11. FERTILIZER USE FOR INCREASING RICE YIELDS IN INDIA

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Rice is cultivated in about 35-36 million hectares of the total 176 million hectares of arable land area, in India. The rice growing conditions in the country are very diverse. The indigenous varieties used by the farmers range in duration anywhere between 80-180 days or even more. The crop is both direct seeded and transplanted and is mostly rainfed. The choice of the variety and mothod of culture depends upon the location of the land (upland, medium or lowland) and the time of onset and cessation of monsoon. The various systems have been evolved since ages and are mostly weather (monsoon) bound. This type of crop is commonly known as the *kharif* (wet season) crop, occurring from June to December. In the *kharif* season, early duration, photoperiod insensitive varieties are grown on uplands whereas medium and late duration photoperiod sensitive varieties are cultivated in medium and lowlands where there is standing water for a longer period. Areas with water stagnation and also with irrigation facilities in the northeast and south India, now being increasingly made available through river valley projects, grow another rice crop from January to May, called the *rabi* (dry season) crop. This crop is mostly transplanted with photoperiod insensitive early duration varieties. The method of cultivation is thus still traditional, at least in some parts of the country, with indigenous or improved varieties, mostly rainfed and receive little or no scientific approach to farming. The crop is subject to vegaries of nature like flood, drought ect. and the econmic conditions of the farmer, many a times, do not allow him to spend money on inputs like improved seeds, fertilizers, pesticides etc. Table 1 gives the statistics of rice area and production in the country during the past four years. The year 1964-65 was considered to be the best year as the rainfall distribution was good and there was no serious incidence of flood and drought. Record rice yield of 39 million tonnes with an average grain yield of 1,073 kg/ha was obtained during this year. The weather and crop growing conditions during the two subsequent years were very adverse because of uneven distribution of rainfall, and occurrence of flood and drought in several parts of the country, as a result of which there was a marked decrease in both the total production and hectare yield. The weather and growing conditions in the last year, 1967-68, was although good, we do not appear to have achieved the figures of 1964-65.

Table 1. Statistics on rice area, production and fertilizer consumption in India

Year	Area (million hectares)	Total grain production (million tonnes)	Fertilizer application (kg/ha)				Average grain yield kg/ha
			N	P_2O_5	K_2O	Total	
1964-65	36.3	39.0	—	—	—	—	1,073
1965-66	35.3	30.7	3.46	0.84	0.49	4.79	869
1966-67	35.3	30.4	5.31	1.57	0.73	7.61	863
1967-68	36.7	37.9	6.65	2.67	1.30	10.62	1,031

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Fetilizer - the king-pin in rice farming

Shortage of rice to feed the ever increasing population of the country is being felt for quite some time and in an effort to increase the total rice output, even marginal and sub-marginal lands are being brought under rice cultivation. A stage has now been reached where it is not possible to further increase the area under rice and at the present time, use of fertilizer appear to be the answer to solve shortage of land and food problem, through increasing hectare yields. It has been estimated that in the United States of America, one tonne of N P K would substitute about 3. 8 ha of land at the 1964 average crop and fertilizer price level. In India, where the average fertilizer application is very low (Table 2), one tonne of nitrogen can substitute for 20-25 hectares of unmanured rice land; and additional production of one million tonnes of nitrogen would, therefore, mean creation of the equivalent of 20 million hectares of unmanured land area (Kanwar, 1969).

Table 2. Fertilizer consumption (zone wise) per unit area in India

Zone	Nutrients	Fertilizer application (kg/ha)			Grain yield(kg/ha)		
		1965-66	1966-67	1967-68	65-66	66-67	67-68
South	N	6. 03	11. 28	12. 13	1312	1479	1460
	P_2O_5	1. 61	2. 69	5. 10			
	K_2O	1. 38	1. 89	2. 73			
	Total	9. 02	15. 86	19. 96			
West	N	2. 09	2. 72	3. 66	489	540	839
	P_2O_5	0. 91	1. 28	1. 93			
	K_2O	0. 31	0. 45	0. 59			
	Tatal	3. 31	4. 45	6. 18			
North	N	2. 89	4. 28	7. 00	1014	775	949
	P_2O_5	0. 21	1. 01	2. 34			
	K_2O	0. 13	0. 33	1. 36			
	Tatal	3. 23	5. 62	10. 70			
East	N	3. 64	4. 36	4. 43	587	522	797
	P_2O_5	0. 61	1. 37	1. 37			
	K_2O	0. 35	0. 54	0. 65			
	Total	4. 60	6. 27	6. 45			
All India	N	3. 46	5. 31	6. 65	869	863	1013
	P_2O_5	0. 84	1. 57	2. 67			
	K_2O	0. 49	0. 73	1. 30			
	Total	4. 79	7. 61	10. 62			

Fertilizers also increase the efficiency of irrigation water and in fact, irrigation without fertilizers is like a resource wasted. Fertilizer use also improves turnover of labour. The overhead labour costs on tillage, irrigation, weed control and other farming operations will not vary very much if one produces one tonne per hectare without fertilizers or 5 tonnes per hectare with fertilizer use, which thus improves the productivity of the man-hours utilized.

