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Rice Culture in the Central Plain of Thailand (IV)

Response to Nitrogen of Some Native Varieties under Field Conditions

by

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In recent years investigation of the rice plant has been promoted energetically in tropical countries. The yielding ability and, particularly, the nitrogen responsiveness of a great number of *Indica* varieties were examined under various conditions. It has been known that the varietal difference among *Indicas* is much greater than that among *Japonicas,* and some *Indicas* are highly responsive to nitrogen application under some conditions. The statement that *Indicas' response to nitrogen is very low* is no longer valid. Nevertheless, it is also true that so-called "typical *Indicas*" are low in their response to nitrogen especially when they are grown in the rainy season. These "typical *Indicas*" are generally tall and leafy with a longer vegetative lag phase. The plant physiologists at I.R.R.I. have clearly showed the vital importance of light conditions as the key factor limiting the low response to nitrogen of the leafy tropical varieties.

The grain yield of the rice plant is composed of four components: panicle number, spikelet number per panicle, percentage of filled grain and weight of one grain. In general, when the amount of nitrogen applied is increased, the grain yield will increase at least to the certain level unless the indigenous fertility is too high. One of the approaches to the understanding of the mechanism of such grain yield response to nitrogen is the study of yield components. In the present study the nitrogen response of two varieties were examined and their responsiveness to nitrogen was viewed from the yield components.

I Materials and Method

Two varieties were selected from the list of the recommended varieties of the Department of Rice. Both are *Indica* and native in Thailand. One is *Pouang Nahk 16,* a late, active tillering, medium height, not too leafy, rather dark green variety which is susceptible to blast disease. The other is *Khao Dawk Mali 105*, an early to medium,

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Table 1 Soil Properties at the Experiment Site
(Rangsit Rice Experiment Station)

Soil No. (Soil Series Name)	T-84 (Ongkharak)				
Horizon	I	II	III	IV	V
Depth cm.	0～10	10～20	20～32	32～60	60～90+
pH (A)	4.3	4.3	4.2	4.1	3.9
pH (B)	4.8				
Total C %	2.25	2.28			
Total N %	0.21	0.23			
C/N	10.7	9.8			
NH_3-N on anaerobic incubation					
mg./100 g. soil	7.8				
% of Total N	3.7				
Total P_2O_5 mg./100 g.	56				
0.2N HCl P_2O_5 (A) mg./100 g.	1.8	0.6	0.0	4.1	2.0
0.2N HCl P_2O_5 (B) mg./100 g.	2.4				
Bray P_2O_5 mg./100 g.	0.9	1.3	0.4	0.1	0.0
0.2N HCl K_2O mg./100 g.	26.40	20.16	14.40	15.84	24.48
pH 4 HOAc SiO_2 mg./100 g.	7.6				
Reducible MnO_2 mg./100 g.	3.03				
Free Fe_2O_3 %	0.94	0.72	2.51	5.62	6.64
0.2N HCl soluble					
Fe_2O_3 %	0.364	0.169	0.234	0.070	0.064
SiO_2 %	0.107	0.073	0.052	0.047	0.087
Al_2O_3 %	0.272	0.480	0.192	0.164	0.140
Si/Al	0.333	0.128	0.231	0.242	0.527
Al/Si+Fe+Al %	45.7	73.9	49.8	66.0	55.0
Texture	HC	HC	HC	HC	HC
Mechanical analysis					
Coarse sand	0.1	0.4	0.8	4.3	4.0
Fine sand	4.6	5.7	10.2	11.6	10.0
Silt	31.3	34.6	40.4	35.9	27.5
Clay	64.0	59.2	48.5	48.2	58.5
Moisture %	5.65	5.36	4.56	4.67	5.98
EC mmho/cm.	2.4	2.2	2.3	2.9	2.7
CEC (A) me./100 g.	16.0	16.0	12.8	12.8	16.6
Exchangeable cation me./100 g.					
Ca^{++}	9.1				
Mg^{++}	7.9				
Water soluble ion me./100 g.					
Ca^{++}	0.68	0.50	0.48	0.60	0.64
Mg^{++}	1.04	0.66	0.82	1.08	1.18
Na^+	0.87	0.98	0.87	1.25	1.63
K^+	0.06	0.03	0.04	0.05	0.13

