has been lost. Plant area measurements with the Rice Gauge can evaluate plant N needs since yield potential is positively correlated to the amount of early vegetative growth.

### Early N Application and Management

The early N application (Table 8-1) (65 to 100 percent of the total N rate) should be applied as an ammonium N source (Table 8-3) onto dry soil immediately prior to flooding at around the 4- to 5-leaf growth stage (Table 8-4). There is not an exact time to apply early N, but actually a window of a couple of weeks that the early N can be applied. The DD50 printout gives the window of dates for early N application. Once the early N is applied, flooding should be completed as quickly as possible, preferably within five days of the

**Table 8-3. Nitrogen Fertilizer Sources**

N Source (in order of preference)	Remarks
<b>Early Season (50% to 80% of total N requirement)</b>	
Urea - 46% N	High N analysis, widely available
Ammonium Sulfate - 21% N, 24% S	Low N analysis, high cost
N Solution - 32% N	Even distribution, very high N loss possible due to nitrates in the solution
<b>Midseason (35% to 50% of total N requirement)</b>	
Urea - 46% N	High N analysis, widely available
N Solution - 32% N	Even distribution, ammonia volatilization loss greater than urea

**Table 8-4. Effect of Preflood Nitrogen Application Timing and Soil Moisture on Rice Grain Yield**

Time Before Flood days	Soil Moisture	N Use Efficiency <sup>†</sup>		Grain Yield bu/A
		Pounds/A	Percent	
		Uptake of applied N		
10	dry	85	71	124
10	mud	46	42	102
5	dry	100	82	129
5	mud	71	59	105
0	dry	107	83	132
0	mud	68	64	111
0	flooded	37	31	75

<sup>†</sup>120 lbs N applied at the 4- to 5-leaf stage.

Source: Norman, et al., 1992. p. 55-57. Ark. Soil Fertility Studies 1991. Ark. Ag. Exp. Sta. Res. Ser. 421.

N application. The flood incorporates the N fertilizer into the soil where it is protected against losses via ammonia volatilization and/or nitrification/denitrification as long as a flood is maintained. Maintain the flood for at least three weeks to achieve maximum uptake of the early applied N (Table 8-5).

**Table 8-5. Percent Nitrogen Uptake by Rice Crop at Different Times after N Application**

N Application Timing	Sampling Period	% N Plant Uptake
	days after application	% of applied N
Preflood <sup>†</sup>	7	11
	14	27
	21	63
	28	65
Midseason <sup>‡</sup>	3	70
	7	67
	10	76

<sup>†</sup>Urea applied on a dry soil surface and flooded immediately.

<sup>‡</sup>Urea applied into the flood.

Source: Wilson, et al., 1989. SSSAJ 53:1884-1887.

For the pre-flood N application, an ammonium N source, such as urea or ammonium sulfate, is preferred over an N fertilizer containing nitrates (i.e., N solution) (Table 8-3). Compared to urea-ammonium nitrate solution (UAN), granular (or prilled) urea applied at pre-flood results in greater

N uptake and grain yield (Table 8-6). Nitrogen solution or UAN solution contains 25 percent nitrates, which will be lost after flooding via denitrification; therefore, its use as a pre-flood N fertilizer is not recommended. Urea and ammonium sulfate are both excellent fertilizers for the early pre-flood N application; however, urea is usually much cheaper per pound of actual N compared to ammonium sulfate and equal in effectiveness if incorporated with the flood in less than five days. If the pre-flood N cannot be incorporated with the flood in a timely manner, the use of ammonium sulfate may be warranted.

**Table 8-6. Comparison of Urea and Urea Ammonium Nitrate (UAN) as N Sources at Three Application Timings in Rice**

N Source	Time of Application			Grain Yield bu/A
	Preflood†	1/2" IE‡	1/2" IE + 10d	
	% of applied N			
Urea	65	83	90	144
UAN	39	72	69	127

†75 lbs N/A pre-flood.

‡30 lbs N/A applied for each midseason [1/2" internode elongation (1/2" IE) and 1/2" IE + 10 days].

Source: Wilson, et al., 1994. SSSAJ 58:1825-1828.

Wet (muddy) soil conditions can prohibit rice farmers from applying the early N onto a dry soil at the 4- to 5-leaf growth stage. Because there is a window of a couple of weeks to apply the pre-flood N, every effort should be made to apply the early N onto a dry soil surface. However, if wet conditions persist and the pre-flood N cannot be applied during this window onto a dry soil, apply the pre-flood N onto the muddy soil and flood as quickly as possible to minimize ammonia volatilization N loss. For best results, the flood should cover the field in five days or less (Table 8-4). **Do not, for any reason, apply the early or pre-flood N into the flood.** Application of the early N into the flood is very inefficient (Tables 8-4 and 8-7). Since the N is not incorporated into the soil, most of the N is lost via ammonia volatilization within seven to ten days after application, before it can be used by the young rice. Increasing the N rate will not compensate for inefficient N use when N is applied into the flood (Table 8-7).

The large N rates required at the early N application time can be difficult to apply evenly and streaking may result. Streaking is not only unpleasing to the eye but can cause significant

**Table 8-7. Nitrogen Uptake Efficiency, Using an N15 Tracer, of Several N Rates and Application Timings**

Treatment†	N Use Efficiency		Grain Yield bu/A
	lbs/A N Uptake	% N Uptake	
30 lbs* PPI + 90 lbs PF	12	40	176
30 lbs* PFS + 90 lbs PF	17	57	181
30 lbs PPI + 90 lbs* PF	72	80	179
60 lbs* PPI + 60 lbs PF	20	33	158
60 lbs* PFS + 60 lbs PF	32	53	166
60 lbs PPI + 60 lbs* PF	47	78	160
120 lbs* PPI	32	27	125
120 lbs* PF	91	76	177
90 lbs PF + 30 lbs* 1 wk§ POF	4	13	158
90 lbs PF + 30 lbs* 2 wk POF	6	20	163
60 lbs PF + 60 lbs* 2 wk POF	8	13	142
60 lbs PF + 60 lbs* 2 wk POF	9	15	14

†PPI = Preplant Incorporated; PF = Preflood; PFS = Preflush; POF = Postflood (in water).

\*Indicates the nitrogen application was labeled with N15 tracer.

§Postflood treatments applied into the water one or two weeks (wk) after flooding at the 4-to 5-leaf stage.

Source: Norman, et al. 1994. p. 138-145. Ark. Rice Res. Studies 1993. Ark. Ag. Exp. Sta. Res. Ser. 439.

yield loss (Table 8-8). The best way to avoid streaking is to use an aerial applicator who knows exactly how to operate the aircraft when applying heavy rates of fertilizer. All aircraft have a maximum material flow rate that limits their useful swath width. Large aircraft and spreaders may be able to apply heavy rates of materials with little or no sacrifice in distribution uniformity. The usable swath width of all aircraft decreases as the application or flow rate increases. Double flying (using one-half the desired application rate and flying at one-half the optimum swath width for that application rate) may be used for most aircraft applications when the maximum practical flow rate is exceeded. Double flying almost typically results in more uniform application.

Calibration workshops allow pilots to determine the best swath width to use for each application rate. The Cooperative Extension Service, University of Arkansas, conducts

**Table 8-8. Influence of Non-Uniform N Distribution (Striking) on Newbonnet Grain Yield**

Preflood N % Distribution	Actual N lbs Distribution	Grain Yield
% : %	lbs N : lbs N	bu/A
100 : 100	75 : 75	170
125 : 75	94 : 56	161
150 : 50	113 : 37	160
175 : 25	131 : 19	146
200 : 0	150 : 0	139

Helms, Unpublished data.

calibration workshops annually to help aerial and ground applicators determine the efficiency of their applications and offers advice on how to make improvements.

An alternative method of reducing the chance of streaking is to split the early N into two applications. Apply about one-third of the early N rate onto dry soil immediately prior to flushing at the 2- to 3-leaf stage and the remainder just before flooding. Always incorporate the N with water when N is applied preflush (Table 8-7). The alternative method is only recommended when the early N rate is 90 pounds N per acre or more. The early split application applied a week or two before permanent flooding is at greater risk to nitrification/denitrification losses and, therefore, is not used as efficiently as when the N is applied immediately before flooding. Preplant incorporation (PPI) of early N to reduce streaking is a poor alternative and is not recommended.

Nitrogen applied immediately prior to flooding or preflush has resulted in the highest yields and greatest N use efficiency in research tests. Therefore, if N fertilizer can be applied evenly, the early N should be applied preflush and not preflush.

### Midseason N Application and Management

Fertilizer N applied at midseason, at the proper times and in the proper amounts, is taken up with a 65 to 80 percent efficiency (Table 8-5). Ideally, midseason N rates should not exceed 60 pounds N per acre. In general, when rates greater than 60 pounds N per acre are recommended, the rice crop is very N deficient and yield

potential has been significantly reduced. Rates of 90 pounds N per acre applied at midseason may gain back some of the lost yield. Thus, one should apply and manage the preflush N so no more than 60 pounds N per acre are needed at midseason. Ideally, no more than 30 pounds N per acre would be required at midseason.

Midseason N applications should be timed according to plant development; that is, applied at or between beginning internode elongation (i.e., BIE, panicle initiation or "green ring") and 1/2 inch internode elongation (i.e., 1/2 inch IE or panicle differentiation) (Table 8-1) (Photo 8-2). If a second midseason N application is required, it should be applied seven days after the first. The DD50 program provides estimated times for these applications. Midseason N can be applied into the flood because, by this growth stage, the plant has developed an extensive root system near the soil surface and has high metabolic activity. Research indicates that N applied at midseason is used by the rice plant within three days (Table 8-5). The smaller amount of N coupled with the rapid rate of N uptake by the rice plant at midseason enables the N to be applied into the flood without the large amounts of N loss that are associated with applying preflush N into the flood.

