

# Mid-term drainage and nitrogen utilization by rice

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## INTRODUCTION

Lowland rice is generally grown under flood irrigation where the rice field is submerged during most of the time from tillering to ripening stage. Submergence, in addition to satisfying the water requirements of the crop, provides many essential nutrients for plant growth (Ponnamperuma, 1955 ; Rodrigo, 1961 ; 1962). On the other hand, it can also result in the release of appreciable concentration of toxic products such as hydrogen sulphide, ferrous iron and organic acids which affect the physiological functions of the rice roots (Ponnamperuma, 1955).

Drainage and drying out of fields for a period of time is considered to be beneficial to the crop under certain conditions. Accumulation of toxic products such as ferrous iron and organic acids can be removed by draining the water before they reach toxic levels. On the other hand, draining and maintaining oxidising conditions in acid sulphate soils (cat clays) could have deleterious effect on the plant because of the high acidity developed on oxidation.

Mid term drainage can also be practised to conserve water ; but experiments at the International Rice Research Institute, Philippines (1965) have shown shallow continuous flooding to be the most efficient system where water is limited or needs to be conserved and managed most efficiently.

Drainage is believed to increase root activity, reduce lodging and promote tillering. In some places in Northern Japan, for broadcast rice, fields are drained for 2-3 days after seed emergence to accelerate the rooting of seedlings. In the warmer regions of Japan, rice fields are drained for several days at the late tillering stage for the purpose

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of controlling root rot. Heavy fertilization in Japan, results in decreased yields due to excess nitrogen uptake; hence drainage is practised to regulate the fertilizer response (Nojima and Tanaka, 1968).

Drainage may directly affect the efficiency of nitrogen fertilizer for lowland rice. This paper deals with studies to determine the above effect carried out in Ceylon under the sponsorship of the Joint FAO/IAEA Division of Atomic Energy in Agriculture, Vienna, Austria. Eight other countries namely, Bangla Desh, Burma, Indonesia, Taiwan, South Korea, Vietnam, India and Philippines also participated in this programme. The experiment in Ceylon was carried out at the Agricultural Research Station, Maha Illuppallama. The soil profile description, soil analysis and climatological data of the two locations are presented in Tables 1-5.

## MATERIALS AND METHODS

### *Dry Season Experiment (Yala 1960)*

The experiment was of a split-plot design (Figure 1) with four water management practices in the main plots and nitrogen fertilizer treatments in the sub-plots. Each treatment was replicated four times. The main and sub-plot treatments were as follows :

#### A.—*Main Plots (Water Management Treatments)* :

1. *Continuous Flooding (CF)*.—Water was maintained continuously at a height of about 5 cm.
2. *Mid-term Drainage—2 days (MTD-2)*.—Plots were fully drained at primordial initiation stage, nitrogen fertilizer applied (where necessary), soil kept just moist† for 2 days and reflooded.
3. *Mid-term Drainage—10 days (MTD-10)*.—Same as treatment 2 except that plots were kept just moist† for 10 days before reflooding.
4. *Mid-term Drainage Early 10 days (MTD-E-10)*.—Plots were drained 10 days prior to primordial initiation stage and kept just moist† for 10 days, nitrogen fertilizer applied (where necessary) and reflooded.

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†This condition was such that there was no deficiency of water in the soil but oxidising conditions persisted in the soil surface throughout this period.

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### *B.—Sub-Plots (Nitrogen Fertilizers) :*

1. Ammonium Sulphate (AS.)
2. Urea (U.)
3. Control (No Nitrogen) (CK).

Nitrogen at 110 kg/ha was applied in two equal doses at planting and at primordial initiation stage. All plots received 107.5 kg  $P_2O_5$ /ha as concentrated superphosphate and 62.5 kg  $K_2O$ /ha as muriate of potash before planting. The plots also received a top dressing of 31.25 kg  $K_2O$ /ha as muriate of potash at primordial initiation stage.

