6. RESPONSE OF RICE VARIETIES TO TIME OF NITROGEN APPLICATION IN THE TROPICS

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The low fertility of rice soils and the limited supply of inorganic nitrogen fertilizers are serious problems in Southeast Asia. For efficient utilization of nitrogen, it is important to study the response of the rice plant to nitrogen applied at different growth stages.

Other important considerations include the method by which the fertilizer is applied and the condition of the field at the time of topdressing, both of which also influence the utilization of added nitrogen. Hall *et al.* (1967) attributed yield increases of up to 500kg/ha to time of nitrogen application, using several nitrogen rates. Evatt (1964) stated that the timing of fertilizer application depend on the nutrient requirements of the crop at different growth stages and the capacity of the soil to supply these nutrients in sufficient quantities at these times.

Tanaka *et al.* (1959a) showed that rice plants of medium growth duration (145 days), when grown at low nitrgen levels (e. g., 20kg/ha) utilize the fertilizer most efficiently for grain production during the maximum tillering stage and the flowering stage (between the booting and milk stages). The same workers showed that, at high nitrogen rates, such as 120kg/ha, the nitrogen absorbed by the plant during the vegetative stage is stored for use at later growth stages, and that after panicle initiation, a high nitrogen supply tends to decrease the number of filled grains and the weight of 1,000 grains. Therefore, they(Tanaka *et al.*, 1959b) consider that a split application of nitrogen, one dose at transplanting and another at panicle initiation, would be most favorable for obtaining high grain yields, particularly in the case of medium and long growthduration varieties.

Abichandani and Patnaik (1959) obtained a grain yield of 1,020kg/ha with a 160-day variety which received 22kg/ha N at transplanting, 11kg/ha 30 days after transplanting, and 11kg/ha 30 days before flowering, as compared to 760kg/ha obtained with a single basal application of 44kg/ha N at transplanting. These yields, however, are so low that valid conclusions cannot be drawn since factors other than nitrogen supply apparently were limiting.

Chandraratna *et al.* (1962) observed the superiority of topdressing with nitrogen during panicle initiation over earlier applications for a wide range of indica varieties indigenous to the tropics. They found that topdressing during panicle initiation increased the number of grains per panicle but not the number of panicles per plant.

Tanaka *et al.* (1959a) stated that nitrogen absorbed by the plant from tillering to panicle initiation tends to increase the number of tillers and panicles, and that which is absorbed during panicle development (from panicle initiation to flowering) increases the number of filled grains per panicle. They also noted that nitrogen absorbed after flowering tends to increase the 1,000-grain weight.

In a direct-sowing experiment, Yanagisawa *et al.* (1967) observed that nitrogen applied at panicle initiation or at flowering reduced the rate of senescence of the lower leaves, probably as a result of a reduction in the amount of nitrogen that was translocated from the lower to the upper leaves.

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Wilson (1965) attributes to nitrogen application at seeding the induction of early tiller development, increased tiller production, and increased number of panicles at maturity. With a traditional U. S. variety, Belle Patna, he found that the increase in the number of panicles at harvest was high enough to more than compensate for the reduction in panicle weight and in 1,000-grain weight.

Typical U. S. varieties such as Zenith, Nato, and Bluebonnet 50 produced high yields when fertilized 45 to 60 days before heading, indicating that, if properly timed with the reproductive cycle of the plant, nitrogen application could increase the number of florets and eventually produce high grain yields (Hall, 1960, 1965).

According to Mikkelsen *et al.* (1967), although topdressing with nitrogen supplements the nitrogen supply, it cannot be used as a substitute for an application before planting. He stated that if topdressing is practiced, it should be done at an early growth stage such as 30 to 40 days, and not 60 days, after seeding, although the latter seemed to improve the appearance of the crop. On the other hand, Lewis (1954) in Texas indicated that topdressing with nitrogen 82 to 84 days after seeding gave somewhat higher yields than applying the entire amount of fertilizer at seeding time.

In greenhouse studies conducted in Arkansas, Hall and Railey (1964) studied nitrogen response at different morphological stages of the rice plant. They found that, with the variety Nato, the correct time to apply nitrogen would be when the internode between the 5th and 6th nodes had reached a maximum elongation of 2 mm, which corresponded to the early jointing stage. Sims (1965) also found that low rates of nitrogen are most effective when applied in a single dose just before panicle initiation (jointing stage). He observed that, under conditions of high soil fertility, nitrogen should be topdressed either during the early stages of crop growth, or not at all in the case of varieties similar to Bluebonnet 50.

Matsushima (1964) cited several studies on the nitrogen requirement of the rice plant at different growth stages. These included those concerned with the effect of time of nitrogen application on the trend and level of dry matter production (Tanaka *et al.*, 1959a ; Yanagisawa *et al.*, 1967), leaf color and leaf senescence (Hall, 1959 ; Hall *et al.*, 1967 ; Yanagisawa *et al.*, 1967), nutrient uptake (Mitsui, 1954 ; Hall, 1960 ; Hall and Tackett, 1962), and plant characteristics including date of maturity (Wells, 1962) and lodging (Hall and Tackett, 1962 ; IRRI Annual Report, 1966).

