Effect of Rates and Timing of Midseason Nitrogen Applications on Performance of Short-season Rice Varieties, 1964-1965

AGRICULTURAL EXPERIMENT STATION

Division of Agriculture

University of Arkansas, Fayetteville

in cooperation with

CROPS RESEARCH DIVISION

Agricultural Research Service

United States Department of Agriculture

JANUARY, 1967 REPORT SERIES 154

CONTENTS

COVER PICTURE

Shown on the cover is a general view of the rate and timing-of-N-fertilization rice variety test at the Rice Branch Station, Stuttgart, near harvest time. Each small block contains several plots. Numerous levees and canals were needed to permit flooding and draining blocks according to scheduled treatments.

Agricultural Experiment Station, University of Arkansas Division of Agriculture, Fayetteville. John W. White, vice-president for agriculture; E. M. Cralley, director. CPC2.5M167

Effect of Rates and Timing of Midseason Nitrogen Applications on Performance of Short-season Rice Varieties, 1964-1965[1]

By JOHN L SIMS, V. L. HALL, T. H. JOHNSTON, and B. G. BLACKMON[2]

Research conducted in Arkansas has shown the value of splitting nitrogen applications made to rice and the importance of proper timing of applications near midseason. Results of these studies recently were presented and references to the world literature on timing of nitrogen applications to rice were reviewed (14).

Generally, studies conducted in Arkansas in the 1940's, 1950's, and early 1960's (1, 2, 10, 16) revealed that single applications of nitrogen applied 6 to 8 weeks after seedling emergence produced higher grain yields than single applications made prior to seeding or from 10 to 15 days after seedling emergence. More recent studies (14) confirmed these results, but indicated that increases in grain yields (up to 1,000 lb/acre) could be obtained from split applications made to rice growing on silt loam soils. Little yield advantage was obtained from nitrogen applied early in the season (10 to 15 days after emergence) to rice growing on clay soils (13).

In field tests conducted in 1961 and 1962 on Crowley silt loam soil at the Rice Branch Experiment Station, Stuttgart, two or three varieties of rice in each of three maturity groups, three rates (75, 120, and 165 lb/acre of actual N), and seven timing treatments of nitrogen fertilization were studied simultaneously and in combination with each other (14). The source of nitrogen was urea and all nitrogen was applied to dry or recently drained soil surfaces immediately before flooding. Nato, Nova, and Northrose were the short-season varieties grown in the 1961 and 1962 tests.

Results from the 1961 and 1962 tests indicated that the most advantageous time to apply nitrogen for maximum grain yield depended on the rate used. The three-variety average from the 75-pound rate applied at 14 days was one of the lowest

[1] Cooperative investigations, University of Arkansas Agricultural Experiment Station, and Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture.

[2] Assistant agronomists (formerly), Arkansas Agricultural Experiment Station; research agronomist, Crops Research Division; and research assistant (formerly), Arkansas Agricultural Experiment Station.

yields but the 165-pound rate at this timing gave one of the highest yields. In contrast, the 165-pound rate applied at 38 days gave the lowest yield of any treatment (4,897 lb/acre) whereas the 75-pound rate at 38 days gave a high yield (5,639 lb/acre). The highest individual treatment yield (6,021 lb/acre) was obtained from 120 lb/acre of nitrogen applied in a three-way split at 14, 38, and 58 days from emergence. However, this yield did not differ significantly from the yields produced by split applications at 14 and 58 days of either 120 or 165 lb/acre of nitrogen (14).

Nitrogen applied in single applications at 38 days to short-season varieties stimulated vegetative growth and resulted in tall plants with delayed maturity and somewhat greater lodging. As compared with split applications of half at 14 and half at 58 days, single applications of the same total amount of nitrogen at 38 days produced an average of 450 lb/acre less grain, 277 lb/acre less head rice, 3.5-inch taller plants, and 12.3 percentage points more lodging, and the plants required 2.4 days longer to reach maturity (14).

The 120-pound rate produced an average of 5,644 lb/acre of grain, compared with about 5,400 lb/acre from the 75- and 165-pound rates. In general, the 75-pound rate was most effective when applied in the latter part of the vegetative growth period whereas the 165-pound rate was most effective when at least a portion of the nitrogen was applied at 14 days.

The preceding studies emphasized the value of applying part of the nitrogen early in the growing season to short-season varieties growing on silt loam soils, and confirmed previous results regarding the importance of making applications near the stage of panicle initiation. The most advantageous time to apply nitrogen was shown to be affected by the rate applied. Timing intervals in most of the above tests were 2 to 4 weeks apart. Since seasonal effects are known to influence greatly the rate of plant growth, additional information was needed regarding applications made near the time of panicle initiation.

Objectives of the present investigations were (a) to determine the optimum time near midseason to make topdress nitrogen applications to short-season rice varieties, (b) to study the interactions of timing treatments with nitrogen rates and varieties, and (c) to determine the limitations in response of varieties to high rates of nitrogen applied at different growth stages. Such information could be used to refine recommendations on timing of nitrogen, thereby increasing production efficiency.

Methods and Materials

The experimental areas used had been cropped to a rotation of rice, soybeans, and oats in recent years. Soil test values determined by the Arkansas Soil Testing and Research Laboratory on a composite sample of surface soil from the experimental sites did not differ greatly between years. Values for pH, percent organic matter, and pounds per acre of P (Bray No. 1), exchangeable K, and Ca, were 6.5, 0.8, 13, 100, and 1,200, respectively, in 1964 and 6.3, 1.3, 15, 120, and 1,400, respectively, in 1965.

The five varieties included were Nato, Nova, Saturn, Nova 66, and Dawn. Nato was grown commercially on about 45 percent of the rice acreage in Arkansas in 1965 (12). Nova was released for commercial production in Arkansas in 1963 (7). Saturn was released in Louisiana in 1964 (5). Nova 66 was distributed to growers in Arkansas in 1966 (9). In 1966, Dawn was named and released in Texas (3), with seed also being distributed in Louisiana and Arkansas (6, 8). Dawn is a long-grain variety whereas Nato, Nova, Saturn, and Nova 66 are medium-grain varieties.

Potassium fertilizer was applied broadcast just prior to seedbed preparation at a rate equivalent to 50 lb/acre of potassium. No phosphorus was added.

Rice was drill-seeded in moist soil at the rate of 110 lb/acre in rows 7 inches apart. Individual plots were 8 rows wide and 16 feet long. In both years plots were treated with propanil at the rate of 3 lb/acre for grass control. Propanil applications were made after rice emerged, when the grass was in the 1- to 3-leaf stage of development.

All nitrogen was applied in narrow bands approximately 14 inches apart on dry or recently drained soil surfaces at rates equivalent to 80, 120, or 160 lb/acre of actual nitrogen. The source was ammonium sulfate. All plots received 40 lb/acre of nitrogen 10 to 15 days after seedling emergence and the remainder at midseason. Plots were flooded immediately after the first application. At midseason, plots were drained one week before nitrogen application and reflooded immediately after application. Midseason treatments were made 43, 49, 55, 61, or 67 days after seedling emergence.