Each individual plot was 4 metres  $\times$  1.25 metres. Three week old seedlings of the variety of IR-22 were planted in 25 cm.  $\times$  25 cm. rows and each hill had three seedlings. Plots which received  $N^{15}$  labelled fertilizer were divided into three areas namely, A (1.25 sq.m.), B (0.9385 sq. m.) and C (2.8125 sq.m.) (Figure 1) using wooden planks.

Area A received  $N^{15}$  labelled fertilizer at transplanting and non-labelled nitrogen at primordial initiation stage, while area B received non-labelled nitrogen at transplanting and  $N^{15}$  labelled fertilizer at primordial initiation stage. Area C received only non-labelled nitrogen at these times of applications.

The  $N^{15}$  labelled fertilizers were obtained from Junta De Energía Nuclear Spain. The isotopic enrichment of urea and ammonium sulphate were 1.37 and 1.41% respectively.

Appropriate agro-chemicals consisting of weedicides, insecticides and fungicides were applied to control weeds and to protect from insects and rice blast disease.

Forty-two hills excluding border line hills were harvested from each plot, that is, 9 hills from area A, 9 hills from area B, and 24 hills from area C (Figure 1) for yield estimation and plant analysis.

Plant samples from each treatment were taken, dried at 70° C and weighed for yield estimation. The dried plant materials were ground in a mill and 5 g. or rough grain and straw from each treatment was sent to the I.A.E.A. Laboratories, Vienna, Austria for  $N^{15}$  analysis. Total nitrogen was determined by Kjeldhal method.

### *Wet Season Experiment (Maha 1970/71)*

The wet season experiment also had a split-plot design but with two water treatments in the main plot and nitrogen fertilizers plus varieties in the sub-plots. There were four replicates. The main and sub-plot treatments were as follows :

**A.—Main Plots (Water Management Treatments) :**

1. *Continuous Flooding (CF)*.—Water was maintained continuously at a height of about 5 cm.
2. *Mid Term Drainage—2 days (MTD-2)*.—Plots were drained at primordial initiation stage, nitrogen fertilizer applied (where necessary); soil kept just moist for 2 days and reflooded.

**B.—Sub-Plots (Fertilizers Plus Varieties) :**

1. Ammonium Sulphate—IR-22 (AS-IR-22)
2. Ammonium Sulphate—Bg-11-11 (AS-BG-11-11)
3. Urea—IR-22 (U-IR-22)
4. Urea—Bg-11-11 (U-Bg-11-11)
5. Control—IR-22 (C-IR-22)
6. Control—Bg-11-11 (C-Bg-11-11)

Nitrogen was split applied at the rate of 10 kg/ha in two equal doses at planting and at primordial initiation stage. Details regarding phosphorus and potassium fertilizers, plot design, harvesting and plant analysis, etc. were same as that described for the dry season experiment.

## RESULTS

**Dry Season Experiment (Yala 1970)**

The three different mid term drainage treatments and the continuous flooding method did not significantly affect either the total dry matter, straw and grain yields or the yield components except the 1,000 grain weight where two mid term drainage treatments MTD-10 and MTD-E-10 gave significantly higher values than the other two water treatments (Table 6).

Both ammonium sulphate and urea gave significantly higher total dry matter, straw and grain yields than the no nitrogen control, but there was no significant difference between these two nitrogen fertilizers (Table 6).

The total and fertilizer nitrogen taken up by the grain and straw confirmed the trends shown by the yield data (Table 7).

The utilization of fertilizer nitrogen by grain plus straw of the variety IR-22 during the dry season was about 20%. The overall efficiency of applied nitrogen expressed in terms of kg grain/kg N was around 8.

Although water treatments and forms of nitrogen fertilizers did not significantly affect the grain yields, in terms of percentage nitrogen derived from fertilizer by grain plus straw, MTD-2 was slightly superior to the other water treatments and ammonium sulphate was somewhat better than urea (Tables 6 and 8).

The most striking result was that the percentage nitrogen derived from fertilizer was considerably more (about 3 to 10 times) from the top dressing (primordial initiation stage) than from the basal dressing. Furthermore, for the basal dressing more nitrogen was derived from urea than from ammonium sulphate while the reverse was true for the top dressing (Table 8).