sum of cations	2.7	2.2	2.2	3.0	3.6
Cl^-	−	−	−	−	−
SO_4^{--}	+	±	+	+	+
Clay mineral composition					
Kaolin	45		45		40
Illite	15		20		20
Others	40		35		40
Mont.	+		+		+
Verm.	++		++		++
Mixed	±		±		±
Al-inter.	+		+		+
Gibbsite	±		±		±
Quartz	+		+		+

pH (A): Measured at the soil-water ratio of 1 : 5 after standing for about one hour.
pH (B): Measured as in the case of pH (A) after 14 days incubation under submergence at 30°C.
0.2N HCl P_2O_5 (A): Determined after 5 hrs incubation of the soil-solution mixture (2.5 g. soil +50 ml. 0.2N HCl) at 40°C.
0.2N HCl P_2O_5 (B): After 2 weeks incubation of the soil-water mixture (10 g. soil +30 ml. water), the soluble phosphorus was determined as in the case of (A).
CEC (A): N $CaCl_2$ solution (pH=7) was used for replacement. The CEC (A) is thought to be CEC at the prevailing soil pH.
Water soluble Cl^- and SO_4^{--}: Expressed according to the following scale ;

0.3	0.9	3.0	9.0	me./100 g.
−	±	+	++	+++

(Source: KAWAGUCHI and KYUMA, *Lowland Rice Soils in Thailand*, Kyoto, 1969)

active tillering, tall, leafy pale green color and scent variety. The field experiments were conducted at the Rangsit Rice Experiment Station which is located about 30 km northeast of Bangkok. The soil is an acid sulphate soil of heavy clay texture developed from brackish water deposit. Its chemical and physical properties are as shown in Table 1.

The experiments were carried out in the rainy season for three years, from 1966 through 1968. After soaking for two days, the seeds were sown on the nursery. On July 19 or 20, the 27–34 days old seedlings were uprooted and upper leaves were trimmed. Three seedlings per hill were transplanted with a spacing of 40×40 cm in 1966 and 30×30 cm in 1967 and 1968. To all plots, in every year, 80 kg/ha each of P_2O_5 and K_2O as superphosphate and muriate of potash, respectively, were applied regardless of the amount of nitrogen applied. Basal nitrogen levels were 0, 30, 60, and 120 kg N/ha for PN-16 in 1966 and 0, 30, 60, and 90 kg N/ha for both varieties in 1967 and 1968. Nitrogen was applied in form of ammonium sulphate. In 1966, the fertilizers were applied on the puddled surface just prior to transplanting. In 1967 and 1968, they were mixed with mud by repeated puddling after their application. To some plots, additional 30 kg N/ha was applied as top dressing 2–3 weeks before flowering. (Table 2)

Table 2 Date of Experimental Procedures (1966-1968)

Year	Variety	Sowing	Transplanting	Top-dressing	Flowering	Harvesting
1966	PN-16	Jun. 16 (−34)*	Jul. 20 (0)	Nov. 7 (110)	Nov. 22 (125)	Jan 4 (168)
1967	PN-16	Jun. 22 (−27)	Jul. 19 (0)	Nov. 6 (110)	Nov. 20 (124)	Dec. 20 (154)
	KDM-105	Jun. 22 (−27)	Jul. 19 (0)	Oct. 10 (83)	Oct. 21 (94)	Nov. 23 (127)
1968	PN-16	Jun. 21 (−28)	Jul. 19 (0)	Oct. 31 (104)	Nov. 23 (127)	Jan. 6 (171)
	KDM-105	Jun. 21 (−30)	Jul. 20 (0)	Oct. 3 (75)	Oct. 21 (93)	Nov. 25 (128)

* The figures in the parentheses are the number of days after transplanting.

At various growth stages, number of tillers, plant height, and dry matter weight were measured. At harvest, the yield components were examined according to the procedure described below. All hills in the harvest plot were harvested. The spikelets,