A 10-foot length of the four central rows of each plot was harvested for grain yield. Harvested bundles were threshed with a Vogel-type nursery thresher that had been carefully adjusted to prevent hulling and breakage of grains. Threshed samples were dried overnight in a laboratory drier with air heated to about 95°F to reduce grain moisture to 12 to 14 percent. Grain weight data were adjusted to 13 percent moisture.

Plant height was determined just before harvest at three different sites within each plot; then the values were averaged. Height was measured in inches, from the soil surface to the tip of the extended panicle (head).

Lodging was determined just before harvest as a visual estimate of the percentage of lodged culms and the degree to which they were lodged.

The number of days from seeding to heading, plus 35, was used as "days to maturity," as outlined previously (14).

The weight of 1,000 grains of rough rice was determined for a representative sample from each plot.

Representative samples of rough rice from each plot were milled as described previously (14). The head rice yields are presented as a percentage of the cleaned rough rice (grain or seed), and in pounds per acre. Head rice yields in pounds per acre were determined by multiplying the percent head rice by the yield of rough rice in pounds per acre.

A split-plot experimental design was used. To facilitate water management, time of nitrogen application was designated the main plot and varieties and nitrogen rates were designated sub-plots. Treatments were replicated four times.

Statistical analyses of data for each year were made following methods of Snedecor (15) and Cochran and Cox (4). In the tables, letters are used to indicate the presence or absence of statistically significant differences in accordance with Duncan's multiple range test for split-plot designs as outlined by Koch (11). Any two individual means in the body of the table or any two averages within a column or within a line that are not followed by the same letter, letters, or letter ranges are significantly different at the 5 percent probability level.

RESULTS

Grain Yields

Grain yields of short-season rice varieties increased with delay in time of midseason nitrogen application at all rates, but the magnitude of increase was greatest at the 160-pound rate (Table 1). Statistically significant (1% level) rate x time interactions existed in both 1964 and 1965. Highest grain yields were obtained from the 40 lb/A of N applied at 61 days in 1964 and at 67 days after emergence in 1965. Lowest yields in both years were obtained from the 120 lb/A of N applied at 43 days. Highest average yields were obtained at 61 days in 1964 (6,276 lb/acre) and at 67 days in 1965 (6,525 lb/acre.)

Table 1. Grain Yields of Short-season Rice Varieties as Affected by Rate and Time of Nitrogen Application, Stuttgart, 1964 and 1965

Nitrogen rate	Time of N application—days from emergence[1]					
(lb/A)	43	49	55	61	67	Average[2]
1964			*Pounds per acre*			
80	5,314 a-d	5,627 b-d	6,129 d	6,425 d	6,310 d	5,961 b
120	3,968 ab	5,009 a-d	5,450 a-d	6,339 d	5,919 cd	5,337 a
160	3,820 a	4,293 a-c	4,845 a-d	6,063 d	5,952 cd	4,995 a
Average[3]	4,367 a	4,976 ab	5,475 bc	6,276 c	6,060 c	....
1965						
80	5,643 a-c	5,433 a-c	5,824 a-c	5,483 a-c	6,705 c	5,818 c
120	5,116 a-c	4,797 a-c	4,612 a-c	4,657 a-c	6,460 bc	5,128 b
160	3,618 a	3,886 ab	3,877 ab	4,170 a-c	6,409 bc	4,392 a
Average[3]	4,792 ab	4,705 a	4,771 ab	4,770 ab	6,525 b	....

[1] Within each year, individual means followed by the same letter are not significantly different at the 5 percent level.
[2] Averages in this column in either year followed by the same letter are not significantly different at the 5 percent level.
[3] Averages in either line followed by the same letter are not significantly different at the 5 percent level.

The 80-pound rate gave highest grain yields in both 1964 and 1965. Within each timing treatment yields were reduced by the 120- and 160-pound rates; however the effect of rate was much less pronounced at the late than at the early application dates. Differences in yields between the 80- and the 160-pound rates were 362 lb/acre at 61 days in 1964 and 296 lb/acre at 67 days in 1965. In contrast, grain yields from the 80- and 160-pound rates at 43 days differed by 1,494 and 2,025 lb/acre in 1964 and 1965, respectively.

The varieties responded differently to time of nitrogen application, as shown by grain yield data in Table 2. In general, yields of all varieties increased with delay in time of application.

In 1964, Nato, Nova, and Saturn tended to reach near maximum grain yields from the 61-day treatment, 6 days earlier than Nova 66 and Dawn. In 1965, all varieties produced their highest grain yields from the 67-day treatment. However, many of the differences were not statistically significant.

The magnitude of response to time of nitrogen application differed among the varieties tested. Maximum differences in 1964 grain yields due to time of nitrogen application to Nova, Saturn, Nova 66, Nato, and Dawn, respectively, were 2,812, 2,-

Table 2. Grain Yields of Short-season Rice as Affected by Variety and Time of Nitrogen Application, Stuttgart, 1964 and 1965

Variety	Time of N application—days from emergence[1] 43	49	55	61	67	Average[2]
1964			*Pounds per acre*			
Nato	4,300 a-c	4,584 a-d	5,269 a-h	5,882 d-i	5,277 a-h	5,062 a
Nova	3,959 a	4,634 a-d	5,171 a-g	6,771 hi	6,203 e-i	5,348 ab
Saturn	4,234 ab	5,708 b-i	6,537 f-i	7,038 i	6,396 f-i	5,983 c
Nova 66	4,436 a-d	5,202 a-g	5,615 b-i	6,561 g-i	6,627 g-i	5,688 bc
Dawn	4,905 a-f	4,753 a-e	4,784 a-e	5,129 a-g	5,795 c-i	5,073 a
Average[3]	4,367 a	4,976 ab	5,474 bc	6,276 c	6,060 c	....
1965						
Nato	4,437 ab	4,659 a-c	4,680 a-c	4,882 a-c	5,906 a-c	4,913 ab
Nova	4,091 a	4,647 a-c	3,980 a	4,268 a	6,754 bc	4,748 a
Saturn	5,100 a-c	4,239 a	5,368 a-c	4,906 a-c	6,956 c	5,314 ab
Nova 66	4,454 ab	4,593 a-c	4,784 a-c	4,849 a-c	6,973 c	5,131 ab
Dawn	5,878 a-c	5,388 a-c	5,042 a-c	4,943 a-c	6,036 a-c	5,457 b
Average[3]	4,792 ab	4,705 a	4,771 ab	4,770 ab	6,525 b	....

[1] Within either year, individual means followed by the same letter are not significantly different at the 5 percent level.
[2] Averages in this column in either year followed by the same letter are not significantly different at the 5 percent level.
[3] Averages in either line followed by the same letter are not significantly different at the 5 percent level.