#### *Wet Season Experiment (Maha 1970-71)*

There was no significant difference between continuous flooding and mid term drainage for 2 days in terms of total dry matter, straw and grain yields and yield components (Table 9). This was also true in terms of nitrogen removed from soil plus fertilizer (total) but in terms of nitrogen taken up from fertilizer, continuous flooding was superior to mid term drainage for 2 days (Table 10).

Ammonium sulphate gave higher yields than urea though statistically not significant, while variety Bg-11-11 was significantly superior to IR-22 in terms of total dry matter, straw and grain yields (Tables 9 and 10). These trends were also reflected in the total and fertilizer nitrogen taken up by the grain and straw (Table 10).

The overall efficiency of applied nitrogen (kg grain/kg N) with ammonium sulphate and urea were 14 and 12 respectively. On the other hand, the efficiency of applied nitrogen, calculated on the basis of percentage of added nitrogen recovered from the grain and straw of IR-22 and Bg-11-11 were 21 and 27 respectively.

The wet season experiment also clearly indicated that nitrogen derived from fertilizer from top dressing was considerably higher than from basal dressing (Table 11).

#### DISCUSSION

Both dry and wet season experiments have clearly shown mid term (or mid season) drainage to be not superior to continuous flooding. Bangla-Desh, Burma, India, South Korea and Thailand, which also carried out these experiments obtained similar results (Rahman, 1971; Khin Win, 1971; Datta, 1971; Shim, 1971; Snitwongse, 1971). On the other hand, experiment conducted in Indonesia indicated mid term drainage—early—10 days (MTD-E-10) to be superior to all the other treatments (Abdullah, 1971).

Similar experiments at IRRI, Philippines have shown that mid term drainage does not give higher grain yields than continuous flooding (IRRI, 1963; 1965; 1967; 1968). In fact, fields drained for a week during panicle initiation stage resulted in a grain reduction of the variety IR-8 by 13% (IRRI, 1968). Further experiments using the varieties H-4 and IR-8 clearly demonstrated that if water was maintained at 5 cm., temporary drainage for nitrogen top dressing offers no advantage in terms of grain yield (IRRI, 1967).

Draining the fields for a period of 5 to 10 days during the growing stage of the crop was found to promote vigorous tillering (Bulanadi, 1966), while draining for several days at the late tillering stage is considered to increase root activity and reduce lodging (Nojima and Tanaka, 1968; IRRI, 1970). There are also reports to indicate that fields drained at both early and late tillering stage gave higher yields than continuously flooded fields; this was attributed to the increased photosynthesis on reflooding (Nojima and Tanaka, 1968). However, in the present experiments, these beneficial affects of mid term drainage were not reflected in the tiller numbers or in the grain yields.

Of the other participants, Bangla Desh, Burma, South Korea, Taiwan and Thailand, also found that more fertilizer nitrogen was taken up from the top dressing than from the basal application (Rahman, 1971; Khin Win, 1971; Shim, 1971; Chu, 1971; Snitwongse, 1971). On the other hand, India, Indonesia and Vietnam did not observe any difference between the two times of nitrogen applications (Datta, 1971; Abdullah, 1971; Thai-Cong-Tung, 1971). It is worth mentioning that experiments at IRRI (1967) indicated that the later the application the higher the percentage of nitrogen recovery.

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The results obtained at Maha Illuppallama can be interpreted to mean that the young seedlings utilize more soil nitrogen than fertilizer nitrogen for their initial growth; at later stages, the plants utilize more fertilizer nitrogen than soil nitrogen for their reproductive stages. Most soils under submergence provide appreciable amounts of soil ammonia from the mineralization of organic matter which the young seedlings can utilize (Ponnamperuma, 1955; Rodrigo, 1961). However, the results obtained in India, Indonesia and Vietnam (Datta 1971; Abdullah, 1971; Thai-Cong-Tung, 1971) indicate that initial soil ammonia released from some soils (low in organic matter) on submergence may not meet the requirements of the young seedlings.