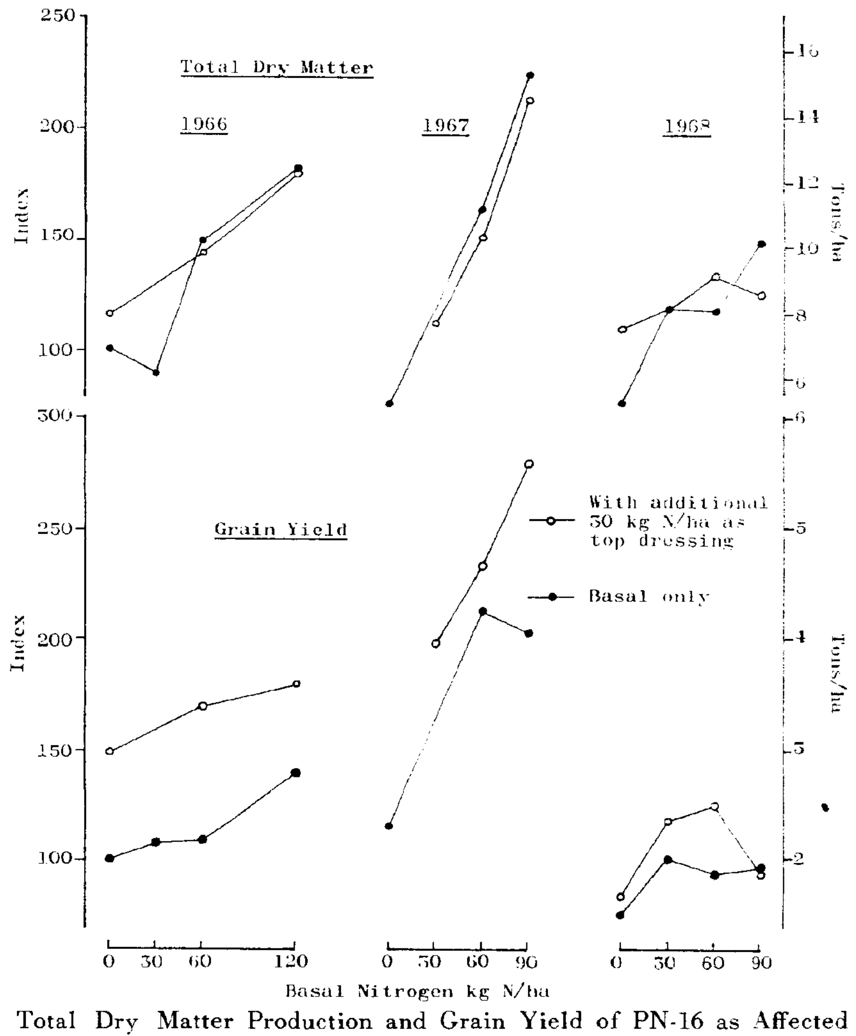

Fig. 1 Total Dry Matter Production and Grain Yield of PN-16 as Affected by Basal Nitrogen Levels with or without Top Dressing (1966–1968)

both filled and unfilled, were carefully threshed, separated, and weighed after drying. Thus, the filled and unfilled grains were expressed by ***weight*** per unit area. Next, the average weight of one filled and one unfilled grain was calculated by counting the number of aliquot weight of each grain portion. The filled and unfilled grains were then expressed by ***number***. Spikelet number per panicle was obtained by dividing total spikelet number per plot by total panicle number per plot. The yield components thus obtained were the averages of one plot, not of one hill.

II Results

As seen in Table 2, the growth duration of PN-16 was about one month longer than KDM-105. This difference in growth duration was mainly attributable to that in