Recent studies conducted jointly by the University of Arkansas and Louisiana State University demonstrated that the **midseason N application can be made in either one or two applications** (Table 8-9). When one application of 60 pounds N per acre at 1/2 inch internode elongation (IE) was compared to two split applications of 30 pounds N per acre, the yields were not significantly different. Additional studies have

**Table 8-9. Influence of Midseason N Timing on Rice Grain Yields**

Number of Midseason Applications	Grain Yields					
	Bengal		Cypress		Drew	
	First Midseason Application Time <sup>†</sup>					
	BIE	1/2" IE	BIE	1/2" IE	BIE	1/2" IE
	bu/acre					
0	128		108		125	
1	143	140	127	124	137	131
2	144	144	129	128	137	128

<sup>†</sup>BIE: beginning internode elongation. 1/2" IE: 1/2" internode elongation.

Source: Norman, et al. 1998. Unpublished data.

shown that to be true for all varieties tested. Consequently, you may be able to reduce application costs with only one application.

Also in this study, they demonstrated that applying the first midseason N at beginning IE or “green ring” (five to seven days prior to 1/2 inch IE) was just as effective as applying the N at 1/2 inch IE, which has been recommended by the University of Arkansas. **Thus, a window of opportunity about one week long between beginning IE and 1/2 inch IE exists for applying the first or only midseason N application.** The standard 3-way split (preflood-midseason-midseason) application has been changed to a 2-way split application (preflood-midseason) with the midseason N applied between beginning IE and 1/2 inch IE when 60 pounds N per acre is applied (Table 8-1). Application of midseason N rates > 60 pounds N per acre should be applied in split applications made seven days apart with the first midseason application applied between the beginning IE and 1/2 inch IE growth stages.

### Midseason N Management with the Rice Gauge

Although midseason N is taken up by rice very efficiently, it is not always required to produce top yields (Table 8-7). When a sub-optimum preflood N rate has been applied or preflood N has been mismanaged, rice normally responds to midseason N application (Table 8-9). Factors that influence the importance of the midseason N on grain yield include variety, native soil fertility, preflood N rate and management of the preflood N. If a sufficient amount of N has been applied preflood and managed correctly, many of the presently grown cultivars require no midseason N or only one 30 to 45 pounds N per acre midseason N application to produce top yields.

The Rice Gauge was developed to evaluate preflood N use efficiency and determine the need for midseason N applications (Table 8-2). If the rice plant has sufficient size at midseason, based on plant area as measured with the Rice Gauge, there is an adequate amount of N in the plant for translocation to the panicle during grain fill (Photo 8-5). Sufficient research has been performed on the Rice Gauge method to indicate that midseason N applications may be reduced or omitted without sacrificing yield in fields which have ample vegetative growth at midseason. Thus, use of the Rice Gauge can potentially save money on N fertilizer

and reduce the chance of increased lodging and disease associated with excessive N fertilization.

Adjustments in midseason N rates should be determined based on the plant area measurements made with the Rice Gauge at the beginning IE growth stage listed on the DD50 printout. Because natural fertility is variable among soils, the amount of N that the rice plant derives from the soil is also variable (Table 8-10). At the Northeast Research and Extension Center (NEREC) and the Southeast Branch Experiment Station (SEBES), grain yields for unfertilized Cocodrie were very low compared to the fertilized plots (Table 8-10). At the Pine Tree Branch Experiment Station (PTBES) and the Rice Research and Extension Center (RREC), grain yields for the unfertilized Cocodrie were higher compared to the other locations, yet the maximum yields obtained on the fertilized plots were very similar to the other locations when the proper N rate was applied. The silt loam soils at PTBES and RREC were capable of contributing more N to the rice crop than the clayey soils at the NEREC or SEBES. Also, optimum yields were obtained with lower N rates at PTBES and RREC compared to NEREC or SEBES.

**Table 8-10. Influence of Nitrogen Rate and Soil Texture on Grain Yields of Cocodrie Rice**

N Rate lb N/A	Grain Yields			
	Silt Loam		Clay	
	RREC <sup>†</sup>	PTBES	NEREC	SEBES
	bu/acre			
0	99	112	67	80
60	142	159	126	128
90	160	162	137	146
120	178	163	146	153
150	176	170	150	160
180	172	147	151	173

<sup>†</sup>RREC = Rice Research and Extension Center; PTBES = Pine Tree Branch Experiment Station; NEREC = Northeast Research and Extension Center; SEREC = Southeast Branch Experiment Station.

Source: Norman, et al. 1999. p. 257-267. Ark. Rice Res. Studies 1998. Ark. Ag. Exp. Sta. Res. Ser. 468.

In other words, soils differ in the amount of N they contribute to the rice crop, and silt loam soils contribute more than clayey soils. A soil test procedure has not been developed that can measure the amount of native soil N that will

become available to the rice crop. Soil nitrates listed on the University of Arkansas soil test reports are not useful in this regard since they will be lost to denitrification when the flood is established. The Rice Gauge is the best measurement tool we have for determining how much pre-flood and native soil N has been taken up by the rice crop and how much, if any, midseason N is needed to maximize grain yields.

To achieve the maximum benefit from the use of the Rice Gauge, as well as midseason N, there are some criteria that must be met, as with any tool or method. Criteria required for the successful use of the Rice Gauge are as follows:

1. The pre-flood N has been applied three weeks prior to beginning IE. This ensures that the pre-flood N has had adequate time to be taken up by the date the Rice Gauge measurement is to be taken. If the pre-flood N is still being taken up, an over estimation of the midseason N required could result.
2. The Rice Gauge measurement has been taken within two days of beginning IE. Too early a measurement could result in an over estimation of midseason N required and too late could result in an under estimation.
3. Rice Gauge height and width measurements have been taken correctly. (Refer to the RICEPA computer program; FSA2122, *Rice Plant Area* and the Extension service video for additional information.) If not, this can also result in an incorrect plant area measurement and an over or under estimation of midseason N required.
4. Lastly, the Rice Gauge method assumes that only N is limiting yield and, thus, that soil test recommendations for application of phosphorus, potassium and zinc have been followed and that the rice has not been significantly damaged by salinity, insects, alkalinity or herbicides. If not, the use of the Rice Gauge could result in an over estimation of the amount of midseason N required.

### **Water Seeding – Pinpoint Flood**

The fundamental principles of N fertility are the same regardless of whether rice is dry- or water-seeded, but the methods used to attain efficient uptake of the early N application are quite different. In water-seeding, the early N

must be applied as an ammonium N source onto the dry soil pre-plant and mechanically incorporated (2 to 4 inches). The flood should be established immediately after N application/incorporation to minimize nitrification. Surface application of N followed by flood establishment for water-seeding does not adequately incorporate the N and prevent loss, in contrast to pre-flood applications made in the dry-seeded, delayed-flood system. This is because in dry-seeded, delayed-flood rice the pre-flood N is applied at or around the 4- to 5-leaf growth stage and takes only three to four weeks to be taken up, whereas in water-seed rice the N is applied around seeding and takes seven to eight weeks to be taken up.

Because of this long time period between application and plant uptake, the early N must be stored for a longer period of time before the rice crop can use the early N. Therefore, it is very important that the early N be incorporated deep and the flood be maintained throughout the vegetative growth stage. If the soil does not stay saturated (flooded), the fertilizer N can nitrify during the unsaturated periods and be lost via denitrification upon reflooding. With the pinpoint flooding method, the field must remain saturated when the field is drained for pegdown. Loss of red rice control may also result if the soil does not remain saturated. One advantage of PPI N application is that early N can be applied with ground equipment which may potentially reduce streaking and application costs. Two alternative methods of early N application for water-seeded systems include N application when the field is drained for pegdown or N application after draining at the 5-leaf to early tillering stage. These alternative methods have been used successfully by several Arkansas growers.

Based on field experiences, incorporate only the early pre-flood N rate recommended for the variety (Table 8-1). If the single optimum pre-flood method is recommended for the variety, then this amount of N should be incorporated prior to establishing the flood for water-seeding. Regardless of the pre-flood N rate, supplemental N has always been required in water-seeded Rice Research Verification Program fields. The need for supplemental N, either during active tillering or at midseason, is highly likely in water-seeded fields. Whichever method is used, the Rice Gauge plant area measurement method should be used to determine if and how much midseason N is needed to produce maximum yields.

## Conservation or No-Till Systems

**No-till dry-seeded, delayed-flood** rice should have the N managed in the same manner as conventional-till dry-seeded, delayed-flood rice. Initial research conducted on silt loam and clay soils found no significant difference between the two tillage systems as concerns the N uptake efficiency of rice. However, if there is a substantial amount of weedy residue, extra N in the amount of 10 pounds N per acre should be added to the pre-flood N rate to compensate for losses due to ammonia volatilization and extra N required to decompose the weedy residue.

**No-till water-seeded** rice is not an efficient N management system. Incorporation of the early N with the flood does not move the N deep enough into the soil to prevent substantial loss. Spoon feeding the rice with biweekly topdress N applications requires about 25 percent more N fertilizer and may still produce lower than normal yield. The only viable alternative to achieve efficient N management for profitable yields in the no-till water-seeded system is to knife into the soil anhydrous or aqua ammonia to a 4- to 6-inch depth prior to planting. This is not a common practice in the southern rice belt, but is the standard practice for N fertilization of water-seeded rice in California. Thus, unless the N fertilizer is knifed deep into the soil, no-till water-seeded rice is not a recommended practice as concerns maximizing N uptake efficiency, grain yield and, thus, profit. One viable option is to drain and dry the field at the 5-leaf to early tillering stage, apply N on to a dry soil and then reflood.