At The International Rice Research Institute in the Philippines, late application of nitrogen (at the booting and heading stages) was found suitable for plant types with tall and weak straw. Early application caused early lodging which prevented proper grain formation. In the case of the short and stiff-strawed and hence, lodging-resistant varieties, the highest yields were obtained when the nitrogen was applied at the maximum tillering and panicle initiation stages. For both plant types, however, there was a significantly higher concentration of nitrogen (and hence, protein content) in the grain when the nitrogen was applied at the booting and heading stages.

The efficiency of nitrogen fertilizer uptake at different times of application can be determined by tracer element techniques. In an experiment conducted by Yanagisawa *et al.* (1967), the nitrogen applied 15 days before heading was 55% utilized : at flowering, 49% ; at tillering, 34% ; and at transplanting as a basal dressing, 7%. In another study, the application of two-thirds of the nitrogen at transplanting and the remaining one-third at the booting stage gave a higher nitrogen recovery (51%) than when the entire amount was applied at transplanting (38%), or when topdressed at the tillering stage (32%). Other studies showed that 18% N^{15} was absorbed when the nitrogen was topdressed at maximum tillering, and 45% when topdressed at the booting stage (Patnaik and Broadbent, 1967 ; Patnaik, 1965).

Water management may directly affect the efficieney of nitrogen utilization by lowland rice. It is generally believed that temporary drainage is necessary when topdressing with nitrogen to bring the fertilizer material as close to the soil particles as possible. This enhances the adsorption of nutrients and minimizes the loss of nitrogen through nitrification and denitrification. In most farmers' fields, however, an adequate water supply is not assured throughout the cropping season, so that draining the field may result in a water shortage at the later stages of plant growth.

This paper report studies conducted by The International Rice Research Institute to investigate (1) the effect of water management systems on the efficiency of nitrogen utilization and the grain yield of two rice varieties of contrasting plant type, and (2) the effect of time application of inorganic nitrogen fertilizer on the yield of the new short, stiff-strawed varieties growh in different soils and crop seasons.

Matreials and methods

Field experiments were conducted during the 1967 crop seasons at the IRRI farm on Maahas clay soil (pH 6.0, organic matter 2%, total nitrogen 0.14%, CEC 45 meq/100g soil, predominant clay mineral montmorillonite) to measure the response of rice plants to time of nitrogen application under two water management systems. The variety H-4 was used alone in the dry season, and together with IR8 in the wet season. IR 8 and H-4 represent contrasting plant types; the former is short and lodging-resistant variety developed by IRRI while the latter is a tall, lodging-susceptible variety from Ceylon.

In the dry season, H-4 was fertilized with a total of 60kg/ha N. This amount was applied in a single dose during final land preparation, and in two and three doses at various combinations on the following growth stages of the crop: final harrowing stage, maximum tillering stage, panicle initiation stage, booting stage, and heading stage (see Table 1). The topdressings were made when more than 50% of the plants had reached a particular growth stage.

In the wet season, H-4 and IR8 were fertilized with 30 and 60kg/ha N, respectively. The amount of nitrogen applied to H-4 was less than that given in the dry season in an attempt to minimize lodging caused by luxurious vegetative growth. The nitrogen applications at transplanting were made before the field was finally harrowed and levelled. Topdressings of nitrogen were broadcast either (a) on previously drained that were immediately reflooded after application (drained) or (b) on fields water 5 cm deep (flooded).

A split-block design was used in both seasons with the variety as the main plot, the time of application as the subplot. and the water condition as the sub-subplot. Each treatment was replicated three times. Plots with the same water management and topdressing were arranged in a block to facilitate drainage and irrigation.

In five of the treatments, part of the fertilizer was added in the form of N^{15}-labelled $(NH_4)_2SO_4$, 1.2% atom excess. This labelled fertilizer, which corresponded to the proper nitrogen rate, was applied to a 1.6 sq m area within a treatment plot. These small areas were enclosed in metal sheets pushed down to the plow sole to prevent the lateral movement of fertilizer in the soil. In the case of the drained treatments, the N^{15} plots were reflooded by pouring the water directly but slowly into the small plots to prevent the fertilizer in the main treatment plot from entering.

Four to six 21-day-old seedlings per hill were planted in straight rows 20 x 20cm apart. Herbicides and insecticides were applied for weed and insect control.

The height and tiller number of the plants were recorded at the maximum tillering and panicle initiation stages, which were about 30 and 65 days after transplanting, respectively. The sequence and degree of lodging were observed closely. The nitrogen content of the plant, the amount of dry matter produced, and the chlorophyll content of the leaves were determined at various growth stages of the crop. The grain yield at 14% moisture and the yield components including panicle number and weight and 100-grain weight were taken at harvest.