804, 2,191, 1,582, and 1,042 lb/acre. In 1965 the maximum differences were, respectively, 2,774, 2,717, 2,519, 1,469, and 1,093 lb/acre. These results emphasize that time of midseason application is considerably more critical for Nova, Saturn, and Nova 66 than for Nato and Dawn.

Average grain yields of Saturn, Nova 66, and Nova were somewhat higher in 1964 than in 1965 whereas the opposite was true for Dawn. Nato yields averaged about the same for both years.

Table 3. Grain Yields of Short-season Rice as Affected by Variety and Rate of Nitrogen Application, Stuttgart, 1964 and 1965

Nitrogen rate (lb/A)	Variety[1] Nato	Nova	Saturn	Nova 66	Dawn	Average[2]
1964			*Pounds per acre*			
80	5,695 a-d	6,132 cd	6,466 d	6,158 cd	5,354 a-d	5,961 b
120	4,767 ab	5,171 a-c	5,933 b-d	5,674 a-d	5,142 a-c	5,337 a
160	4,725 a	4,742 ab	5,549 a-d	5,232 a-c	4,725 a	4,995 a
Average[3]	5,062 a	5,348 ab	5,983 c	5,688 bc	5,073 a	....
1965						
80	5,355 b-d	5,795 cd	6,339 d	5,824 cd	5,779 cd	5,818 c
120	4,894 a-c	4,556 a-c	5,421 b-d	5,326 b-d	5,445 b-d	5,128 b
160	4,491 a-c	3,894 a	4,182 ab	4,244 ab	5,148 b-d	4,392 a
Average[3]	4,913 ab	4,748 a	5,314 ab	5,131 ab	5,457 b	....

[1] Within either year, individual means followed by the same letter are not significantly different at the 5 percent level.
[2] Averages in this column in either year followed by the same letter are not significantly different at the 5 percent level.
[3] Averages in either line followed by the same letter are not significantly different at the 5 percent level.

In both years and for all varieties, an increase in rate of nitrogen above 80 pounds per acre caused an accompanying decrease in grain yield (Table 3). However, in many cases the decrease was not statistically significant. Two-year average differences between yields from the 80- and 160-pound rates were about 630, 900, 1,250, 1,525, and 1,650 lb/acre, respectively, for Dawn, Nato, Nova 66, Saturn, and Nova.

Plant Height

Plant height of short-season rice decreased as time of nitrogen application was delayed for all time treatments in 1964 and 1965 (Table 4).

In 1964, plant height measurements showed no statistically significant differences (5% level) among timing treatments, rates, or varieties. However, Saturn tended to be shorter and Nova 66 somewhat shorter than the other varieties.

In 1965, there were statistically significant differences. Plant height averages from applications made at 61 and 67 days were significantly less than from applications made at 43 days, and the height from the 67-day application also was significantly less than from that at 49 days. By delaying midseason nitrogen fertilization from the 43- to the 67-day timing, plant height was reduced by 8.9 inches. Average height from the 80-pound rate was 1.2 inches less than from the 160-pound rate, a significant

Table 4. Plant Height of Short-season Rice as Affected by Time and Rate of Nitrogen Application and by Variety, Stuttgart, 1964 and 1965

Measure	1964	1965
	Height in inches[1]	
Time of N application (days from emergence)		
43	52.1 a	55.9 c
49	51.0 a	54.4 bc
55	47.7 a	51.8 a-c
61	47.9 a	50.1 ab
67	46.8 a	47.0 a
Rate of N application (lb/A)		
80	49.1 a	51.3 a
120	49.1 a	51.8 ab
160	49.1 a	52.5 b
Variety		
Nato	50.2 a	52.0 b
Nova	50.4 a	54.3 c
Saturn	46.4 a	49.7 a
Nova 66	48.9 a	52.1 b
Dawn	49.8 a	51.1 b
Average	**49.1**	**51.8**

[1] Within each year and each grouping averages followed by the same letter are not significantly different at the 5 percent level.

difference. Saturn was significantly shorter and Nova significantly taller than the other varieties.

In both years, plant height tended to decrease with each 6-day delay in timing from 43 to 67 days.

Lodging

The degree and extent of lodging decreased with each delay in time of midseason nitrogen application in 1964 (Table 5). However, the rate of decrease was greater at the higher rates. By delaying the application from 43 to 67 days, lodging was reduced by 58, 72, and 75 percentage points for the 80-, 120-, and 160-pound rates, respectively. Lodging averaged 73 percent for applications made at 43 days and only 5 percent for applications made at 67 days. Within each timing treatment lodging was

Table 5. Lodging Percentage of Short-season Rice Varieties as Affected by Rate and Time of Nitrogen Application, Stuttgart, 1964

Nitrogen rate (lb/A)	Time of N application—days from emergence[1]					Average[2]
	43	49	55	61	67	
				Percent		
80	64 ab	66 ab	41 ab	28 ab	6 a	41 a
120	75 ab	67 ab	37 ab	34 ab	3 a	43 a
160	81 b	65 ab	49 ab	36 ab	6 a	47 a
Average[3]	73 c	66 bc	42 bc	33 ab	5 a	. .

[1] Individual means followed by the same letter are not significantly different at the 5 percent level.
[2] Averages in this column followed by the same letter are not significantly different at the 5 percent level.
[3] Averages in this line followed by the same letter are not significantly different at the 5 percent level.

Table 6. Lodging Percentage of Short-season Rice as Affected by Variety and Time of Nitrogen Application, Stuttgart, 1964 and 1965

Variety	Time of N application—days from emergence[1]					Average[2]
	43	49	55	61	67	
1964				*Percent*		
Nato	78 e-g	78 e-g	33 a-f	20 a-d	1 a	42 b
Nova	84 fg	83 fg	67 d-g	57 c-g	11 a-c	60 c
Saturn	88 g	85 g	56 c-g	50 a-g	8 a-c	57 c
Nova 66	85 g	69 e-g	54 b-g	33 a-e	1 a	48 bc
Dawn	32 a-e	15 a-c	1 a	4 a	5 ab	11 a
Average[3]	73 c	66 bc	42 bc	33 ab	5 a	....
1965						
Nato	80 ef	81 ef	93 f	59 c-f	6 ab	64 b
Nova	83 ef	83 ef	85 ef	82 ef	47 b-f	76 b
Saturn	91 f	92 f	93 f	88 ef	16 a-c	76 b
Nova 66	74 ef	74 ef	82 ef	73 ef	15 ab	64 b
Dawn	19 a-d	43 a-e	63 d-f	20 a-d	0 a	29 a
Average[3]	69 b	75 b	83 b	64 b	17 a	....