## Soil Sampling and Soil Analysis

There are three steps to any soil testing program including soil sampling, soil analysis and data interpretation. Each step is critical in obtaining optimum fertilizer and lime recommendations. However, the most variable step is the process of soil sampling.

Soils are inherently variable between fields and within fields. **The recommendations received from a soil testing program are no better than the sample that was collected to make those recommendations.** Therefore, correct soil sampling procedures should be followed so that soil test results for lime and other nutrient recommendations are representative of the entire field. Collect composite soil samples

from the area near the water inlet, the center and the bottom portions of the field, as well as areas that differ in soil series or texture within these locations. **One composite soil sample should not represent more than 20 acres.** Composite samples near water inlets should represent only 5 to 10 acres. Grid sampling improves the soil testing process because samples are collected from several areas within the field and less area is represented by each sample. Thus, a "picture" can be made that depicts the variability within the field. Grid sampling and variable rate application equipment are highly recommended for lime or elemental sulfur applications to fields with rice in the rotation.

The second step in the soil testing process is the chemical analysis of the soil conducted by a soil testing laboratory. The University of Arkansas Soil Testing Laboratory uses standard laboratory methods for soil analysis. Availability of nutrients, such as phosphorus, potassium, calcium and magnesium, are determined with the Mehlich 3 extraction at the University of Arkansas Soil Testing Laboratory. Some laboratories use different chemical methods to determine the availability of these nutrients. Therefore, the numbers that are generated may not be easily comparable. Also, the units in which the nutrients are expressed (such as pounds per acre or parts per million) cause problems in comparing numbers if they are not understood. For example 200 pounds per acre of potassium is the same as 100 parts per million of potassium. **Soil test results provide an estimate of nutrient availability to the plant and not the total amount of each nutrient that is found in the soil.**

The last step in the soil testing process is data interpretation and development of recommendations. Once the numbers have been generated by the laboratory, someone must decide what they mean. The two ideas that drive soil testing programs are "fertilize the crop" and "fertilize the soil." The idea of "fertilize the crop" is that fertilizer recommendations are based on crop response at a given soil test level. Enough fertilizer is recommended to provide adequate growth to the current crop. If the available nutrients are sufficient for optimum productivity, no fertilizer recommendation is made. The second idea of "fertilize the soil" is that fertilizer recommendations are based on the needs of the current crop with an additional amount recommended to attempt to build soil fertility levels.

The first idea is used by the University of Arkansas because this is the most economical recommendation for the current crop. It has also been shown to be the most economical in the long-term. The second idea is used by many private laboratories and fertilizer dealers. Each idea has merit. However, research has shown that increasing available nutrients in the soil is more difficult for some nutrients than simply applying additional amounts. While the University of Arkansas generally uses the “fertilize the crop” philosophy, a Soil Fertility Enhancement Program was established in which additional K is recommended on soils that have soil test levels just above the threshold where fertilizer recommendations are made. This was established for those producers who are interested in attempting to increase native soil fertility levels. For more information on understanding fertilizer recommendations and interpreting the numbers on a soil test report, contact your local county Extension agent.

## Sulfur

Rice does not normally require sulfur (S) fertilizer to produce high yields in Arkansas. Generally, adequate amounts of S are naturally provided from soil organic matter, irrigation water and precipitation. Irrigation water from groundwater sources (wells) often contains about 1 meq SO<sub>4</sub>-S per liter which is equivalent to 3.3 pounds SO<sub>4</sub>-S per acre-inch. With an average water use of 30 acre-inches per year, this results in almost 100 pounds SO<sub>4</sub>-S per acre deposited from irrigation water to the rice crop. Thus, in most fields the rice nutritional requirement for S will be supplied from irrigation water. **Sulfur is most likely to be needed on sandy soils due to leaching of plant available SO<sub>4</sub>-S.** Sulfur may also be needed on soils that are continuously flooded for rice production and winter waterfowl habitat as plant available S may be reduced to an unavailable form.

**Sulfur deficiencies normally occur after establishing the permanent flood on permeable sandy soils.** Deficiency symptoms appear similar to those of N. Sulfur deficiency symptoms include initial chlorosis (yellowing) of the entire plant starting with the younger leaves, reduced tillering, delayed maturity and stunted growth. While the chlorosis may start with the younger leaves, this distinction may not be observed as S deficiency eventually results in a uniform yellowing (chlorosis) of young plants. Nitrogen deficiency symptoms begin as a yellowing of the older leaves. Since visual symptoms are

difficult to distinguish from N deficiency, use plant tissue analysis for correct identification (Table 8-11). If an S deficiency is verified, ammonium sulfate applied at 100 pounds per acre will supply sufficient amounts of S. Crop uptake and removal of S are approximately 22 and 7 pounds S per acre, respectively, based on an average yield of 150 bushels per acre and total above ground biomass (grain and straw) of 17,750 pounds per acre. The amount of S removed in the grain comprises approximately 30 percent of the total S taken up by the plant.

**Table 8-11. Guide for Interpreting Nutrient Concentrations from Plant Tissue Analysis<sup>†</sup>**

Nutrient	Plant Part <sup>‡</sup>	Growth Stage	Nutrient Concentration Required for Adequate Growth <sup>§</sup>
Phosphorus (P)	Y-Leaf	Midtiller	0.14% - 0.27%
Phosphorus (P)	Y-Leaf	Panicle Initiation	0.18% - 0.29%
Potassium (K)	Y-Leaf	Midtiller	1.5% - 2.7%
Potassium (K)	Y-Leaf	Panicle Initiation	1.2% - 2.5%
Calcium (Ca)	Y-Leaf	Midtiller	0.16% - 0.39%
Calcium (Ca)	Y-Leaf	Panicle Initiation	0.19% - 0.39%
Magnesium (Mg)	Y-Leaf	Midtiller	0.12% - 0.21%
Magnesium (Mg)	Y-Leaf	Panicle Initiation	0.16% - 0.39%
Iron (Fe)	Y-Leaf	Midtiller	89 - 193 ppm
Iron (Fe)	Y-Leaf	Panicle Initiation	74 - 192 ppm
Manganese (Mn)	Y-Leaf	Midtiller	237 - 744 ppm
Manganese (Mn)	Y-Leaf	Panicle Initiation	252 - 792 ppm
Zinc (Zn)	Y-Leaf	Midtiller	22 - 161 ppm
Zinc (Zn)	Y-Leaf	Panicle Initiation	33 - 160 ppm
Sulfur (S)	WS	Midtiller	0.17%
Sulfur (S)	WS	Panicle Initiation	0.15%

<sup>†</sup>Reuter, D.J., and J.B. Robinson, 1986. Temperate and subtropical crops. p. 38-99. In D.J. Reuter and J.B. Robinson (ed.) *Plant Analysis: An Interpretation Manual*. Inkata Press, Melbourne.

<sup>‡</sup>Y-leaf = youngest fully emerged (uppermost) leaf blade on the rice plant; WS = whole shoot, entire above ground portion of plant.

<sup>§</sup>The range of concentrations listed for the specific plant parts does not increase nor decrease plant growth or production. Concentrations lower than those listed may limit production and result in visual nutrient deficiency symptoms. ppm = mg/kg.

Several Arkansas rice fields have recently shown deficiency symptoms late in the season where S deficiency was suspected despite no visible early-season symptoms. These late-season symptoms include yellowing of the flag leaf that starts at the leaf tip (Photo 8-7). Black streaks between leaf veins usually develop if the problem is left uncorrected. Normally the top two leaves exhibit these symptoms and lower leaves appear perfectly healthy. Tissue analysis suggests that S deficiency is the primary problem. Application of ammonium sulfate to these areas has tended to improve leaf color, but information on yield loss/recovery is not available. In fields showing these symptoms, the soil was either a sandy texture or had been recently leveled. Midseason application of ammonium sulfate may be needed on fields with a history of these symptoms.

Applications of elemental S have proven to be effective at reducing soil pH and improving rice productivity on calcareous soils with a history of high pH related problems (Table 8-12). Application of 500 pounds per acre (90 percent S) has been required to reduce soil pH enough to affect rice grain yields. Also, different elemental S sources require different lengths of time to effectively lower soil pH (Table 8-13). Some elemental S materials work in a few weeks while others may require months or years to effectively reduce soil pH to a desirable level. However, research is still underway to evaluate long-term effects of elemental S applications. Increased rice growth and yield from elemental S application is attributed to the increased availability of other essential nutrients

**Table 8-12. Rice Grain Yield, Soil pH and Electrical Conductivity as Influenced by an Elemental Sulfur Product (S92) at Two Locations**

S92 Rate	Grain Yield	Soil pH <sup>†</sup>	Soil EC <sup>†</sup>
lbs/A	bu/A		μS/cm
0	120	7.5	338
223	123	7.4	347
446	130	7.0	490
670	134	6.8	609
893	141	6.8	611
1785	142	6.5	775

<sup>†</sup>Soil pH and EC measured in a 1:2 soil weight:water volume ratio 34 d after S92 application.

Source: Slaton, et al. 1998. p. 322-325. Ark. Rice Res. Studies 1998. Ark. Ag. Exp. Sta. Res. Ser. 460.

**Table 8-13. Influence of Two Elemental Sulfur Products on Rice Grain Yields and Soil pH 34 Days after Application**

S Rate	Grain Yield		Soil pH <sup>†</sup>	
	Tiger 90	Wettable S	Tiger 90	Wettable S
lb/A	bu/acre			
0	97	97	7.6	7.6
223	109	111	7.4	7.1
446	103	136	7.2	6.6
670	119	127	7.3	6.3
893	123	119	7.4	6.0
1785	111	141	7.2	5.1

<sup>†</sup>Soil pH one year after 1785 lb S/A application was 6.6 and 5.5 for Tiger 90 and Wettable S, respectively.