From the foregoing it appears that mid term or mid season drainage in normal rice fields has no effect on nitrogen utilization or grain yields. However, it will be important in problem fields where toxic products such as ferrous iron have to be removed and oxidising conditions temporarily maintained.

Although rice soils on submergence release ammonia, the amount released from some soils may not be sufficient for initial growth of the plants. This could be more so with improved rice varieties which have higher nitrogen requirements.

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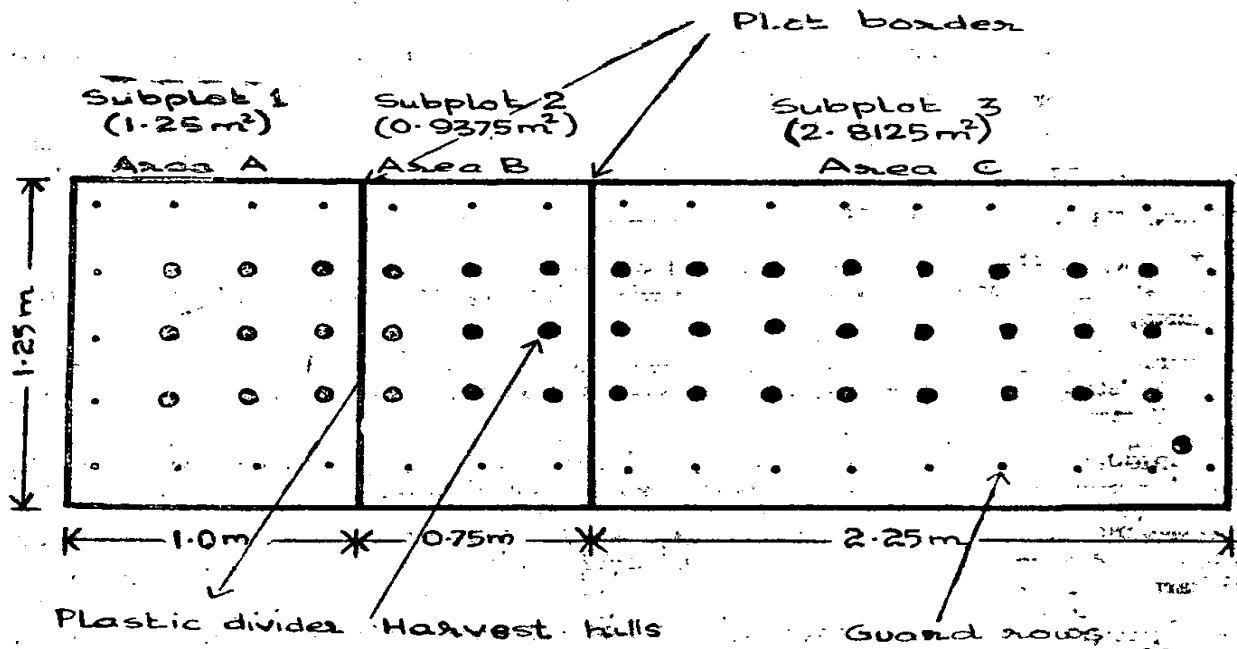


FIGURE 1 Single plot diagram showing sub-plots A, B and C and the number of hills per plot.

Table 1.—DESCRIPTION OF THE SOIL PROFILE (DRY SEASON—YALA, 1970)

Horizon	Depth (cm)	Description
Ap <sub>g</sub>	0-5	Clay—7.5 YR 3/3—dark brown—many fine roots—clear smooth change to :
A12 <sub>g</sub>	5-13	Fine sandy clay—10 YR 2/3—brownish black—many quartz particles—Weakly developed sub-angular blocky—few diffused reddish brown mottles—clear smooth change to :
B21 <sub>gg</sub>	13-30	Sandy clay—7.5 YR 3/4 dark brown—Moderately developed sub-angular blocky, Many quartz particles, few diffused spotty Mn mottles, many impeded pores—Few gley spots (2.5 Y 3/1) brownish black abrupt change to :
B22 <sub>g</sub>	30-70	Clay with grit—7.5 YR 3/4—dark brown—Many reddish brown 10 YR 4/8—reddish filmy. mottles around quartz particles, very weakly developed sub-angular blocky few diffused Mn mottling around quartz particles.