[1] Within either year, individual means followed by the same letter are not significantly different at the 5 percent level.
[2] Averages in this column in either year followed by the same letter are not significantly different at the 5 per cent level.
[3] Averages in either line followed by the same letter are not significantly different at the 5 percent level.

not significantly affected by rate of nitrogen. The rate x time interaction for lodging was not statistically significant in 1965.

Time of midseason nitrogen application affected lodging of varieties differently, as shown by results in Table 6. In contrast to other varieties, lodging of Dawn was not affected significantly by time of application in 1964, although values from applications at 43 and 49 days were somewhat higher than for later applications. In 1965, Dawn showed no lodging from the 67-day treatment but lodged 63 percent in the 55-day and 43 percent in the 49-day treatment plots. In general, noticeable reductions in lodging occurred earlier with Nato and Nova 66 than with Saturn and Nova in both years.

As an average for all short-season varieties, lodging decreased from near 70 percent at 43-day nitrogen applications in both 1964 and 1965 to near 10 percent at the 67-day applications. Lodging of Dawn was significantly lower than that of the other varieties in both 1964 and 1965. Nato and Nova 66 showed somewhat less lodging than Saturn and Nova in both years.

Data shown in Table 7 reveal that lodging of Nova, Nova 66, and Dawn was noticeably higher from the 160-pound than from the 80-pound rate in both years. Nato and Saturn lodged very little more at the 160- than at the 80- pound rate. Dawn lodged less than the other varieties in both years, averaging only 11 and 29 percent in 1964 and 1965, respectively, as compared to about 60 and 76 percent in 1964 and 1965, respectively, for Nova and Saturn. Lodging of Nato and Nova 66 was intermediate in both years.

Table 7. Lodging Percentage of Short-season Rice as Affected by Variety and Rate of Nitrogen Application, Stuttgart, 1964 and 1965

Nitrogen rate (lb/A)	Variety[1] Nato	Nova	Saturn	Nova 66	Dawn	Average[2]
1964			*Percent*			
80	40 bc	57 c	56 c	46 bc	6 a	41 a
120	44 bc	59 c	57 c	48 bc	8 a	43 a
160	43 bc	65 c	59 c	50 bc	20 ab	47 a
Average[3]	42 b	60 c	57 c	48 bc	11 a	....
1965						
80	63 c-e	64 c-e	74 de	51 b-d	20 a	54 a
120	61 c-e	77 de	76 de	67 de	28 ab	62 a
160	67 c-e	86 e	78 de	73 de	40 a-c	69 a
Average[3]	64 b	76 b	76 b	64 b	29 a	....

[1] Within either year, individual means followed by the same letter are not significantly different at the 5 percent level.

[2] Averages in this column in either year followed by the same letter are not significantly different at the 5 percent level.

[3] Averages in either line followed by the same letter are not significantly different at the 5 percent level.

These five plates show effects of time of midseason topdressing on lodging of short-season rice varieties at maturity. Since the 160-pound rate was excessive, grain yields given are the two-year averages for the 80- and 120-pound rates of nitrogen for all five varieties grown. The length of the longest internodes of the main culms (stems) and the time of midseason nitrogen fertilization (in days after seedling emergence) are listed on the opposite page.

A (top left)—Topdressed at 43 days when about half of longest internodes measured at least 1/16 inch. Note severe lodging of all varieties. Average yield was 5,010 pounds per acre.

B (center left)—Topdressed at 49 days when about half of longest internodes measured at least 1/8 inch. Note heavy lodging of most varieties. Average yield was 5,216 pounds per acre.

C (lower left)—Topdressed at 55 days when about half of longest internodes measured at least 1/2 inch. Note fairly heavy lodging of some varieties. Average yield was 5,504 pounds per acre.

D (top right)—Topdressed at 61 days when about half of longest internodes measured at least 1/2 to 1 inch. Note moderate lodging of some varieties. Average yield was 5,726 pounds per acre.

E (lower right)—Topdressed at 67 days when about half of longest internodes measured at least 1 to 1 1/2 inches. Note very little lodging in any variety. This treatment produced the highest average yield of 6,348 pounds per acre.

Maturity

Data presented in Table 8 reveal that time of nitrogen application did not have a statistically significant effect (5% level) on maturity of short-season varieties when either the 80- or 120-pound rates were applied in 1965. However, when these varieties were fertilized at the 160-pound rate, maturity was shortened 3 to 4 days (from 130 and 131 to 127) by delaying time of application from 43 and 49 days to 67 days. When all rates of nitrogen were averaged, time from seeding to maturity was decreased by only 2 to 3 days by delaying midseason application until 67 days from seedling emergence. Maturity data for rates in 1964 are not presented because no statistically significant differences occurred. Within a given timing treatment, rate of application did not affect maturity in either year.

Table 8. Maturity of Short-season Rice Varieties as Affected by Rate and Time of Nitrogen Application, Stuttgart, 1965

Nitrogen rate (lb/A)	Time of N application—days from emergence[1]					Average[2]
	43	49	55	61	67	
80	129 ab	130.bc	130 bc	128 ab	128 ab	129.0 a
120	130 bc	130 bc	130 bc	128 ab	128 ab	129.2 a
160	130 bc	131 c	129 ab	128 ab	127 a	129.0 a
Average[3]	129.6 b	130.4 b	129.8 b	128.0 a	127.7 a	......

[1] Individual means followed by the same letter are not significantly different at the 5 percent level.

[2] Averages in this column followed by the same letter are not significantly different at the 5 percent level.

[3] Averages in this line followed by the same letter are not significantly different at the 5 percent level.

Table 9. Maturity of Short-season Rice as Affected by Variety and Time of Nitrogen Application, Stuttgart, 1964 and 1965

Variety	Time of N application—days from emergence[1]					Average[2]
	43	49	55	61	67	
1964			*Days*			
Nato	127 ef	125 de	123 cd	122 bc	123 cd	124 b
Nova	121 a-c	120 ab	120 ab	119 a	120 ab	120 a
Saturn	121 a-c	120 ab	120 ab	120 ab	119 a	120 a
Nova 66	122 bc	121 a-c	120 ab	120 ab	121 a-c	121 a
Dawn	130 g	129 fg	128 fg	127 ef	127 ef	128 c
Average[3]	124 b	123 ab	122 a	122 a	122 a	....
1965						
Nato	132 gh	133 hi	131 fg	129 de	128 cd	130.6 d
Nova	129 de	129 de	128 cd	127 bc	126 ab	127.8 b
Saturn	127 bc	127 bc	128 cd	126 ab	125 a	126.6 a
Nova 66	128 cd	129 de	129 de	128 cd	128 cd	128.4 c
Dawn	132 gh	134 i	133 hi	131 fg	130 ef	132.0 e
Average[3]	129.6 b	130.4 b	129.8 b	128.2 a	127.4 a	....

[1] Within either year, individual means followed by the same letter are not significantly different at the 5 percent level.

[2] Averages in this column in either year followed by the same letter are not significantly different at the 5 percent level.