Source: Slaton, et al. 1998. p. 326-329. Ark. Rice Res. Studies 1998. Ark. Ag. Exp. Sta. Res. Ser. 460.

(e.g., Zn) from soil acidification and not from increased S nutrition. Application of ammonium sulfate will also reduce soil pH when applied at high rates; however, elemental S is about four times more acidic than ammonium sulfate. Elemental S should be applied in the fall or winter to “problem” high pH areas to allow for the product to degrade and lower pH before seeding.

While the economics of elemental S still limit its widespread use in production situations, the introduction of new technology that allows grid sampling and variable rate applications may increase the affordability of elemental S applications. With this technology, the elemental S can be applied only to problem areas within a field, which reduces the cost compared to blanket applications to the entire field.

## Phosphorus and Potassium

In general, rice response to phosphorus (P) and potassium (K) fertilization is not as dramatic as that from N. Fertilization with P and K, when needed, may be accomplished in several ways. If rice is grown in a rotation of two years of soybeans followed by one year of rice, addition of P and K, according to soil test recommendations, to the soybean crop usually provides adequate residual P and K for an optimum yield of rice. If rice is grown continuously or in a 1:1 rotation with soybeans, additional P and/or K fertilizer may need to be added to the rice crop to maintain productivity of the soil. Routine soil testing is the

best criteria to establish the necessity of applying P and K to rice and rotational crops (Table 8-14). On saline soils, the application of K fertilizer may aggravate a salinity problem. However, data suggests that fertilizer-induced salinity will be reduced if P and K are applied together.

**Table 8-14. Phosphorus and Potassium Recommendations for Rice Based on the Mehlich 3 Soil Test Method**

Soil pH	Soil Test P (lbs/A)	Soil Test K (lbs/A)		
		≤ 125	125 - 175	> 175
< 6.5	≤ 30	X-20-90 <sup>‡</sup>	X-20-60	X-20-0
	> 30	X-0-90	X-0-60	X-0-0
> 6.5	≤ 30	X-60-90	X-60-60	X-60-0
	30-50	X-40-90	X-40-60	X-40-0
	> 50	X-0-90	X-0-60	X-0-0

<sup>‡</sup>N - P<sub>2</sub>O<sub>5</sub> - K<sub>2</sub>O

## Phosphorus

Phosphorus (P) fertilizer recommendations for rice are currently based on soil testing for available P and soil pH. Phosphorus availability to rice is optimum when the pH is below 6.5. For upland crops, P availability is usually optimum when the soil pH is between 6.0 and 6.5. In acid soils (pH < 6.0), the P is associated (“tied up” or “fixed”) with iron and aluminum compounds that are slowly available to most plants. When the soil pH is greater than 6.5, the P is primarily associated with calcium and magnesium. Not all calcium and magnesium phosphate compounds are slowly available to plants since their availability declines as pH increases. In acid soils, P availability increases following establishment of the permanent flood due to the chemical changes that occur to the iron phosphate. Thus, more P is available for rice following the flood than is measured with routine soil test methods. As a result, P is usually not limiting on acidic soils. In contrast, the availability of calcium phosphates tends to be low and remains low after flood establishment in alkaline soils (pH > 6.5). The Mehlich 3 soil test alone does not adequately predict P availability to rice. Subsequently, both Mehlich 3 extractable P and soil pH must be considered when deciding to apply P fertilizer (Table 8-14).

Soil test methods currently used by both university and private laboratories are limited in their ability to predict rice response to P fertiliza-

tion. Most soil test methods are developed for crops that are grown under upland (not flooded) conditions and are very useful for fertilizer recommendations to these crops. Recent research has shown that soil pH is a better predictor of rice response to P fertilization than soil test P. However, soil pH is not static and can vary by as much as 1 pH unit, depending on sample time, environmental conditions and other factors. Despite the variability in soil pH, it is an improvement over recommendations based solely on soil test P. Recommended P fertilizer rates based on soil test P (Mehlich 3) and soil pH are listed in Table 8-14. Application of P fertilizer to undisturbed acid soils that test low in P has failed to show significant yield increases and in some cases has increased lodging, caused rank vegetative growth and/or decreased yield (Table 8-15). Thus, the recommendation to growers is to limit direct P fertilizer applications to rice on these soils.

**Table 8-15. Influence of P Fertilizer Application on Whole Plant P Tissue Concentration and Grain Yield at Two Locations During 1995**

P Fertilizer Rate lbs P <sub>2</sub> O <sub>5</sub> /A	Cross Co.† pH=8.0		Poinsett Co. pH = 5.8	
	Tissue P %	Grain Yield bu/A	Tissue P %	Grain Yield bu/A
0	0.10	64	0.32	155
40	0.10	119	0.36	143

†Mehlich 3 soil test P was less than 20 lbs/A for both locations.

Source: Wilson, et al. 1996. p. 196-200. Ark. Rice Res. Studies 1995. Ark. Ag. Exp. Sta. Res. Ser. 453.

Many growers are concerned about very low soil test P levels and are interested in raising these to higher values with extra P fertilizer application. Research has found that soil test P usually declines (from previous soil test times) when samples are taken following rice in rotation, even when extra P fertilizer was applied. This decrease is usually representative of P availability to upland crops like soybeans and is due to changes in P compounds in the soil from the flooded soil. In general, soil test P slowly increases with time after rice is drained for harvest or when the soil samples are taken after soybeans in rotation the following year. Again, soil test methods are limited in ability to extract some forms of P found in the soil. Thus, an increase in soil test P level is difficult to measure when rice is grown in the rotation.

In addition to recommendations based on soil test results, P fertilizer is also recommended when the soil has been recently precision leveled. **For precision-leveled soils, 40 pounds P<sub>2</sub>O<sub>5</sub> per acre is recommended, unless the soil test calls for a higher amount.** Phosphorus content tends to decline with soil depth and is usually needed on fields that have been precision leveled. This is in addition to the recommended rate of poultry litter. Blanket P fertilizer applications to precision graded soils should be done for three to four years. If productivity appears to be restored to normal, applications of poultry litter and P may be limited to “problem areas” within the field. Subsequent P applications should be based on routine soil testing.

Regardless of the situation where P fertilizer is recommended, several fertilizer sources and application timing options are available to growers. Triple super phosphate (TSP, 0-46-0) is commonly used as the preplant fertilizer source. However, diammonium phosphate (DAP, 18-46-0) is competitive with TSP in price and is frequently used. If other preplant fertilizers are not required, P fertilizer can be blended and applied with preplant N. Preflood P applications have been found to be equally effective to preplant applications and may offer a savings in application costs if applied aerially with preplant urea (Table 8-16). DAP is commonly used in this situation since it also contains some N. On soils that have a history of P deficiency or are highly responsive to P fertilization, preplant applications have been found to be better than preplant application. **If a high rate of P is recommended, a split application may be useful on these highly responsive soils (one-half to two-thirds PPI followed by one-third to one-half at preplant).**

**Table 8-16. Influence of Phosphorus Fertilizer Application Timing on Rice Grain Yields at Four Locations**

Time of Application	Davis Farm		Wimpy Farm	
	1997	1998	1997	1998
	bu/A			
Control	126	152	143	138
Pre-emerge	152	163	150	134
Preflood	143	170	156	139
Postflood (7 days)	157	187	156	136
Panicle Differentiation	131	163	147	133
Soil Test P (lbs/A)	20	34	56	40
Soil pH	7.6	6.8	8.0	7.7

Source: Wilson, et al. 1999. p. 310-316. Ark. Rice Res. Studies 1998. Ark. Ag. Exp. Sta. Res. Ser. 468.

Phosphorus fertilizer should be applied directly (preplant or preplant) to the rice crop on responsive soils, since P fertilizer applied to previous crops or in the fall may be unavailable to rice during critical growth stages.

Midseason applications of P fertilizer have been found to increase grain yield on responsive soils when preplant or preplant was not applied (Table 8-16). **However, yield from midseason P is usually less than yield from P applications made earlier in the growing season.** Phosphorus fertilizer applications later than midseason have not been investigated.

Phosphorus deficiency symptoms on seedling rice may include severe stunting; small, very erect and dark green leaves; small diameter stems; lack of tillering and delayed plant development. These symptoms may be followed by rapid death of the older leaves, especially after the flood is applied. The symptoms have most commonly been observed 7 to 14 days after permanent flooding (midtillering). They may resemble zinc (Zn) deficiency and, like Zn deficiency, have been observed primarily on leveled fields or alkaline (high pH) silt loam soils. Because of the similarity with Zn deficiency symptoms, plant tissue analysis is the best means for correctly diagnosing which nutrient is causing the unhealthy rice (Table 8-11).

An average rice yield of 150 bushels per acre will remove approximately 20 pounds P per acre. This is equivalent to about 46 pounds P<sub>2</sub>O<sub>5</sub> per acre or 0.30 pound P<sub>2</sub>O<sub>5</sub> per bushel. A mature rice crop, including grain and straw (all above-ground biomass), may weigh 15,000 to 20,000 pounds per acre (dry weight) and contain on average 44 pounds P per acre. Thus, total crop uptake expressed as P<sub>2</sub>O<sub>5</sub> is about 100 pounds per acre. The amount of P removed in the grain comprises approximately 50 percent of the total taken up by the plant.

## Potassium

Potassium fertilizer is recommended on soils that test less than 175 pounds K per acre (Table 8-14). Potassium fertilizer recommendations are based solely on soil K levels, regardless of soil salinity. The salts added by recommended amounts of K fertilizer are small compared to the amount of salts in an existing saline soil. **Soils that test < 125 pounds K per acre are very susceptible to K deficiency and should receive extra fertilizer to satisfy crop requirements and build soil test K** (Table 8-14).