Production and consumption of fertilizers

As has been pointed out earlier, the consumption of fertilizers per unit area is very low. The introduction of high yielding and high fertilizer responsive varieties in 1965-66, however, resulted in increased intake of fertilizers, a statistics on which is presented in Table 2. The farmers in the north and south zones use more fertilizers per unit area as compared to those in the east and west zones. There is, however, a noticeable increase in fertilizer use in all the zones from 1965-66 onwards. To cope with the increasing demand on fertilizers due to projected increase in area under the high yielding varieties, the Government of India have taken steps to produce more fertilizers in the country. A comparative statement on the consumption during the Third Five Year Plan period and production targets during the Fourth Five Year Plan period is given in Table 3. It may be seen that the total production of N, P_2O_5, K_2O during the last year of the Fourth Plan will be respectively 2.0, 2.5 and 1.5 times the consumption level existing at the end of the Third Plan period. Even this level of production is considered by many to be inadequate to cover the area growing food crops, cash and other crops.

Table 3. Fertilizer consumption in India during the Third Five Year Plan period and production targets during the Fourth Five Year Plan period (in thousand metric tonnes)

Item	N	P_2O_5	K_2O
Third Plan consumption			
1961-62	400	100	82
1962-63	525	150	100
1963-64	650	225	130
1964-65	800	300	160
1965-66	1,000	400	200
Fourth Plan production targets			
1966-67	750	370	125
1967-68	1,000	500	175
1968-69	1,300	650	225
1969-70	1,600	800	275
1970-71	2,000	1000	350

3. The approach to optimization of fertilizer effects

There will still exist shortage of fertilizers. Further, the economic condition of the farmer is not good enough to invest large sums on inputs, particularly in view of the vegaries of weather and lack of crop insurance. It is, therefore, imperative on the part of the agricultural scientists to devise ways and means of rationalizing fertilizer application, concerning rate, form, method and time of application, so that wastage of fertilizer is avoided, especially under conditions of shortage as at present obtained in India, and the farmer gets, atonce, the best out of a given input and high yields.

The Indian Council of Agricultural Research has been entrusted with coordinating agricultural research in the country. Information of basic nature is obtained from research laboratories at the Central and State Institutes and Agricultural Universities, application of which is carried out in adaptive research projcets through the All India Coordinated Rice Improvement Project (AICRIP) and Coordinated Model Agronomic Experiments Project.

An account of work done which have helped rational use of fertilizers and also improvement of productivity of problem soils is enumerated in the following pages.

Nutritional requirements of rice crop

1) Nutrient removal under intensive cropping :

Data from field tests (Patnaik, 1967) on the effect of continuous intensive cropping on the nutrient removal by improved *indica* and high yielding varieties are summarised in Table 4. It was possible to get total grain yields in the range of 10-13 tonne/ha on the same land form the *kharif* and *rabi* crops of high yielding varieties as compared to 5-6 tonne/ha with improved *indicas* of comparable duration. Such high yields with the new varieties remove 2. 0-2. 5 times more of nitrogen and phosphorus and 4. 0-4. 5 times potassium as compared to the improved *indicas*. Further, the magnitude of removal in the *rabi* season was more than that in the *kharif* season. Continuous intensive cropping with the high yielding varieties might, therefore, bring about considerable depletion of nutrients from the soil, particularly phosphorus and potassium. For sustained productivity, there was thus need

Table 4. **Yield and nutrient removal by different varieties under intensive cropping**

Variety	Season		Yield (tonne/ha)	Nutrients removed (kg/ha)				
				N	P	K	Ca	Mg
Ptb 10	*Rabi*	grain	2. 02					
		straw	1. 99					
		total	4. 01	25	10	50	—	—
	Kharif	grain	2. 87					
		straw	2. 06					
		total	4. 93	45	10	50	—	—
Mtu 15	*Rabi*	grain	3. 36					
		straw	3. 92					
		total	7. 28	50	15	70	—	—
	Kharif	grain	2. 45					
		straw	3. 20					
		total	5. 65	50	15	50	—	—
Taichung(N) 1	*Rabi*	grain	8. 00					
		straw	8. 64					
		total	16. 64	152	37	268	42	45
	Kharif	grain	5. 02					
		straw	5. 42					
		total	10. 44	92	16	183	22	12
Tainan 3	*Rabi*	grain	6. 40					
		straw	7. 46					
		total	13. 86	113	26	223	36	28
	Kharif	grain	4. 21					
		straw	3. 99					
		total	8. 20	82	14	151	14	13
Chianung 242	*Rabi*	grain	7. 85					
		straw	9. 30					
		total	17. 15	162	32	260	45	38
	Kharif	grain	3. 19					
		straw	3. 87					
		total	7. 06	58	13	120	14	6

for balanced application of fertilizers, particularly phosphorus and potassium, in addition to high rates of nitrogen application, and also higher rates for *rabi* as compared to *kharif*.

2) **Response to nitrogen, phosphorus and potassium**:

Field tests on fertilizer response by various crops at experiment stations and simple fertilizer trials in cultivators' fields are being conducted since 1953 under the Model Agronomic Experiments Scheme, mostly with local improved varieties. Trials on a coordinated basis with high yielding varieties have been just started since last year, results from which from all over the country are expected with interest. Fertilizer trials have also been carried out with high yielding varieties under the All India Coordinated Rice Improvement Project.

Information on the response to increasing rates of nitrogen by IR 8 and local *indica* during the *kharif* and *rabi* seasons is summarised in Fig. 1. It might be seen that the yield potential and nitrogen responsiveness was very much higher in IR 8 as compared to local *indica*. For IR 8, the optimum rate in the *kharif* season was 80-120 kg/ha as against 120 -160 kg/ha in the *rabi* season.