[3] Averages in either line followed by the same letter are not significantly different at the 5 percent level.

When maturity data from the three nitrogen rates were combined, delaying time of application from 43 days to 67 days decreased the days from seeding to maturity by about 4 days for Nato and Dawn and about 1 to 2 days for Saturn, Nova, and Nova 66 (Table 9). All varieties except Dawn matured about 7 days later in 1965 than in 1964; the difference for Dawn was about 4 days. Nova and Saturn matured 1 day earlier than Nova 66 in 1964; in 1965 Nova matured 1 day earlier and Saturn 2 days earlier. Nato matured 3 to 4 days later than the other medium-grain varieties in both years. Dawn averaged 4 days later in maturity than Nato in 1964 but less than 2 days later in 1965.

Head Rice Yields

Nato produced a significantly higher and Dawn a significantly lower percentage of head rice than Nova, Saturn, or Nova 66 in 1964 (Table 10). Nato averaged 65.2 percent and Dawn 50.3, in contrast to a range of 58.6 to 60.0 percent for the remaining varieties. In 1965, head rice yields from Nato were significantly higher than those from the other varieties. Dawn averaged 61.7 percent in 1965 but only 50.3 percent in 1964.

Table 10. Percent Head Rice Produced by Short-season Rice Varieties, Stuttgart, 1964 and 1965

Variety	1964	1965
	Percent[1]	
Nato	65.2 c	66.0 b
Nova	58.6 b	60.0 a
Saturn	59.3 b	60.4 a
Nova 66	60.0 b	60.1 a
Dawn	50.3 a	61.7 a
Average	58.7	61.6

[1] Within each year averages followed by the same letter are not significantly different at the 5 percent level.

Since percentages of head rice were not affected significantly by rate or time of nitrogen application, head rice yields in lb/acre generally paralleled grain yields. Hightest average head rice yields per acre were obtained in 1964 from the 61-day treatment and in 1965 from the 67-day treatment (Table 11). Lowest yields were obtained from the 43-day treatment in 1964. In 1965, average yields for the 43-, 49-, 55-, and 61 day treatments did not differ greatly and were much lower than the average yield of 4,119 lb/acre for the 67-day treatment.

Highest head rice yields (lb/acre) were produced by the 80-pound rate in both years. Head rice yields were significantly lower from the 120- and 160-pound rates.

Table 11. Head Rice Yields of Short-season Rice Varieties as Affected by Rate and Time of Nitrogen Application, Stuttgart, 1964 and 1965

Nitrogen rate (lb/A)	Time of N application—days from emergence[1] 43	49	55	61	67	Average[2]
1964	*Pounds head rice per acre*					
80	3,228 a-c	3,267 a-c	3,565 bc	3,917 c	3,544 bc	3,504 b
120	2,306 a	2,946 a-c	3,121 a-c	3,790 c	3,717 bc	3,176 a
160	2,211 a	2,534 ab	2,845 a-c	3,617 bc	3,416 a-c	2,925 a
Average[3]	2,582 a	2,916 ab	3,177 a-c	3,775 c	3,559 bc	....
1965						
80	3,487 ab	3,429 ab	3,591 ab	3,387 ab	4,225 b	3,624 c
120	3,197 ab	2,992 ab	2,835 ab	2,870 ab	4,038 ab	3,186 b
160	2,209 a	2,399 ab	2,307 ab	2,496 ab	4,095 ab	2,701 a
Average[3]	2,964 a	2,940 a	2,911 a	2,918 a	4,119 b	....

[1] Within either year, individual means followed by the same letter are not significantly different at the 5 percent level.

[2] Averages in this column in either year followed by the same letter are not significantly different at the 5 percent level.

[3] Averages in either line followed by the same letter are not significantly different at the 5 percent level.

The optimum time to apply nitrogen for highest head rice yield was affected by the rate used. Generally, highest yields were produced from the 40-lb portion of N applied at 61 or 67 days while lowest yields were obtained from the 160-lb rate with the midseason portion (120 lb) applied at 43 days.

Time of nitrogen application had greater effect on the head rice yields (lb/acre) of Nova and Saturn than it did on yields of Nato, Nova 66, or Dawn (Table 12). In 1964, the maximum difference in head yields attributed to time of nitrogen application on Nova, Saturn, Nova 66, Nato, and Dawn, respectively, was 1,-

Table 12. Head Rice Yields of Short-season Rice as Affected by Variety and Time of Nitrogen Application, Stuttgart, 1964 and 1965

Variety	Time of N application—days from emergence[1] 43	49	55	61	67	Average[2]
1964	*Pounds head rice per acre*					
Nato	2,795 a-d	2,992 a-e	3,379 a-f	3,988 ef	3,676 b-f	3,366 bc
Nova	2,334 a	2,737 a-c	3,079 a-e	4,079 ef	3,420 a-f	3,130 b
Saturn	2,523 a	3,272 a-f	3,873 d-f	4,264 f	3,778 c-f	3,542 c
Nova 66	2,721 a-c	3,132 a-e	3,169 a-f	3,951 ef	4,075 ef	3,410 bc
Dawn	2,535 a	2,449 a	2,383 a	2,593 ab	2,844 a-d	2,561 a
Average[3]	2,582 a	2,916 ab	3,177 a-c	3,775 c	3,559 bc	....
1965						
Nato	2,919 a-c	3,031 a-c	3,064 a-c	3,244 a-c	3,965 a-c	3,245 ab
Nova	2,466 a	2,880 a-c	2,382 a	2,438 a	4,220 bc	2,877 a
Saturn	3,040 a-c	2,588 ab	3,241 a-c	3,012 a-c	4,459 c	3,268 ab
Nova 66	2,699 ab	2,847 a-c	2,848 a-c	2,884 a-c	4,171 bc	3,090 ab
Dawn	3,698 a-c	3,355 a-c	3,021 a-c	3,010 a-c	3,781 a-c	3,373 b
Average[3]	2,964 a	2,940 a	2,911 a	2,918 a	4,119 b	....

[1] Within either year, individual means followed by the same letter are not significantly different at the 5 percent level.

[2] Averages in this column in either year followed by the same letter are not significantly different at the 5 percent level.

[3] Averages in either line followed by the same letter are not significantly different at the 5 percent level.

745, 1,741, 1,354, 1,193, and 461 lb/acre. In 1965, the respective yield differences were 1,838, 1,871, 1,472, 1,046, and 771 lb/acre.

Average head rice yields (lb/acre) of Nova tended to be lower than those of the other medium-grain varieties in both 1964 and 1965. Average yield of Dawn was significantly lower than that of the other varieties in 1964 but in 1965 Dawn produced the highest average head rice yield (3,373 lb/acre).