Silt and sandy loam soils in Arkansas have a very low buffering capacity, and soil test K can decline rapidly if K fertilizer is omitted for several consecutive crops. Studies have shown that in K-deficient soils, yields are potentially more limited by inadequate K levels than by the potential salinity injury resulting from K applications and that P applied with K may substantially reduce salinity damage aggravated by K fertilizer application. Application of K fertilizer in the fall or several months before seeding may help reduce the amount of salts in the root zone. For those producers interested in building soil fertility levels in their fields, the Soil Fertility Enhancement Program was established in such a way that if the soil test K is between 175 and 200 pounds per acre, an application of 0-0-60 is suggested.

Potassium fertilizer is generally recommended when rice shows K deficiency symptoms during the season. It is uncertain how much yield benefit, if any, is obtained from K fertilizer application to deficient rice in the mid- to late-boot stage. However, K fertilizer added at this time probably has some benefit for the rice crop and will remain in the soil for the benefit of future crops. Research continues to search for answers concerning these time of application questions.

Potassium deficiency symptoms include stunted plants with little or no reduction in tillering, droopy and dark green upper leaves, yellowing of the interveinal areas of the lower leaves starting from the leaf tip, leaf tips that eventually die and turn brown and development of brown spots on all leaves (Photos 8-1 and 8-8). The symptoms will often appear in and along the barrow ditches first. The deficiency symptoms generally begin to appear near midseason and may be first observed when the plants do not "green up" after midseason N applications. As the deficiency progresses, the plants may develop severe disease infestation due to the plants' reduced ability to resist infection. Diseases that are normally insignificant, such as brown leaf spot and stem rot, may become severe in addition to diseases such as rice blast. While these diseases are typically more severe in K-deficient areas, they are not, by themselves, indications of K deficiency. Potassium is highly mobile in the plant, and deficiency symptoms will always occur first and be most severe on the oldest leaves. Rice leaf tips of the upper leaves often turn yellow and then brown during hot dry periods. These symptoms should not be confused with K deficiency.

An average rice yield of 150 bushels per acre will only remove approximately 20 pounds K per acre. This is equivalent to about 24 pounds K<sub>2</sub>O per acre or 0.16 pound K<sub>2</sub>O per bushel. A mature rice crop, including grain and straw (all above-ground biomass), may weigh 15,000 to 20,000 pounds per acre (dry weight) and contain on average 210 pounds K per acre. Thus, total crop uptake expressed as K<sub>2</sub>O is 253 pounds per acre. About 10 to 20 percent of the total K taken up by the plant is removed in the grain. University of Arkansas K fertilizer recommendations are based on soil test K and should help build soil K levels when soil test K is low because rice removes a low amount of the total K that is taken up. It should be remembered that immediately after harvest of any crop the K not removed by grain may still be in the stubble. Thus, soil test K should increase as K leaches from stubble back into the soil with time.

## Liming

**Liming a soil is generally for the benefit of the other crops in the rotation because rice grows well in an acid soil.** However, recent research has found that rice yields may also benefit from lime when soil pH is near 5.0. Response of rice to liming is often negative due to uneven distribution, excessive application rate and application to areas that do not require lime. Deficiencies of P and Zn may occur in rice fields, especially near water inlets, where lime has been recently applied. Thus, P and Zn fertilization of the next rice crop should be considered.

If liming is necessary to optimize growth and yield of other crops in the rotation, it should be applied immediately after the rice crop and prior to the production of other crops in the rotation, not immediately ahead of the rice crop (Table 8-17). Use of grid soil sampling and variable rate application equipment are highly recommended for lime application to fields with rice in the rotation. If grid soil samples are not used, take extreme care in soil sampling, especially if the irrigation water source is a well, so that a correct lime recommendation can be made in the appropriate areas of the field.

**Table 8-17. Liming Guide for Sand, Silt Loam and Clay Loam Soils That Have Rice in the Crop Rotation†**

Soil pH	> 5.5	5.5 -5.3	5.2 - 5.0	< 5.0
Lime (tons/A)	0	1.0	1.5	2.5

†Lime upper half of field only when well water calcium concentration is < 3 meq Ca/l and pH of water inlet area is < 5.5. Consult county Extension agent for lime recommendations on clay soils.

Follow correct soil sampling procedures so that soil test results for lime and other nutrient recommendations are representative of the entire field. Collect composite soil samples from the area near the water inlet, the center and the bottom portion of the field, as well as areas that differ in soil series or texture within these locations. **One composite soil sample should not represent more than 20 acres.** Composite samples near water inlets should represent only 5 to 10 acres. To determine the lime contribution of the irrigation source, the irrigation water should be sampled. Water sampling kits (information) may be obtained at the county Extension office.

## Zinc

Zinc deficiency normally occurs on silt and sandy loam soils or on precision graded fields. It is caused by a reduction in the availability of native soil Zn because the soil pH has been increased either by use of calcareous irrigation water or over-liming, not due to a lack of Zn in the soil. The correction of the problem requires either reduction of the soil pH or addition of a suitable Zn source. Zinc deficiency is not commonly observed on clay soils in Arkansas. Therefore, Zn fertilizer is only recommended on silt and sandy loam soils with soil pH greater than 5.9 and soil test Zn (Mehlich 3) < 7 pounds Zn per acre. Growers with high pH clay soils should monitor rice grown on these soils carefully since Zn deficiency on clay soils is known to occur in other rice producing areas of the world.

Zinc deficiency, P deficiency and salinity injury symptoms are easily and often confused. Zinc deficiency symptoms usually occur after flushing or flooding, whereas problems from salinity occur prior to flushing or flooding under dry soil conditions. Both salinity and Zn deficiency can be present in the same field. Phosphorus deficiency is also similar to Zn deficiency in that the symptoms typically occur after flooding. However, leaves are usually more erect and basal chlorosis (yellowing) is usually not present with P deficiency. Also, Zn deficiency appears much sooner after the flood is established, usually within a few days, whereas it generally takes a week or two after flooding to show P deficiency. Plant tissue analysis is the most effective means of correctly distinguishing which nutrient is the cause of the unhealthy rice (Table 8-11).

Many questions remain to be answered concerning Zn fertilizer recommendations; however, research is actively addressing these in

order to improve Zn fertilizer recommendations for rice. Recommendations provided here may change with additional research, so consult your local county Extension agent for up-to-date information.

Zinc deficiency symptoms usually are not observed until shortly after flooding, when they have become severe enough that the flood must be removed in order to salvage the rice. However, the rice is Zn deficient before the flood is applied. Prior to flooding, the symptoms are usually subtle and difficult to observe without very close visual examination. Seedling rice can obtain sufficient nutrients from the seed for about 10 days after emergence. Therefore, Zn deficiency symptoms do not generally appear in seedling rice until at least 10 days after emergence, and it may take several weeks after emergence for the symptoms to appear. The Zn deficiency symptoms, whether subtle if observed before flooding or severe if observed after flooding, include:

1. Basal leaf chlorosis – the portion of the leaf nearest the stem becomes light green while the leaf tip remains a darker green. Usually begins in the youngest leaf (Photo 8-3).
2. The leaves may lose turgidity and tend to float on the water surface if the rice is flooded or being flushed. Flushing seedling rice can aggravate Zn deficiency, cause the visual symptoms mentioned to become more noticeable and enable visual diagnosis before flooding to avoid a salvage situation. So pay close attention to the young rice when flushing.
3. Bronzing – consists of brown to red splotches starting on the surfaces of the oldest leaves (Photo 8-4). Bronzed leaf tissue may eventually turn brown.
4. Stacking of leaf sheaths or joints (Photo 8-6).

Bronzing normally follows basal leaf chlorosis. The loss of leaf turgidity is a difficult symptom to evaluate since deep water may give leaf tissue a similar appearance. The symptoms are often noted within 72 hours after flooding and are aggravated by deep and cold water. If the soil pH is extremely high, deficiency symptoms may appear after a flush or a rain. Environmental factors, such as cool temperatures, may increase the severity of deficiency symptoms. Likewise, excessive P fertilizer applications may aggravate a Zn deficiency. Field history and soil analysis for

soil pH and soil Zn determination are the two best methods for determining if Zn fertilizer may be needed. Zinc deficiency should be documented by plant and soil analysis (Table 8-18).

**Table 8-18. Interpretation of Whole Plant (Seedling) Tissue Analysis for Salt (Salinity), Zinc and Phosphorus Concentration**

Analysis	Tissue Concentration <sup>†</sup>		
	Normal	Possible	Probable
	mg/kg or ppm		
Zinc	> 20	15-20	< 15
Phosphorus	> 0.20%	0.15 - 0.20%	< 0.15 %
Chloride Salt	< 10,000	10,000 - 12,000	> 12,000
Nitrate Salt	< 1,600	1,600 - 2,400	> 2,400

<sup>†</sup>Normal refers to healthy seedling rice tissue concentrations. Possible means that injury could be due to concentrations in this range. Probable means that injury was very likely due to concentrations in this range.

Zinc fertilizer recommendations are now based on soil texture (silt and sandy loam soils), soil test Zn (Mehlich 3 Zn  $\leq$  7 pounds per acre) and soil pH (> 5.9). When all three of these criteria are met, application of Zn fertilizer is recommended. Previously, Zn recommendations were based solely on soil texture and pH. Thus, the residual effect of previous granular Zn applications were not considered. Many soils that have had Zn fertilizer applied to each rice crop over the past 20 years have very high soil test Zn levels (> 15 to 20 pounds Mehlich 3 Zn per acre) and may not need additional Zn. The native soil test Zn (Mehlich 3 Zn) for most Arkansas soils is generally < 5 pounds Zn per acre. Zinc deficiency occurs primarily on soils with moderate to high pH (> 6.0) and low soil test Zn (< 4 pounds Zn per acre). Soil test Zn (Mehlich 3 Zn) levels greater than 10 pounds Zn per acre suggest a history of Zn fertilizer use and a crop response to Zn fertilization is not likely. If soil test Zn is high and rice continues to get sick after flooding, another nutrient may be deficient.