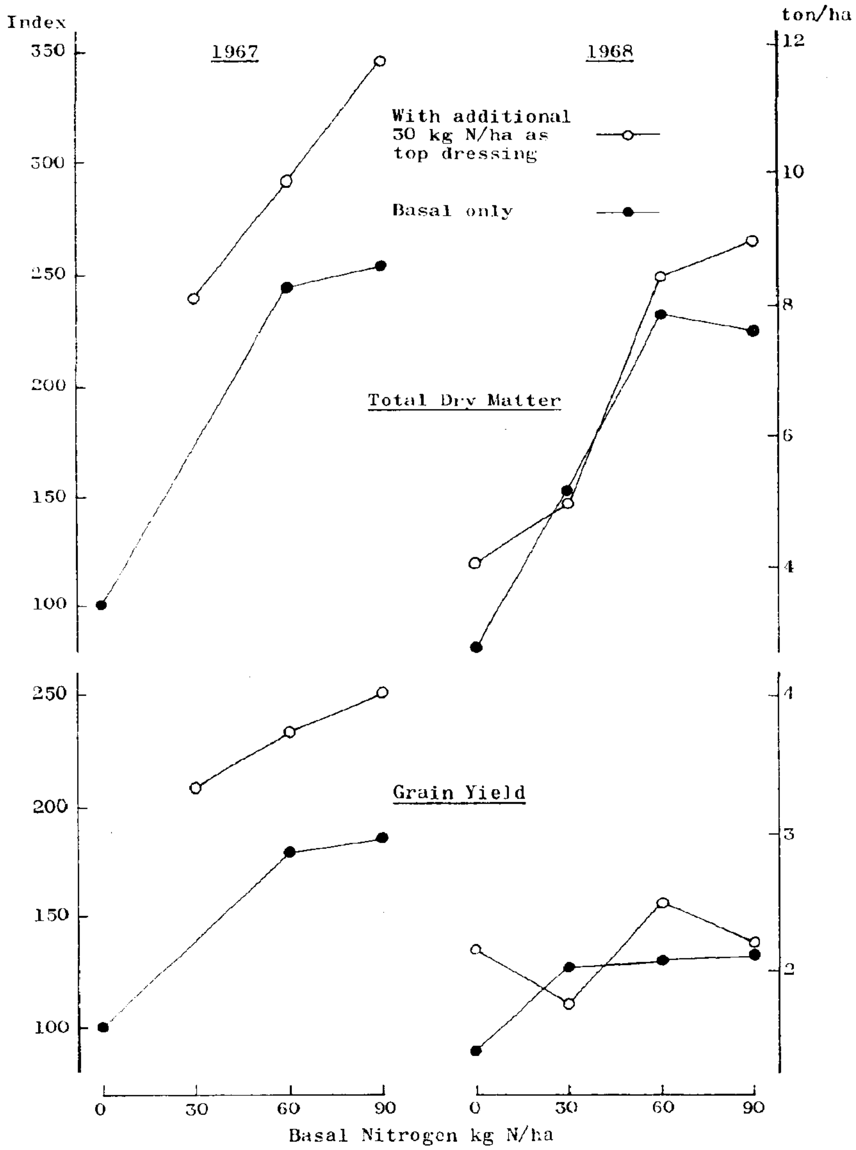

Fig. 2 Total Dry Matter Production and Grain Yield of KDM-105 as Affected by Basal Nitrogen Levels with or without Top Dressing (1967–1968)

the length of the vegetative lag phase: about two months for PN-16 and about one month for KDM-105. Both varieties did not lodge before flowering. At the highest nitrogen level, lodging occurred at the later stage of ripening. This is common in farmers' fields in the Central Plain of Thailand. The grain yield of PN-16 was about 2 ton/ha without nitrogen application. KDM-105 showed a slightly lower yield in the no-nitrogen plot. The increases in grain yield by increased amount of nitrogen differed greatly from year to year. In 1967, the yield of PN-16 reached the 5.5 or 4.0 ton/ha level with or without top dressing, respectively. In 1968, the yield increase by nitrogen could hardly be observed. The result of 1966 was intermediate. (Fig. 1) The other, KDM-105, also showed a good response in grain yield to nitrogen in 1967, but insignificant response in 1968. (Fig. 2) The highest yield attained by this variety in 1967 was about one ton/ha lower than that of PN-16 in the same year. The grain yields of the plots without top dressing were always inferior to those with top dressing no matter how much nitrogen was applied as basal. It seems that the nitrogen level at which the grain yield reached the maximum was lower without top dressing than with top dressing.