The extent of fertilizer utilization was determined from samples of the N^{15}-treated plots. Whole plants were analyzed for nitrogen content, and a portion of the NH_4^+ distillate was sent in sealed glass tubes to the Institute of Physical and Chemical Research in Japan, for N^{15} analysis.

The 1968 crop season experiments were conducted in two locations: at the Institute farm (Maahas clay soil, which has been described earlier) and at the Maligaya Rica Research and Training Center in Nuevea Ecija province, Philippines (soil at Maligaya, pH 6.9, organic matter, 1.5%, total N 0.08%, CEC 36meq/100g soil, predominant clay mineral montmorillonite). The varieties used were IR5 and IR8, with N^{15}-labelled ammonium sulfate being applied to the former, and non-labelled ammonium sulfate being applied to the latter. The experiments at Maligaya were conducted in cooperation with the Philippine Bureau of Plant Industry.

A total of 120 and 80kg/ha N were applied in the dry and wet seasons, respectively, in single or multiple doses before final harrowing or during selected growth stages. The nitrogen was incorporated into the soil when applied before planting. All topdressings were made when the fields were flooded to a depth of 5cm. A split-plot design was used, with variety as the main plot and time of application as the subplot. All treatments were replicated three times. The cultural practices followed and the plant characters and other factors observed were similar to those in the 1967 experiments.

Results and discussion

The data on grain yield obtained from the tests conducted to measure the response of rice plants to time of nitrogen application under two water management systems are shown in Table 1.

(1) Dry season.

The grain yields obtained under the two water management systems were not significantly different. It has previously been observed that nitrogen topdressings on the water surface may cause the loss of some nitrogen (Mikkelsen *et al.*, 1967) due primarily to the nitrification and consequent denitrication of the ammonium-N forms (Mitsui, 1954). In the experiment, the topdressings were made when the plant roots were already well established, so that the amount of nitrogen absorbed by the plants were greater than that lost through nitrification and denitrification. This could be the reason why the yields were not unfavorably affected.

H-4 gave a significantly higher yield when given no nitrogen (control) than when 60 kg/ha N was applied in a single dose before the last harrowing. The highest yield (6,333 kg/ha) was obtained when 60kg/ha N was applied in split dosesat panicle initiation and at booting. H-4 lodged regardless of nitrogen level, with earlier applications of the fertilizer resulting in early lodging and in a higher percentage of grain sterility. The utilization of N^{15}-labelled nitrogen by the grain and straw was 12 to 15% higher when the fertilizer was applied late than when applied early (treatments 3 to 5, Table 2). The percentage of utilization N-labelled nitrogen was high at the panicle initiation stage. Similar values were obtained with 30 and 15kg/ha N^{15}-labelled nitrogen, indicating that the later the application, the higher the percentage of nitrogen recovery.

(2) Wet season.

IR 8 gave significantly higher yields with added nitrogen, irrespective of time of applica-

Table 1. Effect of two water management systems and time of nitrogen application on the grain yield of H-4 in the dry season and H-4 and IR8 in the wet season. IRRI, 1967.

(Grain yield (kg/ha) at 14% moisture)

Treatment no.	Time of application$^+$					Dry season		Wet season			
						Water management		Water management			
						Continuously flooded	Drained before application, then immediately reflooded	Continuously flooded		Drained before application, then immediately reflooded	
	a	b	c	d	e	Variety H-4		IR8	H-4	IR8	H-4
	(kg/ha N)										
1	0	0	0	0	0	5159	—	2199	2531	—	—
2	60	0	0	0	0	3411	—	5180	1983	—	—
3	0	30*	30	0	0	5011	4453	5090	1979	5013	2277
4	0	0	30*	30	0	5943	6333	4681	2483	4820	2395
5	0	0	0	30*	30	5859	6003	4298	2888	4038	3000
6	0	20	20	20	0	5344	6093	4991	1491	5155	2169
7	0	0	20	20	20	5972	5911	4470	2620	4389	2738
8	0	20	20	0	20	5979	6025	5073	2765	4880	2515
9	45	0	0	0	15*	5163	4695	4923	2295	5257	2303
10	45	0	15*	0	0	4628	4887	4964	1915	5443	2181
Mean (water management)						5491	5550	4999	2304	4811	2447

Analysis of variance (dry season):

	s. e.	LSD(5%)	CV(X)%
A^1			
Water management (W)$^{n.s.}$	236	—	21
Treatment mean (T)*	320	971	14
T X W mean$^{n.s.}$	296	—	9
B^2			
Water management (W)$^{n.s.}$	236	—	21
Treatment mean (T)**	335	995	14
T1 vs T2*	—	—	—
T X W mean	296	—	9

Analysis of variance (wet season):

	s. e.	LSD(5%)	CV(X)%
Variety IR8-Treatment mean (T)**	227	674	11
Treatment x water management$^{n.s.}$	146	—	5
Variety H-4-Treatment (T)$^{n.s.}$	306	—	13
Treatment x water management	316	—	23

Duration (days): IR8=118
H-4=130

a last harrowing
b maximum tillering
c panicle initiation
d booting stage
e heading stage
* N^{15}-labelled ammonium sulfate
\+ Half the rate for H-4 (total 30 kg/ha N)

A^1 Analyses exclude treatments 1 and 2.
B^2 Analyses include treatments 1 and 2.