Data on the N-P interactions with respect to the high yielding rice varieties are available only from eight centres and are presented in Fig. 2 a, b. At all locations, application of potassium in combination with nitrogen and/or phosphorus did not give any significant beneficial effect and so the data have been averaged over the potassium treatments. The N-P interaction was high at Rajendranagar and was noticeable to some extent at Coimbatore and Mandya. At Pattambi, application of phosphorus in combination with nitrogen resulted in a decrease in grain yield and the workers at Pattambi attribute this to zinc-phosphorus

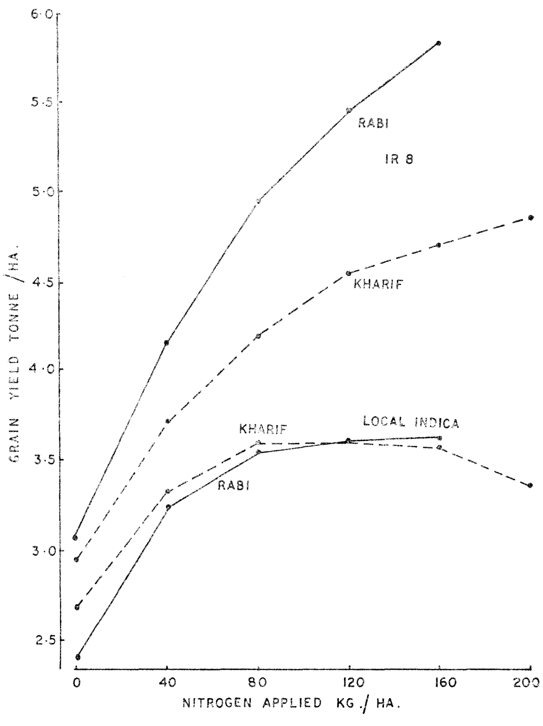

Fig. 1. Comparative performance of IR 8 and local indica at increasing rate of nitrogen - average of three kharif and three rabi seasons
(Aicrip, 1968)

relationship. At Kanke, Garikadadu, Amaravati and at the Central Rice Research Institute, only in *kharif*, application of phosphorus in combination with nitrogen did not appear to give any significant beneficial effect. On the other hand, in the *rabi* season, there was N-P interaction at the CRRI. A close look of the crop in the farmers' fields, however, gives indication of phosphorus hunger even in the local varieties. Simple fertilizer trials in cultivatnrs' fields, now in progrees may be able to throw more light on the N-P interactions.

3) Soil test-crop response correlations:

Ramamoorty and Pathak (1969) are of the view that it is uneconomical to use fertilizers without evaluating soil fertility, as the response to nitrogen under conditions of sufficiency of phosphorus and potassium decreased steadily with an increase in soil test value, even to negative response at very high soil test values. From elaborate field trials with artificially created soil fertility gradient, Ramamoorty *et al.* (1967) have perfected a technique for recommending fertilizer rates based on soil test values for target yields of wheat. This techuique is currently under test for rice through a coordinated project all over the country.

4) Form and method of fertilizer application:

The soil should be able to supply plant nutrients, either native or applied, required to support the plant growth for high yields. Studies on fertilizer-soil interrelationship have resulted in the elucidation of proper form and method of applying different nutrients. So

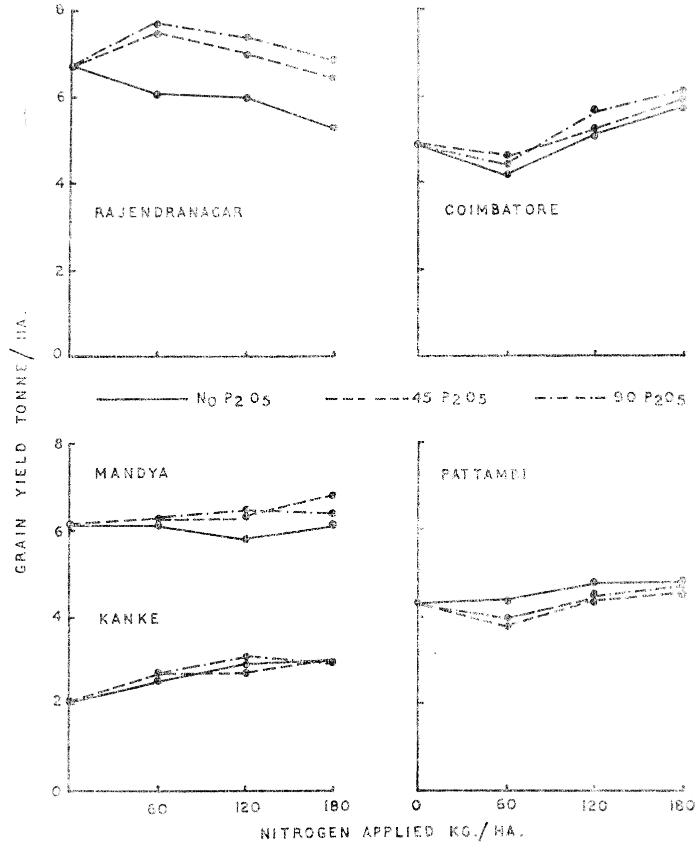

Fig. 2a. Effect of increasing rates of N and application (averaged over K) on the grain yield of IR 8
(Aicrip, kharif 1967)