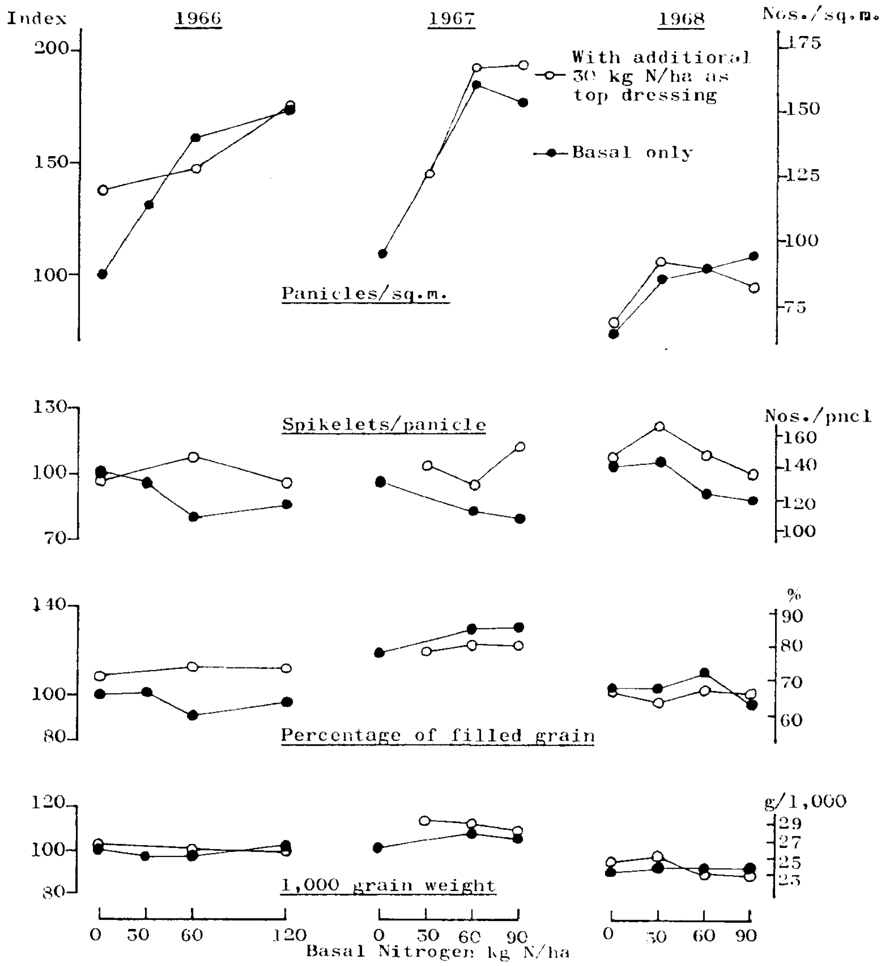

Fig. 3 Yield Components of PN-16 as Affected by Basal Nitrogen Levels with or without Top Dressing (1966–1968)

Without nitrogen application the total dry matter produced by PN-16 at harvest was around 6 ton/ha while that by KDM-105 was less than 4 ton/ha. Increase of total dry matter by higher nitrogen levels differed from year to year and showed the similar tendency to grain yield. The greatest total dry matter was obtained in 1967, followed by that of 1966. The smallest amount was obtained in 1968 by PN-16. However, among different years greater difference was observed in grain yield than in total dry matter production. Though the highest grain yields of both varieties in 1968 were merely around 2.5 ton/ha, total dry matters produced by PN-16 and KDM-105 were 10 and 8 ton/ha, respectively, in the same year. More significant response to nitrogen was observed in total dry matter than in grain yield. The former increased more rapidly than the latter when the amount of basal nitrogen was increased. Total dry matter increased even at high nitrogen level while grain yield did not, particularly when no