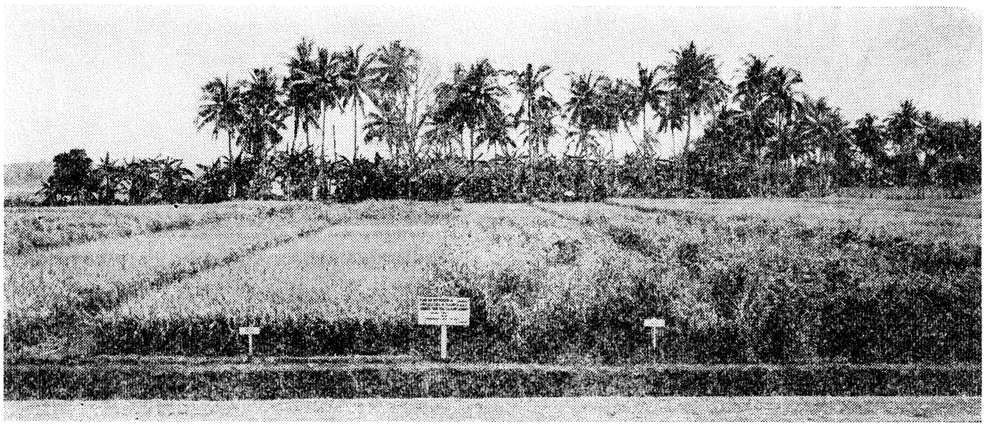

Fig. 1. **H-4, a tall and weak-strawed Ceylonese variety (right), lodged heavily prior to maturity even without fertilizer, while IR8, a short and stiff-strawed indica variety(left) remained erect until harvest with 60 kg/ha N of added nitrogen. IRRI, 1967 wet season.**

tion, than the no-nitrogen check. Early nitrogen applications, either in single or split doses, resulted in higher yields than late applications, particularly at the booting or heading stage. On the other hand, H-4 lodged so severely (Fig. 1), and under all treatments then they were no significant differences in grain yields (Table 1). H-4 and IR8 had similar tiller numbers, percentages of productive tillers, and weight of 100 grains, but the former variety yielded less because of higher grain sterility. Both varieties had fewer sterile grains when nitrogen topdressing was delayed beyond panicle initiation.

An analysis of the N^{15}-labelled nitrogen content of the plants showed that varying amounts of the fertilizer were absorbed at particular growth stages. For H-4, up to 55% of the nitrogen topdressed at the maximum tillering stage was absorbed from the time of transplanting until the booting stage. The value decreased as the crop matured and the older

Table 2. **Effect of time of nitrogen application (mean of two water management systems) on the utilization of added fertilizer (N^{15}) by the grain and straw of H-4 and IR 8. IRRI, 1967 crop seasons.**

Treatment no.	Total utilization (%)		
	Dry season	Wet season	
	H-4	IR 8	H-4[1]
3	33	35	15
4	48	47	31
5	45	41	34
9	60	56	40
10	48	71	26
Mean	47	50	29

[1] N-rate for H-4 in the wet season was only $^1/_2$ of the rate applied to IR8.

leaves died (data not presented here). At harvest, at least one-sixth of the topdressed nitrogen remaind in the grain and straw (Table 2). It appears that in the wet season, a lower percentage of the fertilizer nitrogen remained in the H-4 plants at harvest because of the faster decomposition (leaf rotting) of straw after lodging. A higher proportion of the topdressed nitrogen was absorbed by the plants when it was applied between the panicle initiation and booting stages.

IR8 appears to have absorbed a greater amount of the topdressed nitrogen when it was applied at the panicle initiation stage, but having received and accompanied a basal application just before transplanting than when there was no basal application (treatments 10 and 4, respectively). This is probably because of the more developed and extensive root system for absorption of the plants which received a basal application of nitrogen.

Leaf samples (3rd and 4th leaves from the top) of IR8 and H-4 taken at various crop growth stages upto the heading stage, and flagleaves of IR8 collected at harvest, were analyzed for chlorophyll content. The values are presented in Table 3. The leaves of IR8 had a higher chlorophyll content when the nitrogen was topdressed at the later growth stages than when the entire amount was applied at transplanting. This difference was not found with H-4 (Table 3). The chlorophyll content of the IR8 flagleaf at maturity was also higher when the nitrogen was applied late than when it was applied early. A modest application of nitrogen to IR8 following heading maintained a dark-green flagleaf until maturity, but still topdressing at the later growth stages did not bring about a higher grain yields. Interestingly, the lowest chlorophyll values of IR8 at booting corresponded to the treatments in which the lowest grain yields were obtained. However, practically no correlation was obtaindd between the chlorophyll

Table 3. Chlorophyll content of leaves of two varietal types as affected by time of nitrogen application, IRRI, 1967 wet season.