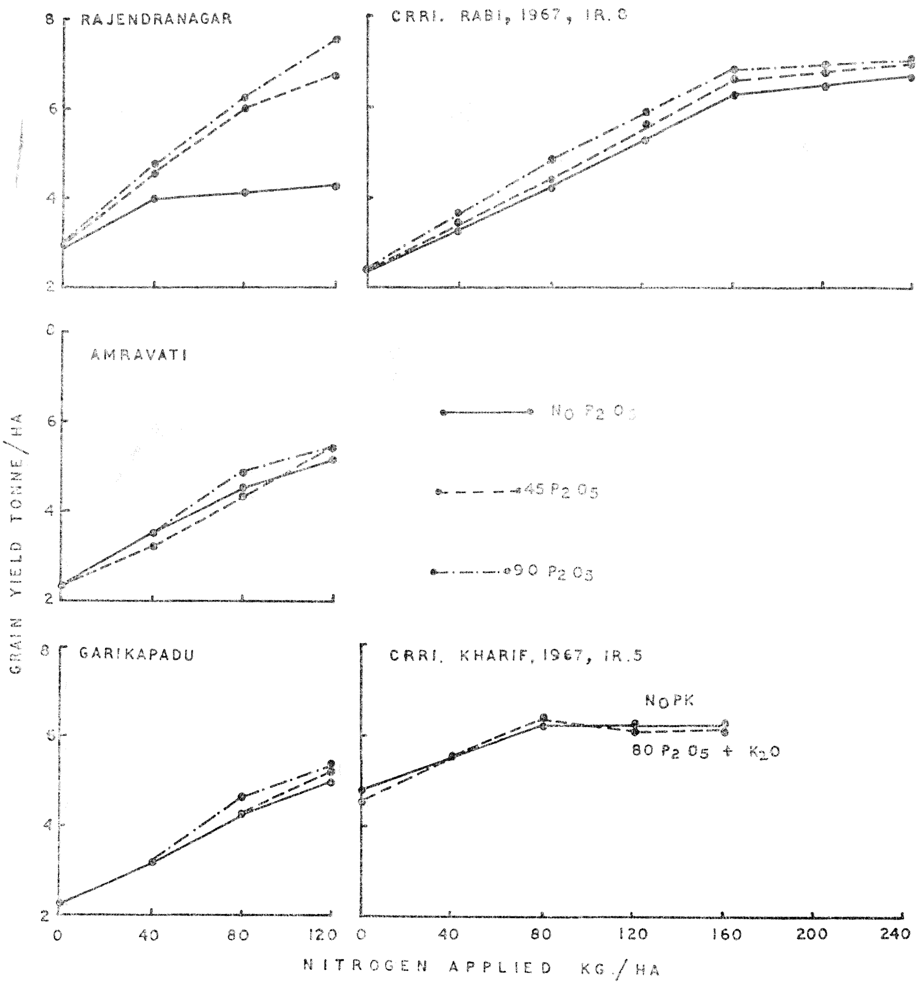

Fig. 2b. Effect of increasing rates of n and p application (averaged over k) on the grain yield of IR 8 (Aicrip 1967)

far as nitrogen is concerned, this is an old story but will not be out of place to mention that ammoniacal fertilizers and urea are superior to nitrate fertilizers and that placement of ammoniacal nitrogen in the reduced sub-surface zone of the soil assures higher recovery and better results. The method of application of highly soluble urea, particularly under heavy rainfall conditions in India needs special mention. From studies on the hydrolysis of urea in different soil types, Patnaik (1965) and Patnaik and Nanda (1967) have suggested soil pretreatment of urea about 48 hours before application to minimise mobility loss of the fertilizer. So far as phosphorus is concerned, studies carried out recently at the CRRI indicate the scope for efficient use of citrate soluble phosphates like fused calcium magnesium phosphate and insoluble rock phosphates, on acid lateritic soilts, by application to moist soil about six weeks before submergence. Results show that the soil acidity *per se* solubulizes phosphorus which gets converted to ferric phosphate and on submergence gets reduced to more soluble ferrous phosphate.

Time of application of N, P, K, in relation to varieties

For getting the best out of a given nutrient, it is desirable that application is done at the time when the plant is in a stage of vigorous absorption and efficient assimilation. In view of the varietal diversity, it is necessary to have information on

1. Varietal differences in growth process ;
2. Nutrient uptake in relation to growth of these varieties, to know the stages of vigorous absorption ;
3. Efficiency of nutrients absorbed during different growth stages of these varieties for grain production ;

which will help identifying the time of application. Experiments have been conducted at the Central Rice Research Insthtute, with early duration tall *indica* (Ptb. 10, Mtu. 15), medium and late duration tall *indica* (T. 141, GEB. 24, T. 1242, Bam. 9), dwarf *indica* (Taichung Native 1, IR 8), *ponlai* (Taichung 65, Tainan 3. Chianung 242) and *japonica* (Norin 17), which have given information on the points raised above (Patnaik, 1966 ; Patnaik and Gaikawad, 1969 ; Patnaik and Nanda, 1969 ; Patnaik *et al.*, 1965, 1967 ; Tanaka *et al.*, 1959 a, b). Some of the salient findings are discussed hereinafter.

1) Varietal differences in the growth process :

The growth process of different varieties has been studied under field condition. The maximum tiller number stage (vegetative growth period) appeared to be independent of the duration of the duration of the variety and was obtained about 6-7 weeks after transplanting. Ear-initiation, onset of the reproductive growth period, overlapped or closely followed the mawimum tiller number stage in the early duration tall *indica*, dwarf *indica* and *ponlai*, whereas in the medium and late duration *indica*, there was a time lag between the maximum tiller number stage and onset of ear-initiation. This period has been termed as the "vegetative lag period". It could, therefore, be seen that the growth process of early duration tall *indica*, dwarf *indica* and the *ponlai* was more or less similar and was quite different from that of the medium and late duration tall *indica*.