Table 2.—DESCRIPTION OF THE SOIL PROFILE WET SEASON—MAHA, 1970/71

Horizon	Depth (cm)	Description
Ap <sub>G</sub>	0-15	Clay loam—5 Y 3/2 Olive black, Many common roots, few faint diffused mottles around root channels, clear change to :
A12 <sub>g</sub>	15-22	Coarse sandy clay—10 YR 3/3—dark brown, few fine rootlets many quartz particles, many gley spots 5 Y 3/1, olive black, non-sticky, smooth change to :
B1 <sub>g(g)</sub>	22-52	Sandy clay, many coarse sandy, mainly quartz particles 5 Y 3/1 to 2/1; Olive black to black, few fine roots, few faint diffused mottles around root channels, moderately developed sub-angular blocky, few micro-fragments, slightly sticky, abrupt change to :
B2	52†	Clay with coarse sand, many quartz particles, 5 Y 3/1, Olive black, few diffused spotty and filmy reddish brown mottles, very weakly developed sub-angular blocky.

Table 3.—SOIL ANALYSIS

Depth (cm)	Dry Season (Yala, 1970)		Wet Season (Maha, 1970/71)	
	0-15	..	0-15	..
pH	6.8	..	7.2	..
Organic Matter %	1.0	..	2.3	..
Total N %	0.15	..	0.16	..
Olsen's Available Phosphorus (kgP <sub>2</sub> O <sub>5</sub> /ha)	46	..	69	..
Exchangeable Potassium (m.e. K/100 g)	0.13	..	0.40	..
Cation Exchange Capacity (m.e./100 g)	13.6	..	13.2	..
Mechanical Analysis				
Sand %	56.9	..	53.7	..
Slit %	5.0	..	10.0	..
Clay %	41.8	..	41.8	..

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TABLE 4.—CLIMATOLOGICAL DATA FROM NURSERY TO HARVEST  
(Dry Season—Yala, 1970)

	Temperature °F		Relative Humidity		Sunshine (hr./day)	Rainfall (mm)
	Max.	Min.	8.30hr.	14.30hr.		
June	90.2	77.4	76	63	N.A.*	1
July	90.2	75.8	75	57	7.8	17
August	91.5	76.4	73	52	8.4	6.5
September	91.2	74.9	72	52	8.1	81
October	88.0	73.1	78	51	7.3	165

N.A.\*—Not available.

TABLE 5.—CLIMATOLOGICAL DATA FROM NURSERY TO HARVEST  
(Wet Season Maha, 1970/71)

	Temperature °F		Relative Humidity		Sunshine (hr./day)	Rainfall (mm)
	Max.	Min.	8.30hr.	14.30hr.		
December '70	81.4	69.0	83	68	N.A.*	131
January '71	83.7	70.2	87	63	N.A.*	201
February	88.0	67.9	80	53	9.0	31
March	91.0	71.5	81	53	8.7	23
April	92.6	72.8	78	54	9.2	294
May	89.6	76.0	78	62	7.4	97

N.A.\*—Not available

TABLE 6.—TOTAL DRY MATTER, STRAW AND GRAIN YIELD AND YIELD COMPONENTS (DRY SEASON—YALA, 1970)  
(Mean of Four Replicates)