Zinc deficiency may be corrected by either acidifying the soil or applying a suitable Zn fertilizer source at the proper rate and timing. Acidification of the soil requires the addition of elemental S at 500 to 1,000 pounds per acre (Table 8-12), but currently is not economical.

Repeated broadcast application of lower amounts of elemental S may not be sufficient to lower the pH and benefit the rice crop (Tables 8-12 and 8-13).

Zinc fertilizer may be applied on the soil before planting, as a seed treatment, on the soil surface after planting or as a foliar application to seedling rice. The Zn source determines the proper rate and application timing (Tables 8-19 and 8-20). Recent studies of granular Zn materials show that the degree to which these materials dissolve in water is an indication of the relative effectiveness at preventing Zn deficiency (Table 8-21). Granular Zn sources should have a minimum of 50 percent water solubility for optimum effectiveness. Sources with water soluble Zn concentration < 50 percent are currently not recommended for use. It is very important that growers know the source/type of granular Zn that they are purchasing. If a source of interest is not included in Table 8-21, a fertilizer sample may be submitted to the Extension rice agronomist through the county Extension office for analysis.

**Table 8-19. Suggested Zinc Fertilizer Sources and Rates**

Fertilizer Source	Actual Zinc (lbs/acre)
<b>Organic chelates</b> EDTA, DPTA, etc.	1.0
<b>Organic complexes</b> ligno-sulfonates, phenols, citrate mixtures, etc.	2.0 - 2.5
<b>Inorganic</b> sulfates, oxides liquids such as nitrates and chlorides	10.0 2.0 - 2.5

**Table 8-20. Quarts of Liquid Zinc Material Differing in Zn Analysis Needed to Supply 1 to 2 Pounds of Elemental Zn.**

% Zinc in Material	Liquid Zinc Source	
	EDTA Chelate (1 lb Zn /A)	Chelate-Complex (1- 2 lb Zn/A)
	qts/A	
4	10	15 - 20
6	6.5	10 - 13
8	5	7.5 - 10
10	4	6 - 8
12	3.5	5 - 7

**Table 8-21. Percent Water Solubility of Selected Granular Zinc Fertilizer Sources**

Source	Zinc Concentration		% of Total Zn that is Water Soluble†
	Total	Water Soluble	
	%		
CoZinco	31	29.4	97.5
Frit	20	7.6	40.4
Frit	36	5.0	13.9
Bin Buster	36	7.0	20.0
Ruffin	10	8.3	82.0
Super Tel	35.5	32.9	93.9
Stoller	36	4.4	12.3

†Only granular Zn sources with at least 50 percent of the total Zn that is water soluble are recommended for use as a preplant Zn source for rice.

Source: J.F. Liscano, M.S. Thesis, Univ. of Arkansas, Fayetteville., 1998.

### Preplant and Delayed-Pre Zn Application

Zinc applied preplant may be blended with other fertilizers and incorporated shallow immediately before planting. Limited research also suggests that preplant or delayed-pre surface applications of Zn fertilizer are equally effective for dry-seeded rice. However, Zn fertilizers should be surface applied on water-seeded fields. Root development under water-seeded conditions is slow; therefore, Zn fertilizer placement is critical for proper plant uptake. Granular Zn sources intended for soil application should be applied at 10 pounds Zn per acre. To calculate the total amount of product required, divide 10 pounds Zn per acre by the guaranteed Zn analysis (i.e., 31 percent = 0.31) of the fertilizer. For example, a Zn fertilizer having an analysis of 36 percent Zn requires  $10 \text{ pounds Zn} \div (36 \text{ percent Zn} \div 100) = 27.8$  pounds of product to obtain 10 pounds Zn per acre. Although the total uptake of Zn in a mature rice crop is less than 1 pound per acre, research has shown that 10 pounds Zn per acre are required for uniform distribution of Zn fertilizer granules in the soil. Fertilizers with a lower guaranteed Zn analysis provide better distribution of fertilizer granules compared to higher analysis fertilizers with similar particle size. Limited research data suggest that liquid Zn sources (Zn Oxides, Zn EDTA and Zn sulfate) may also be applied shortly before or after planting. Liquid sources offer the advantage of more uniform distribution, lower use rates and, depending on

the source, lower fertilizer cost when compared to most granular applications. Inorganic Zn sources (Zn oxide and Zn sulfate) applied in the liquid form at this time should be applied at rates from 2 to 4 pounds Zn per acre.

Zinc seed treatments have recently been shown to be an effective means of Zn fertilization for dry-seeded rice (Table 8-22). The advantages of Zn seed treatments are potential lower cost (depending on the Zn source used to treat the seed) and uniformity of application. Zinc seed treatments with Zn sulfate or Zn oxide sources require only about 0.25 to 0.5 pound of Zn per hundredweight of seed compared to 10 pounds Zn per acre if applied preplant as a granular material. While seed treatment with other Zn sources is also effective, the total Zn rates are basically the same. Some Zn sources have been shown to reduce germination, so caution should be used when selecting Zn sources for seed treatment. The higher Zn application rate should be used when soil pH is high, soil test Zn is low and severe Zn deficiency is expected.

**Table 8- 22. Influence† of Zn Seed Treatments on Rice Yields on an Alkaline Silt Loam Soil**

Zinc Rate	RREC‡		PTBES‡	
	Yield bu/A	Tissue Zn mg/kg	Yield bu/A	Tissue Zn mg/kg
Check	114	17.5	130	17.5
10 lb Zn/A‡	158	31.0	143	19.4
0.10 lb Zn/cwt§	136	16.9	145	20.2
0.22 lb Zn/cwt	146	18.5	142	20.9
0.47 lb Zn/cwt	152	20.9	163	29.7

†N.A. Slaton, unpublished data.

‡31% CoZinco Zn sulfate preplant incorporated at 32 lb/A.

§Zn sulfate applied to seed – values are net seed concentration after treatment.

¶RREC, Rice Research & Extension Center, Stuttgart; PTBES, Pine Tree Branch Experiment Station.

As a rule of thumb, when soil pH is high and soil test Zn is  $\leq 7.0$  pounds Zn per acre (Mehlich 3 Zn) the higher rate of Zn should be applied to seed. **The amount of Zn retained on the seed after treatment is highly important.** Net seed Zn concentration can be checked by most laboratories that perform plant and soil analysis. Submit Zn treated seed to determine the net seed Zn concentration. Research on Zn seed treatments is ongoing and recommendations concerning

application rates and different products may change with additional data, so check with your local county Extension office for up-to-date recommendations. The best approach for management of Zn nutrition in rice may be to build soil test Zn levels above 7 pounds Zn per acre (Mehlich 3 soil test) with broadcast soil Zn applications and use Zn treated seed or other low cost Zn fertilization methods for insurance on future crops.

### Preflood Applications

Liquid organic chelate or inorganic sources can be applied from the 2-leaf stage to five to seven days prior to flooding. Application of liquid Zn immediately before flooding is discouraged since seedling rice may be Zn deficient before flooding. Application of Zn fertilizer to rice foliage a minimum of five to seven days before flooding provides time for fertilizer uptake and correction of the Zn deficiency before the seedlings are stressed by flooding. The rate of Zn is very important. It is critical to know your Zn source (Tables 8-19 and 8-20). Many of the products, sold as chelates, on the market are not well labeled and are often mixtures that contain a very small portion of the Zn in the chelated form. If in doubt as to the reliability of the Zn source, use the higher rate recommended for the nonchelated organic and inorganic liquids. The disadvantage of foliar or low-rate soil applications of Zn fertilizer is they benefit only the current rice crop and do not build soil test Zn to provide residual benefit to future crops. Aerial application of some granule Zn fertilizers a week before flooding has also been successful in limited research tests but is not currently recommended. More research trials are needed to confirm the effectiveness of Zn fertilizer applied in this manner.

Some liquid Zn sources may be safely mixed with herbicides. **Always test for product compatibility prior to loading.** Read and follow the herbicide label prior to tank mixing Zn fertilizer with herbicides since some herbicides cannot be mixed with fertilizers. Avoid applying herbicides and/or herbicide Zn mixtures if the rice is stressed at the desired time of application since increased injury may occur. Application of herbicides under stressed conditions may result in a loss or reduction of stand. Research is currently evaluating the use of granular Zn fertilizers for preflood and postflood correction of Zn deficiency. Contact your local county Extension agent for additional information.

### Salvage Treatment for Zn Deficiency

1. Drain immediately after detecting symptoms. The interval between draining and visual recovery from symptoms is about 7 to 14 days. Correction of the problem by applying Zn fertilizer into the irrigation water without draining is not recommended.
2. When new root and shoot growth can be seen, apply either Zn EDTA at 1 pound per acre or the complexes at 2 to 2.5 pounds per acre.
3. Apply 100 pounds per acre of ammonium sulfate and apply a shallow flood.

Plant development may be delayed by as much as two to three weeks; however, yields approaching 90 percent of normal may be expected if the delay in development does not result in additional losses due to cold weather at heading.

Delaying the flood may help minimize Zn deficiency by allowing further development of the rice root system; however, this may also increase herbicide use to control weeds. A residual herbicide may prevent additional applications if this management strategy is to be followed.