2) Nutrient uptake in relation to growth

The process of nutrient uptake appeared to be markedly related to the growth of the varieties. In the early duration tall *indica*, dwarf *indica* and *ponlai*, there were vigorous absorption of nitrogen, phosphorus and potassium form planting which continued up to flowering or a little after that. The pattern of absorption was more or less continuous and similar for these groups of varieties. For the medium and late duration tall *indica*, there was vigorous absorption of nitrogen, phosphorus and potassium from transplanting up to the maximum tiller number stage after which it slowed down during the vegetative log period. With the onset of ear-initiation, there was again vigorous absorption which continued up to about flowering. Thus, in this group of varieties, there were two periods of vigorous absorption of the three nutrients during the vegetative and reproductive phases, separated by a period of absorption lag during the vegetative lag period.

3) Efficiency of nutrients absorbed during different periods for grain production

A quantitative estimate of the efficiency of nitrogen, phosphorus and potassium absorbed during different growth stages of some of these varieties has been made in solution culture experiments. This has been expressed as "partial productive efficiency" which is a measure of the increase in grain yield per unit increase in absorption during a given period, expressed mathematically as

$$\frac{Y_n - Y_{n-1}}{X_n - X_{n-1}}$$

when Y_n and Y_{n-1} are the grain yields and X_n and X_{n-1} are the nutrients absorbed at the n th. and n-1 th. stages respectively.

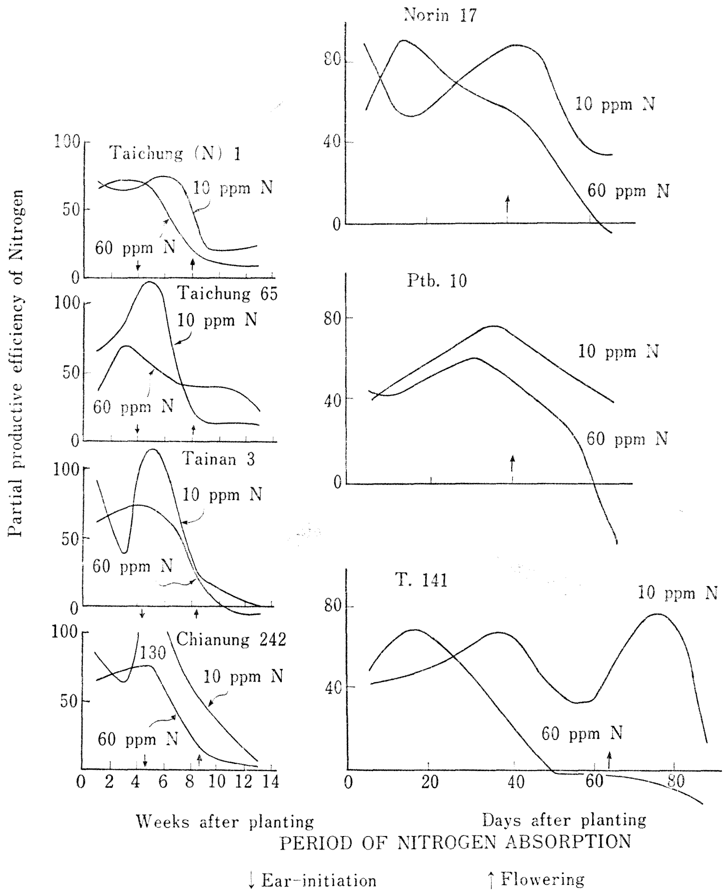

Fig. 3a. Efficiency of nitrogen absorbed during various growth stages of differnt rice varieties for grain production

Partial productive efficiency of these group of variets has been worked at low and high rates of nutrient supply (Fig. 3 a, b). The following results were obtalned:

1. At high rates of nitrogen supply, only one peak of partial productive efficiency was obtained in all the varieties, sometime during the vegetative growth period.
2. At low rates of nitrogen supply, only one peak was obtained with Ptb. 10 and Taichung 65, sometime during the vegetative growth period.
3. At lower levels of nitrogen, Taichung Native 1, Tainan 3, Chianung 242, Norin 17 and T 141 had two peaks of partial productive efficiency. In the former four varieties, the first peak was obtained immediately after transplanting and the second peak sometime during the period from ear-initiation to flowering. With T 141 on the other hand, the first peak was obtained at about the maximum tiller number stage and the second peak near about flowering.
4. In case of phosphorus and potassium, only one peak of partial productive efficiency was obtained during the vegetative growth period, irrespective of the variety (Ptb 10, T 141 and IR 8) and rate of nutrient supply.

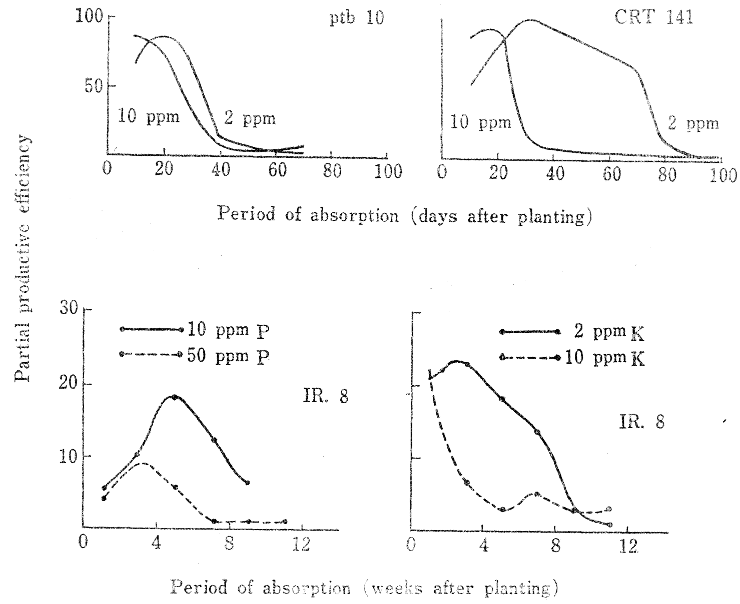

Fig. 3b. Effieiency of phosphorus and potassium absorbed during various growth stages of different rice varieties for grain production

It might, therefore, be seen thet although the early duration tall *indica*, dwarf *indica* and *ponlai* had similar pattern of growth and nitrogen absorption, which was different from those of the medium and late duration tall *indica*, data on partial productive efficiency showed that, in respect of nitrogen, the behaviour of Ptb 10 and Taichung 65 was different from that of the rest of the varieties, the pattern within each group being more or less similar.