Treatments	Total Dry matter (kg/ha)	Straw (kg/ha)	Grain			Panicles (No/hill)	Panicle weight (g)	1000 grain weight (g)
			(Filled & Ufilled) (kg/ha)	(Filled) (kg/ha)	(Hulled) (kg/ha)			
<b>Water Management</b>								
CF	9,375	4,030	5,281	5,062	3,757	19.1	1.74	23.10
MTD—2	8,998	3,791	5,119	4,933	3,723	18.5	1.71	23.10
MTD—10	9,058	3,922	5,096	4,945	3,684	19.9	1.68	23.40
MTD—E—10	9,377	4,025	5,308	5,117	3,839	19.3	1.77	23.30
L.S.D. 5%	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.16
C.V.	14.3	18.4	11.2	10.4	11.6	14.3	7.5	0.75
<b>Fertilizers</b>								
CK	7,985	3,380	4,517	4,409	3,415	16.9	1.67	23.30
U	9,895	4,292	5,528	5,321	3,952	20.3	1.73	23.30
AS	9,725	4,155	5,504	5,312	3,885	20.4	1.76	23.10
L.S.D. 5%	360	222	170	161	114	1.3	n.s.	n.s.
L.S.D. 1%	488	301	231	218	154	1.7	—	—
C.V.	5.3	23.6	4.4	4.4	4.2	9.3	6.6	1.3

TABLE 7.—TOTAL AND FERTILIZER NITROGEN REMOVED BY GRAIN AND STRAW DRY SEASON—YALA, 1970

Treatments	Rough Grain (kg/ha)			Hulled Grain (kg/ha)			Straw (kg/ha)		
	Grain yield	Total N	Fertilizer N	Grain yield	Total N	Fertilizer N	Straw yield	Total N	Fertilizer N
<b>Water Management</b>									
CF	5,062..	67.9..	14.1..	3,757..	59.0..	—	4,030..	36.4..	7.3
MTD—2	4,933..	65.2..	14.9..	3,723..	55.8	—	3,791..	34.1..	7.4
MTD—10	4,945..	63.9..	13.2..	3,684..	53.8..	—	3,922..	34.1..	6.5
MTD—E—10	5,117..	67.3..	16.1..	3,839..	57.7..	—	4,025..	35.6..	7.1
<b>Fertilizers</b>									
U	5,321..	70.0..	14.8..	3,952..	58.7..	—	4,292..	36.7..	7.0
AS	5,312..	69.5..	14.4..	3,885..	58.0..	—	4,155..	35.7..	7.2
CK	4,409..	58.6..	—	3,415..	52.5..	—	3,380..	32.8..	—

TABLE 8.—EFFECT OF TIME OF APPLICATION OF NITROGEN ON THE PERCENTAGE-N DERIVED FROM FERTILIZER (DRY SEASON—YALA, 1970)

Treatment	Grain	Straw	Grain + Straw	
<b>CF</b>				
U—a	5.2	5.1	10.3	} 40.7
b	15.7	14.7	30.4	
AS—a	1.9	1.4	3.3	} 37.3
b	17.1	16.9	34.0	
<b>MTD—2</b>				
U—a	4.0	3.1	7.1	} 40.8
b	17.1	16.6	33.7	
AS—a	2.0	1.5	3.5	} 44.8
b	20.7	20.6	41.3	
<b>MTD—10</b>				
U—a	3.9	4.0	7.9	} 37.3
b	15.9	13.5	29.4	
AS—a	1.9	1.7	3.6	} 39.2
b	17.5	18.1	35.6	
<b>MTD—E—10</b>				
U—a	5.7	5.4	11.1	} 37.0
b	13.4	12.5	25.9	
AS—a	2.4	2.0	4.4	} 42.8
b	19.4	19.0	38.4	

a=basal application

b=top dressing at primordial initiation stage

Mean (Water Treatment)				Mean (Fertilizer)	
CF	MTD—2	MTD—10	MTD—E—10	U	AS
39.0	42.8	38.3	39.9	38.9	41.0

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TABLE 9.—TOTAL DRY MATTER, STRAW AND GRAIN YIELD AND YIELD COMPONENTS (WET SEASON—MAHA, 1970/91)  
(Mean of Four Replicates)