### Salinity

Salinity damage occurs mainly on rice during the seedling stage and on larger rice located on levees both prior to and after flooding. Injury results when soluble chloride or nitrate salts (i.e., calcium, magnesium, potassium, sodium, etc.) become concentrated within the root zone of the seedling rice plant. Salt accumulation is often the result of irrigation water containing high quantities of soluble salts. In addition, salinity problems are commonly associated with poor soil drainage, and some soils and subsoils have naturally high levels of soluble salts. The poor drainage characteristics that are beneficial for flood maintenance in rice are the same characteristics that increase the likelihood of salinity. Salinity injury occasionally occurs when the field is flushed due to irrigation water containing high levels of soluble salt.

When salts are deposited in the soil, the salts move up and down in the soil profile with the water. During periods of high rainfall or irrigation, salts leach downward through the soil profile, the extent of which is determined by the soil's permeability. During dry periods, water is removed from

the soil through evaporation and salts move up and accumulate at the soil surface. This salt accumulation at the soil surface can cause reduced stands in certain areas of the paddy, such as the breaks of ridges, stagnant water areas and on the top of levees. Usually salinity damage on levees does not occur until the field is flooded and water is present to be evaporated through the levee. Most evaporation of water through the levee occurs on the top and southwestern side. The soil surface on top of the levee may have a black, oily appearance from the accumulation of salt and organic matter that was dissolved in the soil water prior to evaporation.

Research has shown that reduced tillage may enhance salt accumulation during the seedling growth stage on soils that have a history of salinity injury. Yield reductions of as much as 20 percent have been measured as the result of reduced tillage on soils that have a history of salinity damage (Table 8-23). Thus, it is advantageous to avoid using conservation tillage practices on soils that have a history of salinity injury.

**Table 8-23. Influence of Tillage on Salinity and Rice Grain Yields**

Tillage Operation	Grain Yield bu/A	Salt in root zone at 2-3 leaf stage
		EC <sup>†</sup> ( $\mu$ mhos/cm)
Conventional	146	585
Chisel Plow	158	500
Para-till	159	485
No-till	130	775

<sup>†</sup>EC, Electrical conductivity measured on a 1:2 soil wt: water volume ratio.

Source: Wilson, et al. 1997. p. 142-146. Ark. Rice Res. Studies 1996. Ark. Ag. Exp. Sta. Res. Ser. 456.

Plant symptoms of salinity damage are as follows:

- Plants are usually at the 2- to 5-leaf stage. Rice is tolerant to salinity during germination; however, it becomes quite sensitive to damage during early seedling development.
- Symptoms include leaf tip die-back, leaf rolling, stunting and rapid death, increased sensitivity to herbicides and reduced stand densities. Salt stressed plants may turn chlorotic (yellow), with the chlorosis beginning in the youngest leaves.

- Plant analysis usually indicates an excessive level of chlorides and/or nitrates in the tissue (Table 8-18).

Soil samples taken from the affected area may show an elevated electrical conductivity (EC) along with higher than normal levels of such cations as sodium, calcium, magnesium and potassium or nitrate anions and chloride. Salinity problems are difficult to predict from routine soil tests since salt concentrations in the top inch of the soil are greatly influenced by precipitation. Soils are classified as saline if they have an EC > 400 micromhos/cm (Table 8-24) for a mixture of one part soil to two parts water.

**Table 8-24. Saline and Sodic Soil Identification Parameters**

All Soil Textures	
Condition	Electrical Conductivity, micromhos/cm
Normal	< 150
Excessive	> 400
Sodic	
	% Na Saturation <sup>†</sup>
Normal	< 3
Excessive	> 8

<sup>†</sup>Exchangeable Sodium Percentage (ESP).

### Management of Saline Soils

1. Flush the seedling rice frequently with good quality, salt-free irrigation water to minimize accumulation of salts within the root zone.
2. Flood the rice as soon as it can tolerate a flood.
3. Have irrigation water tested for quality. Minimize the use of poor quality water by substituting good quality surface water for poor quality groundwater. **CAUTION:** Surface water can also be of poor quality in regards to salt content. Salts are soluble and water that is relifted from drainage ditches or tailwater recovery systems may actually increase in soluble salt content.

Occasionally, a field may have both a Zn deficiency and a salt problem. In this situation, diagnosing both problems is important. Apply the Zn as early as possible; otherwise, flushing the rice may intensify damage from Zn deficiency while attempting to reduce salt damage. In

addition, the flush water must be applied and removed in the least possible time. This may require rearranging the flood gates.

Sodic soils are different from saline soils in that they contain very high amounts of exchangeable sodium (Na). Often precision leveling will expose subsoils that are naturally high in Na. Sodic soils may have a high pH and have very poor physical properties. High amounts of exchangeable Na indirectly affect rice growth by causing poor soil physical properties. Poor physical properties, such as lack of soil structure, may make stand establishment more difficult. Some of the Arkansas soils that are classified as having Natric (sodic) horizons are Foley, Hillemann, Lafe and Stuttgart silt loams. The exchangeable sodium percentage (ESP) of the topsoil and subsoil test results can be used to identify potential sodium problems (Table 8-24).

### **Diagnostic Soil and Plant Tissue Sampling**

In addition to routine soil tests, diagnostic soil tests for salt content (EC), sodium, pH and calcium can help determine why seedling rice is dying. Diagnostic soil testing consists of sampling both the affected and unaffected areas at different depths – 0 to 1, 1 to 2 and 2 to 4 inch depths. Be sure to pay attention to differences in soil texture when sampling.

Correct diagnosis of nutritional problems is not always easily performed through soil testing and visual identification of deficiency symptoms. This is especially true of precision leveled fields. Plant tissue analysis should be used to help identify the nutritional problem (Table 8-11). This service is offered through the University of Arkansas for a small fee. For seedling rice, complete plants (without the roots) should be submitted for analysis of both healthy and unhealthy plants. About 30 to 40 seedlings are needed to provide enough tissue for analysis. For Zn analysis, rinse fresh tissue with distilled water to remove soil contamination. Place the seedlings from each part of the field in a separate paper sack and deliver to the county Extension office. Older plants can either be submitted as entire plants or samples of the affected tissues (i.e., top or bottom leaves). Use Table 8-18 to aid in interpretation of tissue analysis of seedling rice for Zn, P and salt injury.

Results from plant tissue analysis may not be received quickly enough to salvage a sick crop, but can be used to avoid problems in future years. A method that frequently identifies and solves nutritional problems quicker than plant analysis is the application of different fertilizers to small plots within the affected area. The nutrient(s) that give a growth response identifies the nutrient(s) that are limiting and should be applied. Usually a growth response from the fertilizer applied in the plots occurs in about three to five days if the field is flooded or if the fertilizer has been watered into the soil.

### **Fertilization and Management of Precision Graded Soils**

Precision grading of fields for improved water management is continually being performed in eastern Arkansas. A decrease in productivity often results from precision grading of silt and sandy loam soils. When soils are precision graded, topsoil is removed from areas of higher elevation and deposited in areas of lower elevation. In many cases, the subsoil material that is exposed or moved is unproductive and difficult to manage. In these areas, it is generally true that the deeper the cut, the greater the decline in crop productivity and the more beneficial it will be to invest in soil reclamation. Routine soil testing is often unable to identify the nutrient(s) that are limiting plant growth on the cut areas. The application of poultry litter helps restore lost productivity to leveled soils. Realizing that some soils may be graded without a loss of productivity, application of poultry litter to these soils is not economical. For example, clay soils do not generally exhibit reduced productivity following grading. The following is a summation of research conducted to refine recommendations for the application of litter and fertility management on precision graded soils. Suggestions on rice crop management have also been included where appropriate.

#### **General Fertility**

Follow recommended N rates for the variety to be planted despite the application of recommended amounts of poultry litter. Litter commonly contains about 2 to 4 percent N (Table 8-5). However, only about half the total N is available during the first growing season. Nitrogen rates should only be adjusted when extremely high rates of litter are applied immediately prior to planting.

Although routine soil testing seldom identifies fertility problems on cut fields, soil samples should be submitted for general recommendations for P, K and Zn and to identify pH and Na levels. Refer to the *Rice Production Handbook* sections that discuss P, K, Zn and saline and sodic soils for recommendations.

A blanket application of 40 pounds P<sub>2</sub>O<sub>5</sub> per acre is recommended on cut soils because the P content of many Delta subsoils is very low. Research results have shown that rice growing on cut soils frequently responds to applications of P fertilizer (Table 8-26). Furthermore, the data indicate that application of both litter and P is likely to produce yields in excess of those obtained when either material is applied alone. Therefore, P should be added in addition to poultry litter amendments.

Inorganic fertilizer (P, K, Zn and S) has in some cases increased productivity of cut soils (Table 8-27); however, yield responses to commercial fertilizer applications alone have been inconsistent and not always as great as those from poultry litter applications. Data also indicate that inorganic fertilizer is less effective on soils with deep cuts. Apply inorganic fertilizer in amounts recommended by soil test results, in addition to poultry litter amendments. Diagnostic soil testing and plant tissue analysis may be useful to correctly identify problem areas during the growing season.

### Rate of Litter

Poultry litter may be a viable source of P and K on undisturbed soils; however, the primary benefit of litter is restoring lost productivity on cut soils. Numerous research studies indicate that poultry litter rates less than 1,000 pounds per acre are inconsistent in producing significant yield increases on leveled soils (Table 8-28). Consequently, no less than 1,000 pounds of litter (dry weight basis) per acre should be applied to precision leveled silt loam soils. When applying litter, adjust the application rate to compensate for moisture content of the litter. For example, 1,000 pounds of fresh litter at 30 percent moisture contains about 300 pounds of water and 700 pounds of litter. Poultry litter data included in Tables 8-25 through 8-31 refer to dry weight litter rates.