Information on the stages of occurrence of the peak of partial productive efficiency give precise indication of the time of fertilizer application. Nutrients absorbed during the period when the partial productive efficiency increased towards the peak value is increasingly utilized for grain production, while that absorbed during the decreasing period is not. So far as nitrogen is concerned, this is more applicable at lower rates of application as compared to higher rates, as the rice plant can absorb more nitrogen than the requirement and store for considerable time. Therefore, from the consideration of the curves obtained at the lower rates, it can be concluded that Ptb 10 and Taichung 65 may not need fractional application of nitrogen whereas the rest of the varieties may benefit more from fractional application. The time of application in this case, basal at planting of 75-80% of a given amount and the rest top dressed sometime during the period from ear-initiation to the emergence of the boot leaf.

These findings have been field tested with tall *indica* in the earlier years and dwarf *indica* and *ponlai* in the coordinated field experiments. With the tall *indica* group, there was beneficial effect due to fractional application with T 1242 but not with Ptb 10. Results from the coordinated experiments may be summarised as follows:

1. In the dry season, when the nitrogen assimilating power was high, fractional application was superior to single rate application in Taichung Native 1 whereas with Taichug 65,

application of the entire amount at planting was the best.

2. In the wet season, when the nitrogen requirement was compartively lower, there was no difference between the treatments.

A field experiment was conducted at several locations through the AICRIP, to test the efficiency of single and fractional application of 60, 80 and 100 kg/ha nitrogen, on the grain yield of IR 8. There were several treatment combinations and only a few are given in Table 5 for illustration. It could be seen that the treatments 60-20 and 100-0 were more or less on par in several locations whereas 80-20 was superior to the former two treatments. It, therefore, follows that the efficiency of a given amount of nitrogen can be increased through fractional application.

Table 5. Effect of fractional application of nitrogen on grain yield (kg/ha) of IR 8 (Aicrip, 1968)

Location	Control	60*-0**	80-0	60-20	100-0	80-20	LSD 0.05
Amaravati	2,708	3,656	4,414	4,521	4,085	4,551	506
Bankura	3,833	5,090	5,034	4,887	5,133	5,250	756
Coimbatore	2,757	4,491	5,073	6,263	6,403	6,770	62
Cuttack(CRRI)	3,576	4,765	5,162	5,342	5,109	5,426	293
Faizabad	2,675	4,048	3,997	4,490	4,438	5,019	697
Garikapadu	2,664	3,884	4,368	5,208	4,310	4,692	904
Kapurthala	5,568	6,675	7,037	7,262	7,481	7,681	752
Mandya	4,632	5,180	5,569	5,054	5,702	5,580	228
Maruteru	3,439	4,383	4,673	4,845	4,953	4,883	603
Pantnagar	4,086	5,046	6,664	8,363	8,700	8,993	729
Patna	2,609	3,779	3,870	3,323	4,236	4,156	556
Pattambi	3,579	3,740	4,256	4,564	4,264	4,125	498
Rajendranagar	2,842	3,754	3,938	3,714	3,892	4,206	593
Sirsi	1,850	3,433	3,047	3,812	3,590	3,812	419
Average	3,334	4,433	4,793	5,118	5,164	5,367	

* Application basal at puddling

** Top-dressing at the panicle initiation stage

As regards phosphorus and potassium, although their pattern of absorption along with nitrogen was similar for a given variety in all cases, the peak of partial productive efficiency was obtained during the initial growth stages, indicating need for basal application of these two nutrients.

Efforts for dissemination of knowledge to farmers

For the cultivation of high yielding varieties in the country, a "package of practices" has been worked out which include results of research from cultural, fertilizer, water management, plant protection trials etc. In an endeavour to carry the results of research to the farmer, National Demonstrations are being conducted since 1965 in farmers' fields. Each demonstration occudies an area of 0.4-0.5 hectare with a minimum yield target specified for each year. During the year 1968-69, a total of 1,287 demonstrations on rice were carried out. Results of 551 trials obtained at the time of review at the Annual Workshop held in April, 1969, are summarised in Table 6. It might be seen that average grain yields in different states was in the range 3.5-9.2 tonne/ha, with the highest yield in the range 4.6-15.3