Treatment no.	Variety	Chlorophyll in leaves* (%, oven-dry basis)				
		Growth stage				
		Maximum tillering	Panicle initiation	Booting	Heading	Harvest
1	H-4	0.48	4.38	0.26	0.32	0.19
	IR8	0.55	0.40	0.34	0.34	—
2	H-4	0.61	0.54	0.53	0.44	0.15
	IR8	0.57	0.45	0.34	0.32	—
3	H-4	—	0.51	0.47	0.62	0.20
	IR8	—	0.51	0.41	0.29	—
4	H-4	—	—	0.50	0.88	0.24
	IR8	—	—	0.35	0.35	—
5	H-4	—	—	—	0.70	0.33
	IR8	—	—	—	0.32	—
6	H-4	—	0.55	0.48	0.72	0.23
	IR8	—	0.45	0.37	0.29	—
7	H-4	—	—	0.41	0.68	0.27
	IR8	—	—	0.30	0.34	—
8	H-4	—	—	—	0.53	0.24
	IR8	—	—	—	0.29	—
9	H-4	—	—	0.37	0.51	0.21
	IR8	—	—	0.28	0.26	—
10	H-4	0.63	0.47	0.45	2.53	0.17
	IR8	0.57	0.44	0.36	0.28	—

* Leaves no. 2 and 3 from the top until harvest and flagleaf at harvest.

Table 4. Effect of time of nitrogen application on the grain yield and some components of yield of IR 8 and IR 5 when grown on Maahas clay soil. 1968 dry season.

Treatment no.	Time of application					IR 8					
	a	b	c	d	e	Grain yield	Statistical Significance^s	Panicle (no./m^2)	Panicle weight	Unfilled grains	Grain/straw ratio
	(kg/ha N)					(kg/ha)	(5%)		(g)	(%)	
1	0	0	0	0	0	3832	e	250	2.1	16	1.2
2	120*	0	0	0	0	6854	ab	425	3.3	6	0.9
3	0	60*	60*	0	0	7638	a	400	2.9	14	1.2
4	0	0	60*	60*	0	6642	abc	450	2.4	13	1.4
5	0	0	0	60*	60*	5498	d	475	2.3	9	1.2
6	90*	0	30*	0	0	7712	a	400	2.6	10	1.1
7	90*	0	0	0	30*	6408	bcd	375	2.3	6	1.1
8	0	40	40	40	0	7302	ab	350	2.6	14	1.3
9	0	0	40	40	40	6248	bcd	375	2.4	10	1.4
10	0	40	40	0	40	7124	ab	350	3.3	7	1.2
11	60	0	30	30	0	7560	a	400	2.6	8	1.1
12	60	0	0	30	30	5721	cd	375	2.6	4	1.1
	Mean (variety)					6544		400	2.6	10	1.2

Treatment no.	Time of application					IR 5						
	a	b	c	d	e	Grain yield	Statistical Significance^s	Panicle (no./m^2)	Panicle weight	Unfilled grains	Grain/straw ratio	Grain yield (mean)
	(kg/ha N)					(kg/ha)	(5%)		(g)	(%)		(kg/ha)
1	0	0	0	0	0	4090	d	250	2.4	18	1.0	3961
2	120*	0	0	0	0	7570	a	400	3.2	14	0.8	7212
3	0	60*	60*	0	0	6696	abc	350	3.2	22	0.8	7167
4	0	0	60*	60*	0	4802	d	325	3.0	21	0.7	5722
5	0	0	0	60*	60*	5848	c	300	2.9	13	1.0	5673
6	90*	0	30*	0	0	7366	ab	325	2.8	20	0.8	7539
7	90*	0	0	0	30*	6352	bc	325	2.8	12	0.8	6380
8	0	40	40	40	0	7022	ab	325	3.3	29	0.8	7162
9	0	0	40	40	40	6510	abc	325	3.3	15	1.0	379
10	0	40	40	0	40	7338	ab	300	3.2	15	1.0	7231
11	60	0	30	30	0	7374	ab	325	3.1	21	1.0	7467
12	60	0	0	30	40	6538	abc	350	2.5	13	1.0	6129
	Mean (variety)					6458		325	3.0	18	0.9	

a last harrowing　　b maximum tillering stage　　c panicle initiation stage

d booting　　e heading

*N^{15}-labelled $(NH_4)_2SO_4$ applied to IR5 only

s means marked with the same letter are not significantly different at the 5% level.

Table 5. Effect of time of nitrogen application on the grain yield and some yield components of IR 8 and IR 5 when grown on Maligaya soil. IRRI, 1968 dry season.