Weight of 1,000 Grains of Rough Rice

The weight of 1,000 grains of rough rice increased with delay in time of nitrogen application in both years at all rates (Table 13), with applications at 61 and 67 days giving highest weights. Average weight decreased with increase in rate of nitrogen in both years. The lowest weight in 1964 was from 160 pounds of nitrogen at 43 days and in 1965 it was from the same rate at 55 days. The lowest weights from all rates were at 43 days in 1964 and at 55 days in 1965.

Table 13. Weight of 1,000 Grains of Rough Rice of Short-season Varieties as Affected by Time and Rate of Nitrogen Application, Stuttgart, 1964 and 1965

Nitrogen rate (lb/A)	Time of N application—days from emergence[1]					Average[2]
	43	49	55	61	67	
1964	*Grams per 1,000 grains*					
80	23.0 a-e	23.1 b-e	24.8 ef	25.8 f	25.9 f	24.5 b
120	21.5 ab	22.5 a-d	24.3 d-f	25.6 f	26.0 f	24.0 ab
160	20.9 a	22.0 a-c	23.9 c-f	25.0 ef	25.5 f	23.5 a
Average[3]	21.8 a	22.5 a	24.3 b	25.5 bc	25.8 c	....
1965						
80	23.8 a-e	24.0 a-e	22.6 a-c	25.4 b-e	26.0 de	24.4 b
120	22.9 a-d	22.9 a-d	21.8 a	24.7 a-e	26.4 e	23.7 a
160	22.3 ab	21.8 a	21.5 a	23.9 a-e	25.8 c-e	23.1 a
Average[3]	23.0 ab	22.9 ab	22.0 a	24.7 bc	26.1 c	....

[1] Within either year, individual means followed by the same letter are not significantly different at the 5 percent level.

[2] Averages in this column in either year followed by the same letter are not significantly different at the 5 percent level.

[3] Averages in either line followed by the same letter are not significantly different at the 5 percent level.

Average grain weights for each variety were approximately equal in 1964 and 1965 (Table 14). Nova and Nova 66 had almost identical average weights, exceeding those of Saturn, Nato, and Dawn by about 1.1 to 2.2, 2.8 to 3.6, and 3.7 to 4.0 gm per 1,000 grains, respectively.

The weights of 1,000 grains of Nova and Nova 66 rice were affected to a greater extent by time of nitrogen application than were weights of the other varieties. Weights of Nova 66 and nitrogen applications from 43 or 49 days to 61 or 67 days.

Table 14. Weight of 1,000 Grains of Rough Rice of Short-season Rice as Affected by Variety and Time of Nitrogen Application, Stuttgart, 1964 and 1965

Variety	Time of N application—days from emergence[1] 43	49	55	61	67	Average[2]
1964			*Grams per 1,000 grains*			
Nato	21.2 a	20.7 a	22.9 b	23.2 b	23.8 bc	22.4 a
Nova	22.9 b	24.5 b-d	26.9 ef	28.0 f	27.9 f	26.0 c
Saturn	20.9 a	23.0 b	24.5 b-d	24.9 b-d	25.5 c-e	23.8 b
Nova 66	22.9 b	24.3 b-d	26.1 de	27.9 f	28.1 f	25.9 c
Dawn	21.2 a	20.2 a	21.2 a	23.3 b	23.9 bc	22.0 a
Average[3]	21.8 a	22.5 a	24.3 b	25.5 bc	25.8 c	....
1965						
Nato	21.7 a-e	21.8 a-e	20.6 ab	23.8 c-h	24.1 d-h	22.4 b
Nova	24.4 e-i	24.1 d-h	23.6 c-h	27.0 ij	28.1 j	25.4 d
Saturn	23.4 b-g	22.9 b-f	23.6 c-h	24.8 f-i	26.0 g-i	24.1 c
Nova 66	24.2 d-h	24.4 e-i	22.8 b-f	26.3 h-j	28.1 j	25.2 d
Dawn	21.5 a-d	21.2 a-c	19.2 a	21.4 a-d	24.0 c-h	21.5 a
Average[3]	23.0 ab	22.9 ab	22.0 a	24.7 bc	26.1 c	....

[1] Within each year, individual means followed by the same letter are not significantly different at the 5 percent level.
[2] Averages in this column in either year followed by the same letter are not significantly different at the 5 percent level.
[3] Averages in either line followed by the same letter are not significantly different at the 5 percent level.

DISCUSSION

Nitrogen applied in large amounts to rice during the latter half of the vegetative growth period (43-, 49-, and 55-day applications) stimulated vegetative growth and resulted in taller plants with greater lodging, delayed maturity, and lowered grain and head rice yields (see Figures 1 and 2 as well as tables in the Results section). Nitrogen applied at 38 days to short-season varieties in previous studies (14) had caused excessive vegetative growth. Consequently, knowing when not to apply nitrogen may be as important as knowing the proper dates for applying nitrogen.

Existing information does not permit accurately delimiting the period during which topdress applications of nitrogen should not be made. Among factors of importance are season, soil fertility levels, and water management. However, for the short-season varieties presently being grown in Arkansas, it appears unwise to apply nitrogen between 35 days and 55 days after seedling emergence, primarily because of the likelihood of excessive plant height and lodging.

The significant rate x time interactions for grain and head rice yields, lodging, and maturity obtained in this study indicate that moderate vegetative response and high (but seldom maximum) yields may be obtained from low to moderate nitrogen rates applied during the more vegetative stages of plant growth. However, in some years considerable amounts of nitrogen may

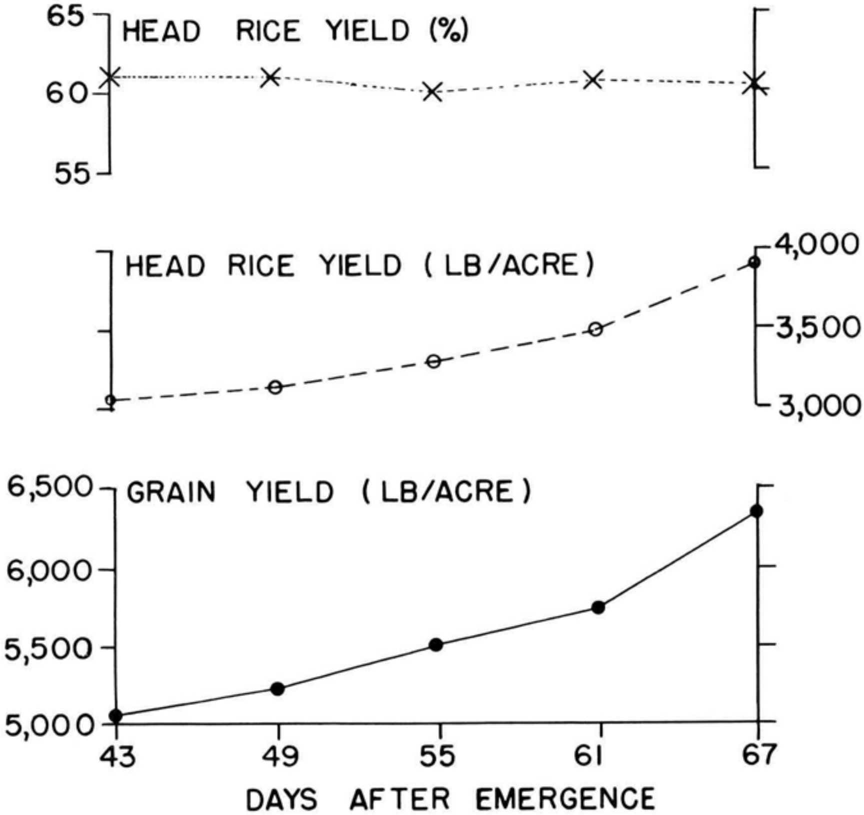

Figure 1. Effect of Time of Midseason Nitrogen Application on Grain and Head Rice Yields of Short-season Varieties, Stuttgart, 1964 and 1965