Treatments	Total Dry matter (kg/ha)	Straw (kg/ha)	Grain Filled & Unfilled (kg/ha)	Grain Filled (kg/ha)	Grain Hulled (kg/ha)	Panicles (No/hills)	Panicle weight (g)	1000 grain weight (g)
<i>Water Management</i>								
CF	10,509	3,839	6,081	5,532	3,833	14.7	2.70	19.48
MTD-2	10,658	3,879	6,146	5,599	3,886	13.7	2.78	19.63
L.S.D.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
C.V.	13.2	17.1	11.5	8.6	8.7	14.7	13.6	3.4
<i>Varieties and Fertilizers</i>								
AS-IR 22	10,193	3,785	5,826	5,313	3,703	17.8	2.01	22.44
AS-Bg 11-11	13,169	4,764	7,610	6,986	4,791	15.9	3.66	15.72
U-IR 22	9,705	3,593	5,541	5,033	3,517	14.9	1.92	23.05
U-Bg 11-11	12,668	4,522	7,343	6,689	4,498	14.4	3.65	16.59
O-IR 22	8,399	3,048	4,885	4,332	3,091	11.2	1.75	23.07
O-Bg 11-11	9,367	3,443	5,478	5,040	3,557	11.7	3.44	16.45
L.S.D. 5%	1,575	499	802	742	568	2.5	0.36	0.91
L.S.D. 1%	2,122	672	1,081	999	765	3.4	0.49	1.23
C.V.	10.3	8.9	9.1	9.2	10.1	12.5	9.2	3.3

TABLE 10.—TOTAL AND FERTILIZER NITROGEN REMOVED BY GRAIN AND STRAW (WET SEASON—MAHA, 1970/71)

Treatments	Rough Grain (kg/ha)			Hulled Grain (kg/ha)		Straw (kg/ha)		
	Grain Yield	Total N	Fertilizer N	Grain Yield	Total N	Straw Yield	Total N	Fertilizer N
<i>Water Management</i>								
CF	5,532	74.4	18.4	3,833	60.2	3,839	36.5	8.5
MTD-2	5,599	76.1	15.4	3,886	61.5	3,879	35.4	6.2
<i>Fertilizers</i>								
AS	6,150	87.7	18.9	4,247	70.3	4,275	46.6	9.4
U	5,861	76.7	14.8	4,008	61.1	4,058	31.4	5.3
CK	4,687	61.3	—	3,324	51.2	3,246	29.9	—
<i>Varieties</i>								
IR-22	4,893	66.7	15.2	3,437	54.3	3,476	33.0	6.3
Bg-11-11	6,293	83.7	18.5	4,282	67.5	4,248	38.9	8.4

TABLE 11.—EFFECT OF TIME OF APPLICATION OF NITROGEN ON THE PERCENTAGE —N DERIVED FROM FERTILIZER (WET SEASON—MAHA 1970/71

<i>Treatment</i>			<i>Grain</i>		<i>Straw</i>		<i>Grain+Straw</i>	
<i>CF</i>								
U-IR-22	a	..	4.5	..	4.5	..	9.0	44.8
	b	..	20.1	..	15.7	..	35.8	
U-Bg 11-11	a	..	2.4	..	3.4	..	5.8	45.1
	b	..	21.8	..	17.5	..	39.3	
AS-IR-22	a	..	2.8	..	2.7	..	5.5	41.3
	b	..	19.5	..	16.3	..	35.8	
AS-Bg 11-11	a	..	4.3	..	3.4	..	7.7	49.1
	b	..	21.2	..	20.2	..	41.4	
<i>MTD-2</i>								
U-IR-22	a	..	3.6	..	2.5	..	6.1	30.5
	b	..	13.0	..	11.4	..	24.4	
U-Bg 11-11	a	..	6.8	..	5.5	..	12.3	38.5
	b	..	14.4	..	11.8	..	26.2	
AS-IR-22	a	..	3.6	..	3.7	..	7.3	31.6
	b	..	12.9	..	11.4	..	24.3	
AS-Bg 11-11	a	..	4.2	..	3.5	..	7.7	39.0
	b	..	17.1	..	14.2	..	31.3	

a=basal application

b= top dressing at primordial initiation stage