Treatment no.	Time of application					IR 8					
	a	b	c	d	e	Grain yield	Statistical significance[s]	Panicle (no./m^2)	Panicle weight	Unfilled grains	Grain/straw ratio
	(kg/ha N)					(kg/ha)	(5%)		(g)	(%)	
1	0	0	0	0	0	4869	e	375	1.9	13	1.1
2	120*	0	0	0	0	8363	bc	525	2.4	11	0.8
3	0	60*	60*	0	0	9024	ab	450	2.6	16	1.0
4	0	0	60*	60*	0	7712	cd	425	2.2	14	1.3
5	0	0	0	60*	60*	5397	e	400	2.1	10	1.1
6	90*	0	30*	0	0	9268	a	550	2.0	13	1.0
7	90*	0	0	0	30*	8444	b	500	2.0	8	0.9
8	0	40	40	40	0	8374	bc	425	2.0	18	1.1
9	0	0	40	40	40	7389	d	400	2.2	17	1.4
10	0	40	40	0	40	9021	ab	425	2.7	10	1.2
11	60	0	30	30	0	8563	ab	475	2.1	11	1.1
12	60	0	0	30	30	7339	d	500	2.3	10	0.9
Mean (variety)						7814		450	2.0	13	1.1

Treatment no.	Time of application					IR 5						Grain yield (mean)
	a	b	c	d	e	Grain yield	Statistical significance[s]	Panicle (no./m^2)	Panicle weight	Unfilled grains	Grain/straw ratio	
	(kg/ha N)					(kg/ha)	(5%)		(g)	(%)		(kg/ha)
1	0	0	0	0	0	5088		350	1.8	16	0.9	4978
2	120*	0	0	0	0	7465	de	475	2.4	11	0.7	7914
3	0	60*	60*	0	0	8279	ab	450	2.9	23	0.8	8652
4	0	0	60*	60*	0	7070	de	350	2.2	21	1.2	7391
5	0	0	0	60*	60*	6790	e	400	2.0	8	1.1	6094
6	90*	0	30*	0	0	7607	bcd	525	2.3	16	0.8	8438
7	90*	0	0	0	30*	7429	de	500	2.2	7	0.7	7936
8	0	40	40	40	0	7585	cd	400	2.2	23	1.0	7980
9	0	0	40	40	40	7082	de	350	2.0	24	1.3	7236
10	0	40	40	0	40	8501	a	425	3.0	12	1.0	8761
11	60	0	30	30	0	8196	abc	450	2.4	15	0.9	8380
12	60	0	0	30	30	7558	cd	550	2.1	10	0.8	7448
Mean (variety)						7388		425	2.3	16	0.9	

a last harrowing b maximum tillering stage c panicle initiation stage

d booting stage e heading stage

*N^{15}-labelled $(NH_4)_2SO_4$ applied to IR5 only

s means marked with the same letter are not significantly different at the 5% level.

content of the leaves and the yield of H-4 as the latter seemed to be controlled more by lodging. Leaf color by itself may not be a satisfactory indicator of the productivity of the plant since it can change throughout the growing season and is not always related to an increase or a decrease in yield (Hall, 1959).

The results obtained from the field experiments conducted in two locations during the 1968 crop seasons using two improved varieties and N^{15}-labelled fertilizer are summarized in Tables 4 through 9.

(3) **Dry season.**

The highest yield of IR8 (7, 700kg/ha) was obtained with treatment 6 in which the nitrogen was applied in two doses, two-thirds at planting time and one-third at the panicle initiation stage. Besides the control, the lowest yield was obtained with treatment 5, in which a split application of nitrogen was made at the booting and heading stages. All the plots which received added nitrogen gave significantly higher yields than the no-nitrogen plots (Table 4).

With IR5, the highest yield (7. 570kg/ha) was obtained with treatment 2, in which the entire amount of nitrogen was applied before the last harrowing (Table 4). This yield, however, was only slightly higher than that obtained with treatment 6 (7, 366kg/ha), Beside the control, the lowest yield of IR5 was obtained with split applications of nitrogen at the panicle initiation and booting stages (treatment 4). The difference in yield between the control and treatment 4 was not significant apparently because at the early growth stages there was insufficient soil nitrogen for adequate tiller production, thus reducing the number of potential panicles.

The yields of IR8 and IR5 under the same treatments were not statistically different except in treatment 4 in which the former gave over 1, 800kg/ha more grain than the latter. This difference appeared to be related to the significantly greater number of panicles, higher grain-straw ratio, and lower percentage of unfilled grains of IR8. IR5 had a slightly greater panicle weight, but this was not enough to compensate for its lower number of panicles and higher percentage of unfilled grains (Table 4).

The plants grown at the Maligaya Center gave higher mean yields than those grown at the Institute. The control plots at Maligaya gave about 1, 000kg/ha more grain than those at the Institute. The highest yield obtained at Maligaya (9, 268kg/ha, with IR8) was over 1, 500kg/ha more than the highest obtained at the Institute farm (7, 712kg/ha) (Table 5). It also marked the first time in which a yield of over 9, 000kg/ha was obtaincd at this experiment station. The higher yields at Maligaya may be attributed to the higher solar radiation and the longer sunshine hours there, especially during the later crop growth stages. During the last three months of crop growth (April, May, and June), the solar radiation recorded at Maligaya (14, 800, 16, 500, and 14, 000g-cal-cm^{-2}) was consistently higher than that at the Institute farm (13, 101, 12, 149 and 10, 952g-cal-cm^{-2}).