Since the 160-pound rate was excessive, the averages for only the 80- and 120-pound nitrogen rates are presented.

be released from soil organic matter in the field and this, combined with fertilizer nitrogen, may provide an excess of nitrogen and greater likelihood of lodging. Plots were harvested by hand in this study and a much larger percentage of the grain from lodged plants probably was recovered than would be possible in combine harvesting of commercial fields.

The rate x time interactions also suggest that excessive rates of nitrogen are less likely to reduce yield if applied near the early jointing stage of development (e.g. 60 to 65 days after seedling emergence to short-season varieties) than during the latter half of the vegetative growth stages (35 to 55 days). This finding is important since the nitrogen soil test methods commonly used, on which fertilizer recommendations are based,

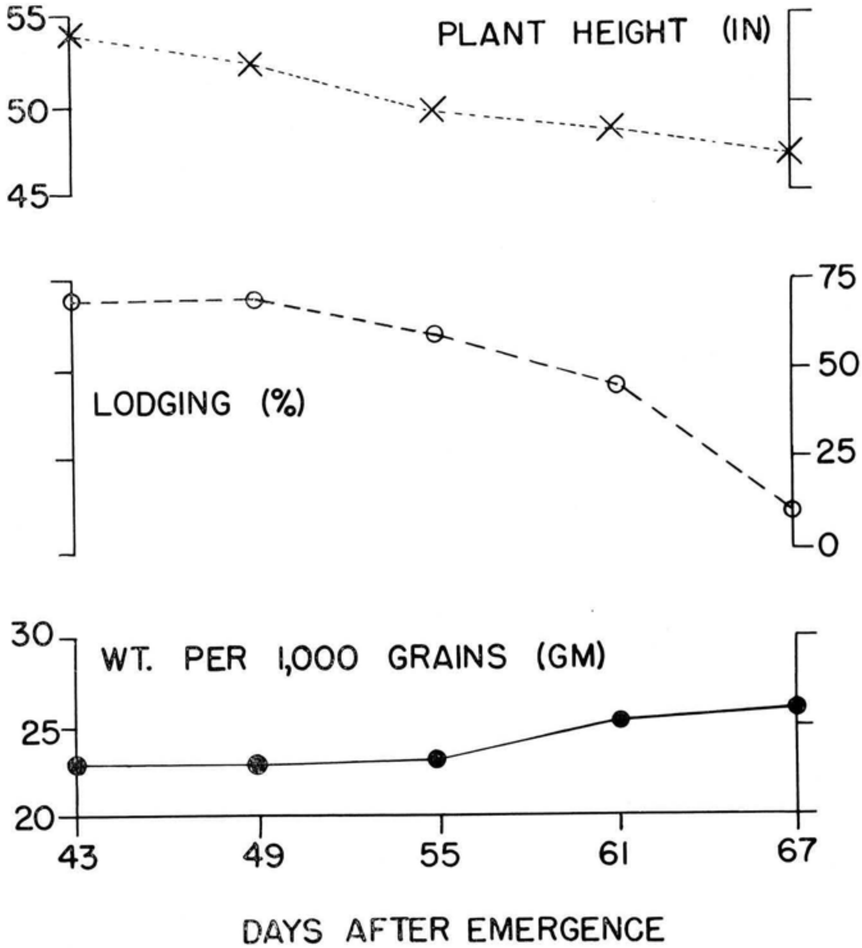

Figure 2. Effect of Time of Midseason Nitrogen Application on Plant Height, Lodging, and Weight of 1,000 Grains of Rough Rice of Short-season Varieties, Stuttgart, 1964 and 1965

Since the 160-pound rate was excessive, the averages for only the 80- and 120-pound nitrogen rates are presented.

often fail to predict accurately the optimum amount of nitrogen fertilizer needed.

Maximum grain yields tended to be produced from earlier applications of nitrogen (61 days) in 1964 than in 1965 (67 days). Also significant reductions in plant height and lodging occurred from earlier applications in 1964 than in 1965. All these short-season varieties matured earlier in 1964 than in 1965. These data reveal the limitations of basing recommendations for timing of nitrogen solely on the number of days from seedling emergence. Many factors such as temperature, duration and intensity of sunlight, soil fertility, and water management practices may cause rice plants to reach a certain stage of development much earlier in some years.

Data in Tables 13 and 14 reveal that the weight of 1,000 grains of rough rice increased as application of nitrogen was delayed from 43 days to 67 days after seedling emergence. These data suggest that at each time treatment grain yields were influenced by yield components as well as by lodging. Grain weights might differ because (a) later nitrogen applications usually produce grains that are plumper and/or have higher density than grains from earlier applications even on unlodged plots, (b) plants in plots topdressed early lodged earlier in the season than in plots treated late, or (c) both a and b. Lodging of rice culms before the grain is mature often hinders transport of carbohydrates and nutrient elements through the stems to the seed. The nitrogen supply apparently was adequate at all times and since in both years there was a differential in time of lodging this may have been the factor having greatest influence on weight of 1,000 grains.

It is believed that the stage of plant growth when topdressing is applied has an important effect on the response of rice to nitrogen fertilizers. In previous studies (14, 16) the optimum time to apply midseason applications of nitrogen was found to be very near the midpoint of the growing season; consequently the time to apply nitrogen should be closely related to maturity of rice varieties. Results of this study indicate that factors other than maturity, such as strength of straw, height, and yielding potential, also need to be considered when determining the optimum application time. Whereas the maturity of all varieties varied less than 8 days within a given year (Nova, Nova 66, and Saturn differed by as little as 2 days), varieties differed considerably in the magnitude of their response to time of nitrogen application. Dawn, a relatively stiff-strawed variety, was affected by differences in timing to a much lesser extent than Nato and Nova 66, and these varieties were affected less than Nova and Saturn. Generally, varieties that are highly subject to lodging because of relatively weak straw, high yielding capacity, or greater plant height should be fertilized somewhat later than varieties less subject to lodging.