Research shows that spring applications of litter produce higher rice yields compared to fall applications of equal amounts (Table 8-29). Data also indicate that pound for pound, fresh litter and composted litter produce equal yield responses

**Table 8-25. Ranges and Mean Values for N, P, K and Zn Found in 1 Ton of Poultry Litter<sup>†</sup>**

Element <sup>‡</sup>	Mean	Range	
		Low	High
lbs/A/ton litter (dry weight basis)			
N	81.6	34	136
P	28.6	16	52
P <sub>2</sub> O <sub>5</sub>	65.5	37	119
K	41.4	26	92
K <sub>2</sub> O	49.9	31	111
Zn	0.4	0.2	0.5

<sup>†</sup>Edwards, D.R., and T.C. Daniels. 1992. Environmental Impacts of On-Farm Poultry Waste Disposal – A Review. *Bioresource Technology*, Vol. 41, p. 9-33.

<sup>‡</sup>P x 2.29 = P<sub>2</sub>O<sub>5</sub>; K x 1.2 = K<sub>2</sub>O

**Table 8-26. Rice Yield Response on Precision Graded Silt Loam Soils to Poultry Litter and P Fertilizer**

Treatment	Location		
	Lewis Farm	Connor1 Farm	Connor2 Farm
rate/A	grain yield, bu/A		
Control	40	106	88
46 lbs P <sub>2</sub> O <sub>5</sub>	52	124	121
2000 lbs compost	114	129	142
46 lbs P <sub>2</sub> O <sub>5</sub> + 2000 lbs compost	101	135	164

**Table 8-27. Rice Grain Yield Response Comparing Inorganic Fertilizers and Poultry Litter on Precision Graded Silt Loam Soils**

Location/Year	Treatment		
	Control	Inorganic Fertilizer	Litter
grain yield, bu/A			
Lewis, 1989 <sup>†</sup>	40	73	114
Connor1, 1989 <sup>†</sup>	106	113	129
Connor2, 1989 <sup>†</sup>	88	144	142
Connor, 1990 <sup>‡</sup>	50	80	88
Dunklin East, 1992 <sup>§</sup>	9	32	80
Dunklin West, 1992 <sup>§</sup>	37	93	99

<sup>†</sup>Litter: 2000 lbs compost/A; Inorganics: 1 lb Zn (Zn EDTA) + 2 ton gypsum + 46 lbs P<sub>2</sub>O<sub>5</sub> (TSP)/A.

<sup>‡</sup>Litter: 2000 lbs fresh litter/A; Inorganics: 1 lb Zn (Zn EDTA) + 20 lbs S (elemental S) + 72 lbs K<sub>2</sub>O (KCl) + 46 lbs P<sub>2</sub>O<sub>5</sub> (TSP)/A.

<sup>§</sup>Litter: 2000 lbs fresh litter/A; Inorganics: 300 lbs Rainbow Mix/A (10-14-4-11(S)-2(Zn)).

(Table 8-30). Since timing of poultry litter influences yield response, the frequency of litter applications is also important to maximize production in future years.

A single application of litter after leveling produces higher yields for several years compared to leveled areas which did not receive any litter.

**Table 8-28. Rice Grain Yield Response to Six Composted Poultry Litter Rates in 1992**

Location	Poultry Litter Application Rate (dry weight basis)					
	0	250	500	750	1000	2000
	grain yield, bu/A					
Dunklin East	29	68	65	83	82	103
Dunklin West	9	19	46	57	78	87

**Table 8-29. Grain Yields of Fresh Litter Applied in the Spring at Five Rates on a Shallow and Deep Cut Field Near Lodge Corner, Arkansas**

Litter Rate	Shallow Cut		Deep Cut	
	Spring <sup>†</sup>	Fall	Spring	Fall
lbs/A	grain yield, bu/A <sup>‡</sup>			
0	37		9	
1000	86	58	45	5
2000	99	79	80	22
4000	111	80	98	47
6000	102	88	107	73

<sup>†</sup>Fresh litter applied in October (fall) and June (spring) on a dry weight basis.

<sup>‡</sup>Field seeded with Lemont rice on June 16, 1992.

**Table 8-30. Comparison of Rice Grain Yields When Fresh and Composted Poultry Litter Were Applied in the Spring on a Cut Field**

Litter Rate	Litter Source <sup>†</sup>	
	Fresh	Composted
lbs /A	grain yield, bu/A	
0	37	
1000	86	94
2000	99	103
4000	111	110
6000	102	102

<sup>†</sup>Field seeded in Lemont on June 16, 1992, near Lodge Corner, AR. Litter applied on a dry weight basis.

**Table 8-31. Rice Yield Response During the 2nd Year Following Fresh Poultry Litter Application for Two Consecutive Years Compared to One Single Application at Three Nitrogen Fertilization Rates**

Litter Application Time	Preflood N Rate	Litter Application Rate, lbs/A (dry weight basis)				
		0	900	2700	5400	8100
		grain yield, bu/A				
1st and 2nd year	0	12	23	54	86	103
1st year only	0	12	—	22	—	31
1st and 2nd year	40	17	36	81	87	115
1st year only	40	17	—	31	—	54
1st and 2nd year	80	29	70	82	92	90
1st year only	80	29	—	70	—	80

Litter has a small residual effect and may increase production for several years. The greatest benefit of litter applications to grain yield occurs the first year (Table 8-31). Grain yields declined the second year after litter application when additional litter was not applied. Areas that received litter applications both the first and second year produced higher yields the second production year after leveling. Sequential litter applications may be needed to fully restore lost productivity to leveled soils. Usually the deeper the cut, the longer the litter has to be applied. Shallow cuts usually require only a year or two of litter application and the deeper cuts three to five years of litter application for full restoration.

### Management Tips

Management of rice on precision leveled fields is difficult since the severity of lost production is unknown and reasons for poor growth are not easily identified. The location of areas which may have poor growth are often random and unknown prior to planting. Areas of poor growth may be the result of a combination of factors or due to a single nutritional problem. Due to the variability of cut soils, a complete set of management guidelines that would apply to all situations is impossible to assemble, but certain guidelines can be followed to reduce spending large amounts of money to produce a low yield.

Before starting the leveling process, study the county soil survey maps to determine the soil series within the field to be leveled. Soil survey reports provide the physical and chemical properties of the topsoil and the subsoils which may be exposed. This helps pinpoint certain problems that may be present after leveling. Further information can be obtained by soil sampling the topsoil and the subsoil to the depth which the field will be cut. The use of global positioning systems (GPS) and grid soil sampling both topsoil and subsoil can pinpoint areas in the field that may present problems if the topsoil is removed via precision leveling.

Variety selection is very important for precision leveled fields. Select a variety that has good grain and milling yield potential but has a low cost of production. Semi-dwarf varieties (i.e., Cypress, Cocodrie) usually have higher production cost for weed control, N fertilization and sheath blight control compared to taller varieties (i.e., Drew). Reduced growth may intensify yield reductions caused by sheath blight, especially on short-statured varieties, and nutritionally stressed plants may also be more susceptible to yield losses from blast infections. Nutritional disorders associated with cut fields often result in a delay in maturity; therefore, maturity group is also important. Poor soil physical properties (i.e., soil structure) regularly occur in leveled fields. This may affect seedling emergence and flushing frequency to establish an adequate stand of rice. Consider a variety that has excellent seedling vigor and seed treatments, such as gibberellic acid products, to aid in quick, uniform stand establishment. Drew and Kaybonnet are excellent varieties for leveled fields due to their relatively low N requirement, excellent disease resistance, yield potential and seedling vigor.

A preemergence or delayed preemergence residual herbicide may provide effective and economical weed control. However, some residual herbicides are not labeled for use on first year precision-leveled fields or caution that increased injury may occur from herbicide application. Always read the entire label. Stressed rice seedlings may also be sensitive to contact herbicide applications, resulting in excessive injury or reduced stands. In addition, stressed weeds may be less susceptible, resulting in poor control and necessitating an additional herbicide application to control escaped weeds.

Flood water is often delayed due to high pH or Zn deficiency on cut soils. Residual herbicides may provide weed control long enough to allow the delay of flooding without the loss of weed control.

Observation of growth of winter vegetation and previous crops (if any) may help identify areas of poor production prior to seeding. If this is the case, application of higher rates of litter to these identifiable areas may be helpful. Diagnostic soil tests may also be submitted to identify the problem. During the growing season, use plant tissue analysis to correctly classify the nutritional disorder (Tables 8-11 and 8-18). Areas with high levels of sodium (Table 8-24) are often exposed and typically have poor soil structure. Upon drying, these areas form a hard crust, making seedling emergence difficult. The time, before or after the flood, that rice starts to exhibit poor growth can help in identifying the problem.

Contact your county Extension agent if problems occur during the growing season. Check with your local county Extension office for the latest research findings on management of precision leveled fields.

**Photographs are referenced throughout  
Section 8 - Efficient Use of Fertilizer.**



**Photo 8-1. Potassium deficient leaf (top) compared to healthy leaf (bottom). Note the severe brown spot and yellow/brown leaf margins of K deficient leaf.**



**Photo 8-2. Various stages of internode elongation at midseason**



**Photo 8-3. Basal chlorosis of bottom leaf and midrib of zinc deficient rice plant.**



**Photo 8-4. Mottled color due to chlorosis and bronzing of lower rice leaves caused by prolonged Zn deficiency.**



**Photo 8-5. Plant area board or Rice Gauge used to adjust midseason N rates for rice.**



**Photo 8-6. Stacked leaf collars of zinc deficient rice plant (left) compared to normal plant (right).**



**Photo 8-7. Symptoms (on upper leaves) due to late season sulfur deficiency.**



**Photo 8-8. Potassium deficient rice at heading. Note brown spot on leaves and panicles.**