Statistical analysis showed that treatments 6, 3, 10, and 11 gave better yield results as a group than treatments 4, 9, and 12 also as a group. Among the nitrogen treatments, the lowest yields of IR8 and IR5 were obtained with treatment 5, in which the nitrogen was topdressed at the booting and heading stages.

The results from Maligaya indicate a fast rate of nitrogen exhaustion in the soil. Topdressed nitrogen can apparently sustain the plants for only a short period, possibly because it is absorbed rapidly by the plants during the metabolic processes the efficiency of which is enhanced by the high solar energy in the dry season. Preliminary results indicate also that ammonium fixation is higher in the soil at Maligaya than in the Maahas clay soil at the Institute.

An examination of the yield component data reveals that the plants in the treatments without a basal application of nitrogen had significantly fewer panicles than those in the treatments with a basal application. The plants in the treatments with delayed nitrogen topdressing had a fewest panicles.

The dry matter and nitrogen contents of the plants increased after each nitrogen top-

Table 6. Effect of time of nitrogen application on the utilization of added fertilizer (N^{15}) by the grain and straw of IR5. IRRI and Maligaya Rice Research and Training Center, Nueva Ecija 1968 dry season.

Treatment no.	Utilization of added nitrogen (%)					
	IRRI			Maligaya		
	Grain	Straw	Total	Grain	Straw	Total
2	23	10	33	15	9	24
3	31	18	49	27	14	41
4	26	25	51	35	13	48
5	35	22	57	44	20	64
6	27	12	39	20	11	31
7	23	17	40	27	14	41
Mean	28	17	45	28	14	42

Table 7. Effect of time of nitrogen application on the grain yield of IR8 and IR5 grown under flooded condition. IRRI, 1968 wet season.

Treatment no.	Time of application a	b	c	d	e	Variety IR8	IR5	Mean	Statistical significance[1]
			(kg/ha N)			(kg/ha)		(kg/ha)	(5%)
1	0	0	0	0	0	4157	2347	4252	ab
2	80*	0	0	0	0	5599	5102	5350	ab
3	0	40*	40*	0	0	5711	5375	5543	ab
4	0	0	40*	40*	0	5543	5147	5345	ab
5	0	0	0	40*	40*	5381	5213	5296	b
6	60*	0	20*	0	0	5839	5600	5719	a
7	60*	0	0	0	20*	5623	5380	5502	ab
8	0	27	27	27	0	5431	5227	5330	ab
9	0	0	27	27	27	5449	5730	5590	ab
10	0	27	27	0	27	5663	5639	5651	ab
11	40	0	20	20	0	5791	5265	5528	ab
12	40	0	0	20	20	5670	5335	5503	ab
Mean (variety)						5488	5280		

a last harrowing
b maximum tillering stage
c panicle initiation stage
d booting stage
e heading stage

1 Means followed by the same letters are not significantly different at the 5% level using Duncan's multlple range test.

*N^{15}-labelled $(NH_4)_2SO_4$ applied to IR5 only.

dressing. At harvest, the plants which received nitrogen topdressings at the later growth stages (treatments 4, 5, 9, 10) had the highest nitrogen content, and therefore protein content, in both grain and straw while greater amounts of dry matter were produced at harvest by the treatments which included basal applications of nitrogen (treatments 2, 6, 7, 11). More nitrogen, however, was removed from the soil at harvest in the treatment in which the nitrogen was applied late.

In both locations, treatment 5 -topdressing at booting and at heading- showed the highest utilizatian of added nitrogen (Table 6). As the Institute farm, basal application (treatment 2) showed a lower proportion of fertilizer nitrogen in the grain than late nitrogen applications (treatments 3, 4, and 5). At Maligaya, the fertilizer nitrogen was found in greater amounts in the grain in treatments with nitrogen topdressings during and after panicle initiation.

The considerable difference in the total utilization of nitrogen in treatment 2 at the Institute and as compared to that at Maligaya shows the low level of nitrogen in the Maligaya crop, especially at the later growth stages. The nitrogen utilized earlier by the Maligaya crop probably was returned to the soil in the form of dead leaves.

(4) Wet sason.

The wet season experiment had the same design as the dry season test, and similar cultural practices were followed.

Table 7 shows the yields of IR8 and IR5 at the Institute farm. The highest mean grain yield of the varieties was obtained with a split application of nitrogen, two-thirds at plant-

Table 8. Effect of time of nitrogen application on the grain yield of IR8 and IR5 grown under flooded condition. Maligaya Rice Research and Training Center, Nueva Ecija, 1968 wet season.