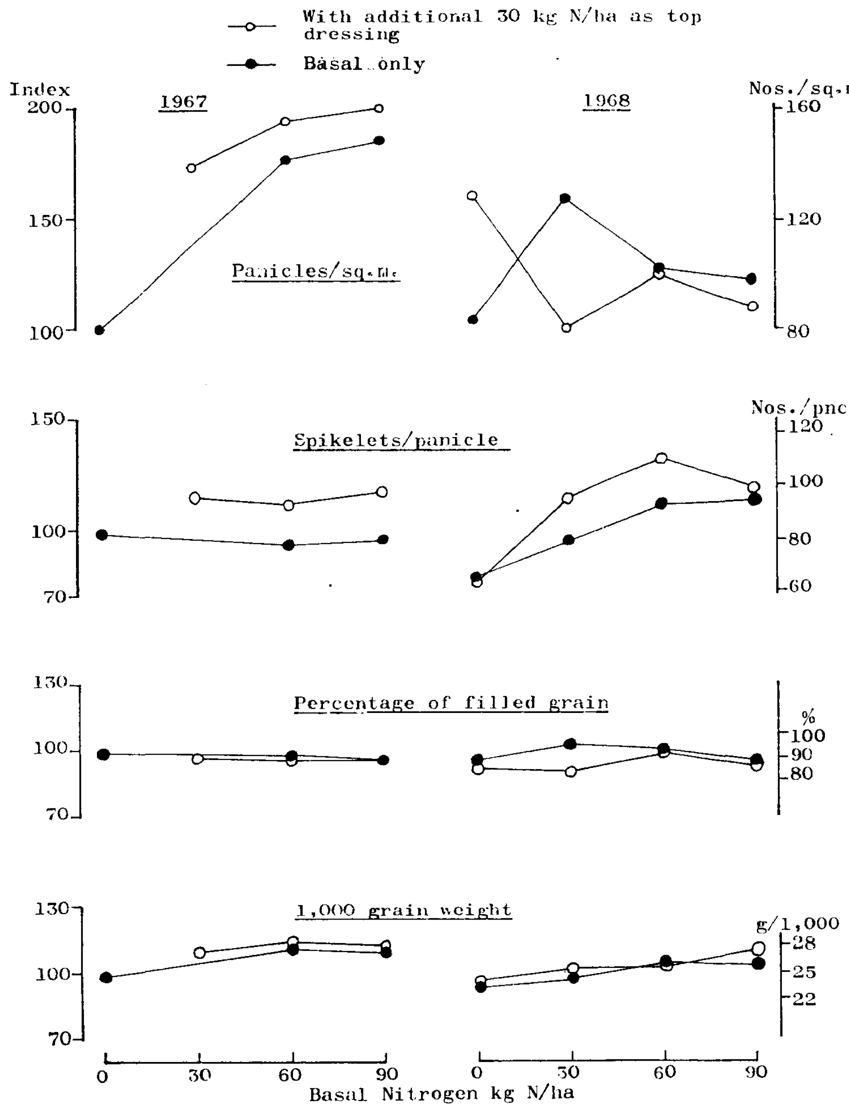

Fig. 4 Yield Components of KDM-105 as Affected by Basal Nitrogen Levels with or without Top Dressing (1967–1968)

additional nitrogen was top-dressed. The effect of the top dressing which was highly significant on grain yield, was not significant on total dry matter production except in the case of KDM-105 in 1967.

As shown in Fig. 3, the values obtained for the no-nitrogen plot in 1966 were taken as the standard, and given the index numbers of 100. The same scales were adopted for the index numbers of the other three components and shown on the vertical axes at left. Fig. 4 was drawn for KDM-105 in the same manner as that mentioned above, that is, taking the values of the no-nitrogen plot in 1967 as standard. The relative importance to grain yield of each of the four components can easily be judged from these figures.

Among the four components, panicle number increased or decreased most drastically in different years and according to different levels of nitrogen. The difference by year showed a similar trend to grain yield and total dry matter production. PN-16 had more than 150 panicles per sq. m. in 1967 but less than 100 per sq. m. in 1966 at high level of nitrogen. Though the panicle number increased significantly by increasing amount of nitrogen, it leveled off at a certain nitrogen level. Two hundred panicles per sq. m. or more cannot be expected by the spacings employed in this study. In most cases, the effect of top dressing on panicle number was not significant.

Spikelet number per panicle did not show any significant difference by year contrary to the great differences observed in grain yield and panicle number. By increasing basal nitrogen it either decreased slightly (PN-16) or was almost constant (KDM-105) if no nitrogen was top-dressed. With top dressing, however, it significantly increased at higher levels of basal nitrogen.

The percentage of filled grain of PN-16 was higher in 1967 than in the other years at any nitrogen level. The high grain yield in 1967 can be attributed partly to the higher percentage of filled grain. The nitrogen level scarcely affected this component. A slight negative effect of top dressing was observed in some cases but not consistently. The top dressing of PN-16 in 1966 improved the percentage of filled grain significantly. One thousand grain weight was less influenced by year or by nitrogen level. The effect of top dressing was also insignificant on the fourth component.

The last two components, percentage of filled grain and 1,000 grain weight, were hardly affected by year or by nitrogen level when compared with the other two components, panicle number and spikelet number per panicle. Therefore, the contribution of the third and fourth components, if any, to grain yield can be ignored when such a great difference as seen in Fig. 1 and 2 in grain yield is to be discussed. This indicates that the spikelet producing process rather than the ripening process was vital to grain yield under the conditions of this study.

The spikelet number per unit area is decided by panicle number and spikelet number per panicle. The latter did not show any significant increase or decrease by year. A slight decrease of spikelet number per panicle by increasing amount of basal nitrogen without top dressing was prevented by top dressing as stated in the previous pages. Therefore, the spikelet number per panicle was not the main limiting factor of grain yield if additional nitrogen was top-dressed two or three weeks before flowering. Thus, panicle number per unit area has primary importance among the four components. In other words, two factors; (a) the effect of nitrogen level on panicle number in different years, and (b) the effect of top dressing on spikelet number per panicle, can well explain not only high and low yield in 1967 and in 1968, but also the grain yield increase by increasing amount of nitrogen and its leveling off at the certain level of nitrogen.