Table 6. **Yields obtained in National Demonstrations in India during 1968-69**

State	Number of demonstrations	Fertilizer (kg/ha)			Grain yield (tonne/ha)		
		N	P_2O_5	K_2O	Lowest	Highest	Average
Andhra Pradesh	94	100	60	35	3.4	14.9	6.1
Assam	23	45	30	20	2.6	7.3	4.9
Bihar	42	90	45	25	2.5	8.1	5.5
Delhi	5	110	46	14	2.0	4.6	3.5
Gujrat	9	130	70	40	1.5	7.9	5.2
Haryana	21	150	50	40	4.4	9.8	5.7
Himachal Pradesh	5	119	86	20	3.2	9.0	6.7
Jamm & Kashmir	46	42	33	22	3.2	12.0	7.8
Kerala	20	100	65	55	4.2	9.9	5.9
Madhya Pradesh	49	100	50	34	1.9	10.4	4.5
Madras	32	105	50	40	3.4	8.3	5.5
Maharashtra	17	90	50	28	2.4	8.8	5.5
Mysore	17	130	58	54	2.2	7.8	5.2
Orissa	13	110	58	60	4.1	7.8	6.9
Punjab	30	130	60	50	4.3	9.6	5.8
Rajastan	4	100	50	30	5.8	15.3	9.2
Uttar Pradesh	69	120	50	40	2.1	8.4	5.8
West Bengal	28	86	54	46	2.7	7.0	5.1

tonne/ha. The Central Rice Research Institute has so far conducted 39 demonstrations since 1965 where grain yield in the range of 3.5-9.3 tonne/ha were obtained. This appears to have caught up well with the farmers as we have been hearing several claims for grain yield of 7-10 tonne/ha from all corners of the country.

Improvement of rice yields on problem soils

1) Acid laterite and lateritic soils:

Low productive acid laterite and lateritic soils constitute quite a good proportion of rice lands in the country. Rice crop grown on these soils suffers from some sort of bronzing disease. Sahu (1968) attributed the cause of bronzing to iron toxicity which could be overcome by provision of drainage, soil application of lime, phosphate and foliar application of urea.

Pot experiments were conducted at the Central Rice Research Institute, with six acid laterite and lateritic soils obtained from different places, to study the effects of elimination of one nutrient from the complete fertilizer (N+P+K+Ca) on grain yield and untrient uptake. Data on grain yield are summarised in Table 7. It might be seen that elimination of nitrogen and phosphorus and to some extent, potassium from the complete fertilizer resulted in a marked decrease in grain yield. In these treatments and also in the control, there was occurrence of bronzing symptoms almost similar to those reported by Sahu (1968). Elimination of calcium did not make much difference in many of the soils. The plants grew well in the treatment receiving complete fertilizers as could be seen from the grain yield obtained from two plants per each pot. The problem in these soils was possibly neither iron toxicity nor soil acidity but lack of adequate amounts of nitrogen, phosphorus and potassium.

Table 7. **Effect of elimination of nutrient from complete fertilizer on grain yield (gm/pot) of rice on acid lateritic soils**
(Ph. D. work of Mr. S. K. Mohanty, CRRI, Cuttack)

Soil Na.	Complete	Complete-N	Complete-P	Complete-K	Complete-Ca	Control
3	53	8	42	39	42	6
6	56	8	—	56	50	3
7	48	6	—	45	48	3
8	56	14	6	53	56	15
10	70	31	53	52	64	32
16	60	8	3	62	62	8

Table 8. **Effect of application of balanced fertilizers on the grain yield of IR 8 on acid lateritic soils** (kg/ha)

	Compost (tonne/ha)	Lime (tonne/ha)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Time of fertilizer application	Grain(kg/ha) *kharif*	*rabi*
1.	—	—	100	40	50	20-40-40 at puddling, 60-0-10 about five weeks after seeding and 20-0-0 at panicle initiation	4, 255	7, 633
2.	12	2. 5	100	40	50	-do-	4, 718	8, 326

A field plot test was, therefore, taken up in the Deras farm representing such a problem soil and the data from two seasons' trial are given in Table 8. It could be seen that grain yields of 4. 5-8. 0 tonne/ha could be obtained with the application of compost, lime nitrogen, phosphorus and potassium on these problem soils known to exhibit the so called bronzing disease and give yields of 1. 0-1. 5 tonne/ha.

2) **Management of upland rice soils**:

Considedable proportion of rice lands grow direct seeded rainfed rice under upland soil conditions. Although more remunerative crops like sorghum, maize, *ragi* etc. can be grown on these soils, the prevailing socio-economic conditions and favourable temperature and high rainfall in July and August force the farmers to grow rice on these lands, considered marginal and sub-marginal for this crop-only to get very low yields of 400-700 kg/ha.

In the research projects on rice improvement, vary little attention has been paid to the management of these marginal and sub-marginal uplands for increasing rice yields. In an attempt to improve yields of direct seeded rice under upland, rainfed conditions, fertilizer experiments were conducted at the Central Rice Research Institute in 1963 and 1964, with early duration tall *indica* variety Ptb 10 (Patnaik and Nanda, 1965). It was found that :

1. There was almost a linear increase in grain yield up to 90 kg/ha nitrogen. This variety, under normal transplanted conditions, had a tendency to lodge and give decreasd yields beyond 40 kg/ha nitrogen application.

2. The fertilizers ammonium sulfate, ammonlum sulfate nitrate, calcium ammonium nitrate and urea were equally efficient in increasing grain yields whereas under normal transplanted lowland conditions, ammonia containing fertilizers and urea are known to be superior to nitrate fertilizers.

3. On an average, acout 20-25% of the applied nitrogen was utilized by the crop as measured from the data on nitrogen uptake in control and nitrogen treatments.

4. It was possible to increase grain yield from 748 kg/ha in control to 2,117 kg/ha in some nitrogen treatments, the average for two years' study being 716 kg/ha for control and 1,250 kg/ha for mean of the nitrogen treatments.