Treat-ment no.	Time of application					IR8		IR5		Mean
	a	b	c	d	e	Grain yield	Statistical significance[1]	Grain yield	Statistical significance[1]	
	(kg/ha N)					(kg/ha)	(5%)	(kg/ha)	(5%)	(kg/ha)
1	0	0	0	0	0	3758	e	3670	d	3714
2	80*	0	0	0	0	5537	ab	4425	bc	4981
3	0	40*	40*	0	0	5223	bc	4376	bc	4799
4	0	0	40*	40*	0	5487	ab	4779	abc	5133
5	0	0	0	40*	40*	4463	d	4478	abc	4470
6	60*	0	20*	0	0	5784	a	4921	ab	5353
7	60*	0	0	0	20*	5601	ab	4615	abc	5108
8	0	27	27	27	0	5125	bc	4316	c	4721
9	0	0	27	27	27	5328	abc	4998	a	5163
10	0	27	27	0	27	4926	cd	4435	bc	4680
11	40	0	20	20	0	5847	a	4817	abc	5832
12	40	0	0	20	20	5493	ab	4981	a	5237
Mean (variesy)						5214		4568		

a last harrowing
b maximum tillering stage
c panicle initiation stage
d booting stage
e heading stage

1 Means followed by the same letters are not significantly different at the 5% level using the Duncan's multiple range test.

*N^{15}-labelled $(NH_4)_2SO_4$ applied to IR5 only.

ing and one-third at panicle initiation (treatment 6). However, this treatment was significantly better than only two other treatments- treatment 1, the no-nitrogen control, and treatment 5, a split application at the booting and heading stages.

At the Maligaya Center (Table 8), a split application of nitrogen did not produce a marked increase in the yield of IR8 over a single application. Treatments involving a basal application of nitrogen tended to increase yields while topdsessing at the later growth stages (Treatment 5 -at booting and heading) gave the lowest yield among the treatments (4,463 kg/ha), except for the control. Apparently the nitrogen in the soil at Maligaya was not sufficient to sustain the crop for a long period after transplanting. This deficiency reduced the valuse of such important yield component as tiller number, panicle number and grain number. Topdressing at the later stages helped only slightly, if at all, to increase yield.

With IR5, significantly higher yields were obtained when the nitrogen was applied in multiple doses than when the entire amount was applied at transplanting. Presumably, split applications caused less mutual shading, minimized leaching losses, and delayed lodging. This yield response was not observed in the more fertile, less sandy Maahas clay soil at the Institute farm.

The results of these studies indicate that with lodging-susceptible varieties, nitrogen applications should be delayed to avoid excessive vegetative growth and to delay lodging for as long as possible, particularly if the soil is fertile. With lodging-resistant varieties, however, the application of nitrogen just before transplanting will increase the number of panicles and consequently the grain yield. At the Institute farm a split application of nitrogen did not increase the yields of IR8 or IR5 significantly over a single basal application of nitrogen. Splitting the application of nitrogen resulted in a higher grain yield for only IR5 at Maligaya.

Table 9. Fffect of time of nitrogen application on the utilization of added fertilizer (N^{15}) by the grain and straw of IR5. IRRI and Maligaya Rice Research and Training Center, Nueva Ecija, 1968 wet season.

Treatment no.	Utilization of added nitrogen (%)					
	IRRI			Maligaya		
	Grain	Straw	Total	Grain	Straw	Total
2	22	13	35	11	7	18
3	41	24	65	34	13	47
4	40	20	60	43	13	56
5	44	18	62	46	15	61
6	30	15	45	25	11	36
7	34	15	49	25	9	34
Mean	30	15	45	26	10	36

The mean utilization of added nitrogen by IR5 on Maahas clay soil was similar in the wet and dry seasons. At Maligaya, less nitrogen was utilized by IR5 in the wet than in the dry season. In both locations, however, the application of nitrogen in a single dose gave the lowest utilization of added nitrogen (Tables 2 and 9). This confirms our earlier results which showed that split applications bring about a significantly higher utilization of added nitrogen by grain and straw than incorporating the fertilizer in a single dose into the soil at transplanting (De Datta *et al.*, 1968). However, the higher utilization values obtained with a split application of nitrogen did not produce significant increases in grain yield, except in the case of IR 5 at Maligaya.

Summary

Data from the 1967 crop season experiments showed that if the water depth of the field is maintained at 5 cm, temporary drainage at the time of nitrogeen topdressing dose not necessarily result in increased grain yields and therefore it is not recommended in areas where there is not an assured water supply.

The experiments conducted over a two-year period demonstrated that there is no advantage to a split application of nitrogen if the variety is lodging-resistant and is grown on a highly fertile, haavy clay soil, such as Maahas clay. A single basal application will do just as well, if adequate nitrogen is applied if it is thoroughly incorporated into the soil, and if the soil is kept continously flooded. On the other hand, split applications of nitrogen may result in significantly higher yields if the soil is not highly fertile and if the variety has a long growth duration as was true in the case of IR5 at Maligaya. In such instance, split applications may prevent excessive vegetative growth and consequently, early lodging.

Discussion

A. Fujiwara, Japan: How much do you estimate the amount of microbial nitrogen fixation in IRRI field?

Answer: The amount of mineral nitrogen released during a crop season was estimated to be about 60kg/ha. This amount was estimated from a field study on the IRRI farm (Maahas clay).

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