Panicle number at harvest is the product of a maximum number of tillers by the percentage of effective tillers. The maximum number of tillers of PN-16 was increased linearly by increasing the amount of basal nitrogen. (Fig. 5) The smaller number of

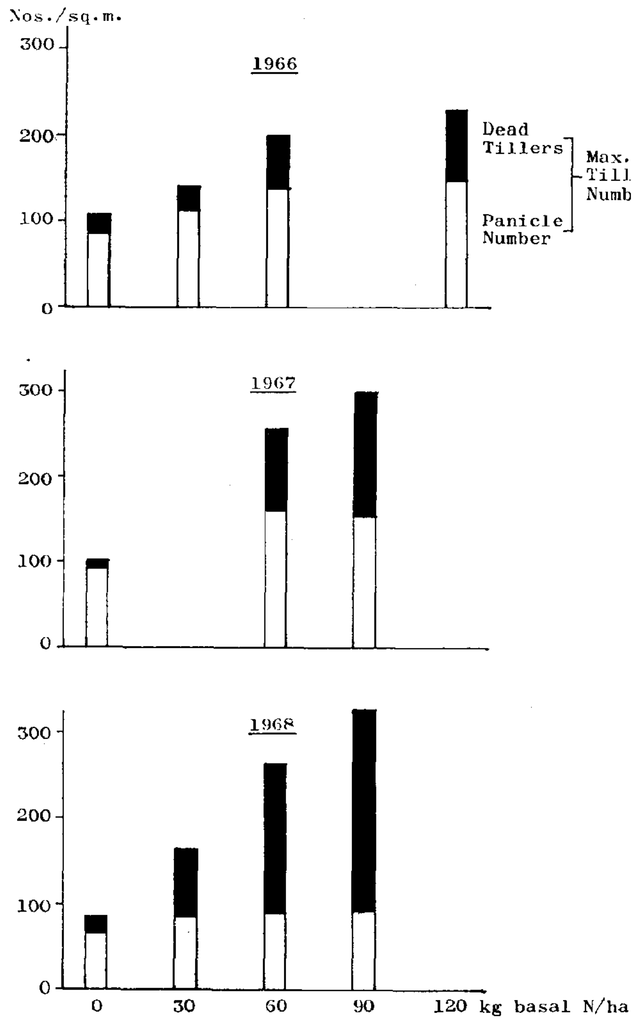

Fig. 5 Maximum Tiller and Panicle Number of PN-16 at Different Nitrogen Levels (1966–1968)

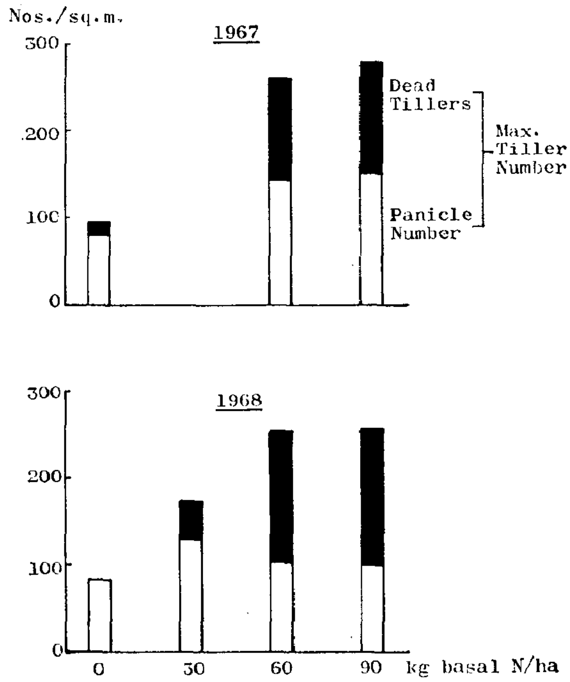

Fig. 6 Maximum Tiller and Panicle Number of KDM-105 at Different Nitrogen Levels (1967–1968)

tillers in 1966 is considered due to wide spacing. At 30 × 30 cm spacing, more than 300 tillers per sq. m. were found at high nitrogen level. Althouth the maximum number of tillers of KDM-105 did not show a significant increase at nitrogen levels higher than 60 kg N/ha, more than 250 tillers per sq. m. were attained. (Fig. 6) The maximum number of tillers could not explain the significant differences among years and nitrogen levels in panicle number which were found to be the most important factor affecting grain yield under the conditions of these experiments. If the maximum number of tillers can be the criterion of "tillering ability", both varieties in this study are active, if not very active, in tillering.