Linear response to nitrogen application, comparable efficiency of ammonium and nitrate fertilizers and lower recovery of applied nitrogen in the crop was explained due to near saturation of the soil which favoured nitrification and the nitrates thus formed were lost in the heavy downward movement of rain water, due to the upland location and loose texture of the soil. Attempts were made to minimize these nitrogen losses by reducing the downward movement of water. This was achieved through moderate soil compaction which destroyed the macropores

Table 9. Effect of soil compaction on rice yield (tonne/ha) on upland soils

I tem		No nitrogen	50 kg/ha nitrogen	100 kg/ha nitrogen	Mean
1966	(Chianung 242 x CI 9155)				
	No compaction	1. 0	2. 5	3. 9	2. 5
	Moderate compaction	1. 4	3. 8	5. 1	3. 4
	High compaction	1. 0	3. 0	4. 1	2. 7
	Mean	1. 1	3. 1	4. 4	
1967	(IR 8) Personal communication				
	No compaction	2. 2	3. 7	4. 8	3. 6
	Moderate compaction	2. 5	4. 2	5. 7	4. 1
	High compaction	2. 3	4. 2	4. 8	3. 7
	Mean	2. 3	4. 0	5. 1	

Pot and field experiments were conducted during 1966 and 1967 to determine the effects of moderate compaction of loose textured upland soil, on rice yield and nutrient uptake (Patnaik *et al.*, 1968). Data on the grain yield in the field experiments are presented in Table 9. It was possible to get high grain yields of 5. 1-5. 7 tonne/ha on these marginal and sub-marginal uplands with moderate soil compaction and 100 kg/ha nitrogen, as against control yields of 1-2 tonne/ha. Further, grain yieldt at 50kg/ha nitrogen with compaction and 100 kg/ha nitrogen without compaction were comparable(3. 8-3. 9 and 4. 2-4. 8 tonne/ha in the two years), thus indicating almost a two-fold increase in the fertilizer efficiency. These beneficial effects could be explained from the following basic information obtained in the pot studies :

1. Compaction resulted in increased uptake of phosphorus, iron and manganese (Fig. 4), indicating higher water retention as a consequence of which, the availability of these three nutrients increased due to near reduced conditions of the soil.

2. Compaction increased grain yield and nitrogen uptake from applied urea, indicating lower downward movemeat of water and loss of applied nitrogen.

Thus, there is a scope for increasing the yield of direct seeded rice grown on marginal and sub-marginal uplands, to very high levels through moderate soil compaction and fertilizer use. There may, however, be certain difficulties for the universal adoption of this practice by the farmer. The first to be encountered is the engineering problem of devising a suitable implement, light enough for transport to the plot but heavy enough to compact the soil. In

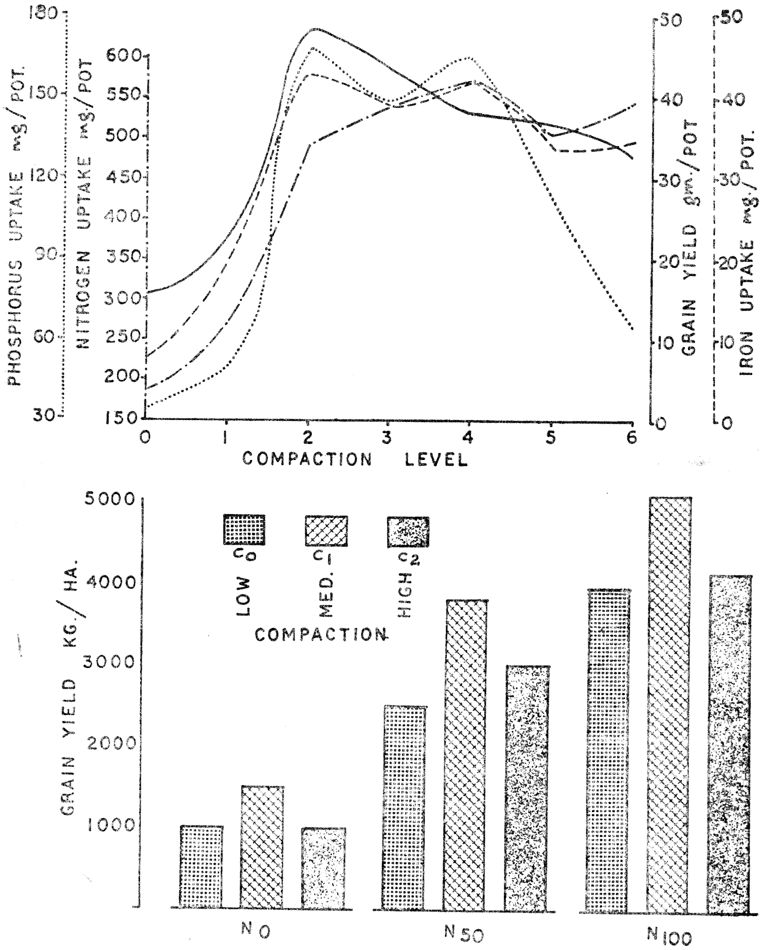

Fig. 4. **Effect of soil compaction on rice yield and nutrient uptake**

the field experiments just discussed, compaction was achieved by cement rollers mounted on the tractor. There is a scope for adopting this technique in large compact areas where introduction of full or partial mechanization is possible. Next to be encountered is the problem of controlling the enormous weed population on these lands. Conventional application of MCPA and DCPA, many a times, fail to control the weeds because the fields cannot have standing water all the time. It is, therefore, necessary to workout suitable weed control schedule through proper tillage operations is summer and use of preemergence herbicides. The use of nitrification inhibitors along with fertilizers also offers good promise. Investigations on some of these aspects have already been initiated at this Institute. It is, however, recognised that these marginal lands are any day more suited and more remunerative for growing crops other than rice, but till such time the assured and productive rice lands are in a position to meet the rice needs of the Nation, some efforts have to be made to overcome the predicament of the farming community owning these marginal lands, because of favourable temperature and rainfall during the growth period of rice.

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