Disregarding characteristic differences among varieties, grain yields of all varieties generally increased by more than 1,000 lb/acre as nitrogen applications were delayed from 43 days after emergence to 61 or 67 days.

Based on results from these tests, using a total of 80 lb/-acre of nitrogen on Nato rice with the midseason portion being applied at 61 days after emergence in 1964 and at 67 days in 1965 would have resulted in about 43 and 70 dollars per acre higher returns, respectively (at 1965 market prices) than an application of the same amount at 43 days.

SUMMARY

Field studies were conducted in 1964 and 1965 at the Rice Branch Experiment Station, Stuttgart, on Crowley silt loam soils that had been cropped for many years. Five short-season (early) varieties of rice (Nato, Nova, Saturn, Nova 66, and Dawn), 3 rates of nitrogen, and 5 times of midseason application of nitrogen were studied simultaneously and in combination with each other. The source of nitrogen was ammonium sulfate which was applied to dry or recently drained soil surfaces immediately before reflooding.

The objectives of the investigations were (a) to determine the optimum time near midseason to make topdress nitrogen applications to short-season rice varieties, (b) to study the interactions of nitrogen timing with nitrogen rates and with varieties, and (c) to determine the limitations in response of varieties to high rates of nitrogen applied at different growth stages.

Grain and head rice yields, as an average of all varieties and rates, were inversely related to plant height, lodging, and maturity, and generally increased as time of nitrogen application was delayed from 43 days to 61 or 67 days from emergence. The grain yields of 6,276 lb/acre for the 61-day applications in 1964 and 6,525 lb/acre for the 67-day application in 1965 exceeded by 1,909 and 1,733 lb/acre, respectively, the yields from applications made at 43 days in the two years. Head rice yields from applications made at 61 or 67 days in both years were more than 1,000 lb/acre greater than yields from applications made at 43 days.

Nitrogen applied at 43, 49, or 55 days after seedling emergence produced greater vegetative growth than applications made at 61 or 67 days. This resulted in taller plants, increased lodging, and slightly delayed maturity. As contrasted with 43-day applications, nitrogen applied at 67 days in 1964 and 1965, respectively, resulted in reductions of 5.3 and 8.9 inches in plant height, 68 and 52 percentage points in lodging, and 2.0 and 2.2 days in maturity.

Statistically significant rate x time interactions were obtained for grain yield, head rice yield, lodging, maturity, and

weight of 1,000 grains of rough rice. Generally, highest yields of grain and head rice and highest weight of 1,000 grains were obtained from 80 lb/acre of nitrogen when the midseason portion (40 lb) was applied at 61 or 67 days, and lowest values were obtained from 160 lb/acre when the midseason portion (120 lb) was applied at 43 days. In contrast, highest values for lodging and maturity were obtained, generally, from the 160-pound rate when the midseason portion was applied at 43 days, while lowest values were obtained from the 80-pound rate when 40 pounds were applied at 61 or 67 days after emergence rather than at 43, 49, or 55 days after emergence.

Significant variety x time and variety x rate interactions were obtained for grain yield and lodging, and significant variety x time interactions were obtained for maturity, head rice yield, and weight of 1,000 grains of rough rice. The maximum differences in grain yield due to time of nitrogen application to Nova, Saturn, Nova 66, Nato, and Dawn, respectively, were 2,812, 2,804, 2,191, 1,582, and 1,042 lb/acre in 1964 and 2,774, 2,717, 2,519, 1,469, and 1,093 lb/acre in 1965. The same ranking of varieties also prevailed for maximum reduction in yield due to nitrogen rate and maximum difference in lodging due to time of nitrogen application. Generally, Saturn and Nova showed the greatest response to time of application, Nova 66 and Nato were intermediate in response, and Dawn showed the least response.

The rate of nitrogen application had more effect on lodging of Nova, Nova 66, and Dawn than it did on lodging of Nato or Saturn.

Head rice yield (in percent) was not significantly affected by rate or time of nitrogen application. Head rice yields of Nato (in percent) were significantly higher than those of other varieties tested.

LITERATURE CITED

1. Beacher, R. L. "Rice fertilization—results of tests from 1946 through 1951." Ark. Agr. Expt. Sta. Bul. 522, 1952.

2. Beacher, R. L. and J. P. Wells. "Rice fertilizer studies, 1952-1958." Ark. Agr. Expt. Sta. Bul. 620, 1960.

3. Bollich, C. N., J. G. Atkins, J. E. Scott, and B. D. Webb. "Dawn—a blast resistant, early maturing, long grain rice variety." Rice Jour. 69 (4):14, 16, 18, 20, 1966.

4. Cochran, W. G. and G. M. Cox. Experimental Designs, John Wiley & Sons, Inc., N. Y., New York, 1950.

5. Jodon, N. E. and J. G. Atkins. "Saturn—a blast resistant medium-grain variety released in Louisiana." Rice Jour. 67(5):24-28, 1964.

6. Jodon, Nelson E. and Earl A. Sonnier. "Dawn—performance and seed production in Louisiana." Rice Jour. 69(4):20,22, 1966.

7. Johnston, T. H., C. Roy Adair, G. E. Templeton, John L. Sims, and S. E. Henry. "Nova and Vegold—new rice varieties." Ark. Agr. Expt. Sta. Bul. 675, 1963.

8. Johnston, T. H., G. E. Templeton, John L. Sims, V. L. Hall, and K. O. Evans. "Dawn rice—its performance in Arkansas." Rice Jour. 69-(4):26-28, 1966.

9. Johnston, T. H., G. E. Templeton, John L. Sims, V. L. Hall, and K. O. Evans. "Performance in Arkansas of Nova 66 and other medium-grain rice varieties, 1960-1965." Ark. Agr. Expt. Sta. Report Series 148, 1966.

10. Kapp, L. C. "Rice fertilizer experiments, 1938-1945." Ark. Agr. Expt. Sta. Bul. 477, 1948.

11. Koch, E. J. "Presentation of experimental results." Paper presented before joint symposium of Amer. Soc. Hort. Sci. and ENAR Biometric Soc. at Pa. State Univ., 1959.

12. Rice Millers Association. "U. S. rice acreage statistics." Compiled annually and published in the Rice Journal, Annual Issue 1965.

13. Sims, J. L. "'Nitrogen fertilization of rice growing on clay soils." Ark. Farm Res. 14(2):7, March-April, 1965.

14. Sims, J. L., T. H. Johnston, and S. E. Henry. "Effect of rates and timing of nitrogen fertilization on performance of rice varieties, 1957-1962." Ark. Agr. Expt. Sta. Report Series 142, 1965.

15. Snedecor, G. W. Statistical Methods, The Iowa State College Press, Ames, Iowa, 1955.

16. Wells, J. P. "Effect of timing of nitrogen fertilization on rice yields." Ark. Agr. Expt. Sta. Report Series 112, 1962.