The percentage of effective tillers was decreased significantly by increasing the nitrogen, resulting in a less significant response of panicle number to nitrogen. Without nitrogen application, most of the tillers at the maximum tiller number stage had panicles at harvest. At high nitrogen level, about half or even less than half of the tillers had panicles. The number of dead tillers increased progressively at higher nitrogen levels. The death of these tillers took place immediately after the maximum tiller number stage and continued until the ripening stage. (Fig. 7) The number of remaining tillers at

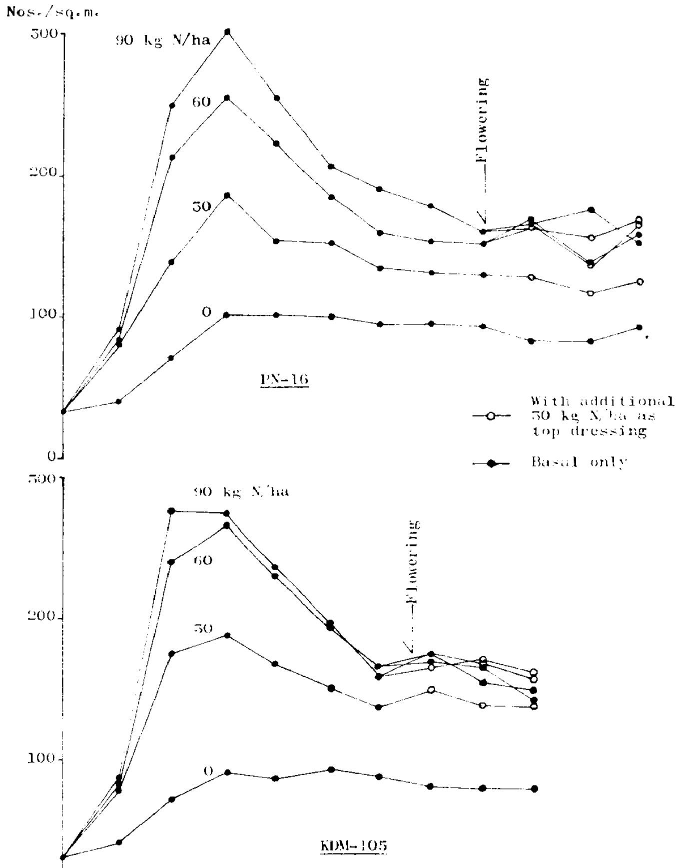

Fig. 7 Number of Tillers of PN-16 and KDM-105 at Successive Growth Stages (1967)

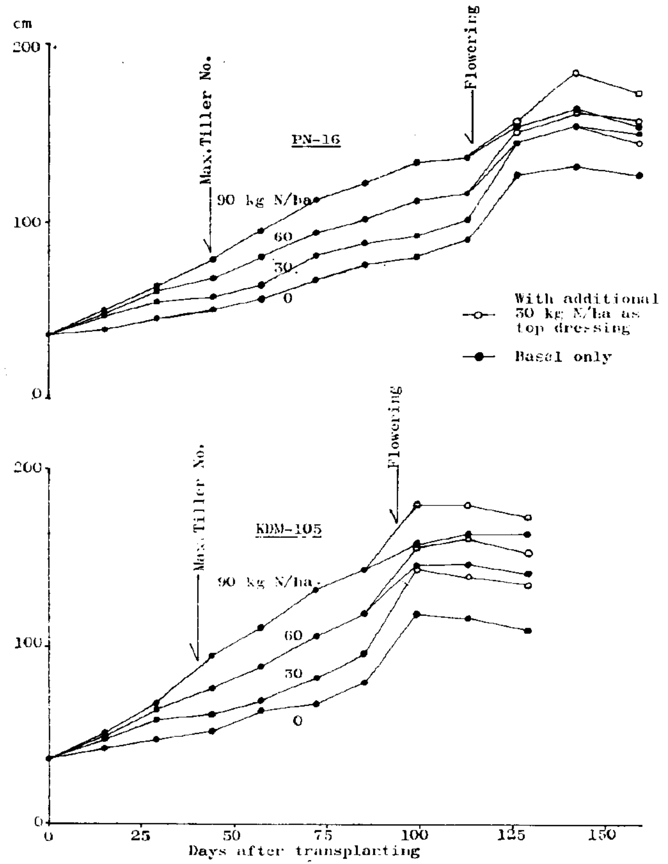

Fig. 8 Plant Height of PN-16 and KDM-105 at Successive Growth Stages (1967)

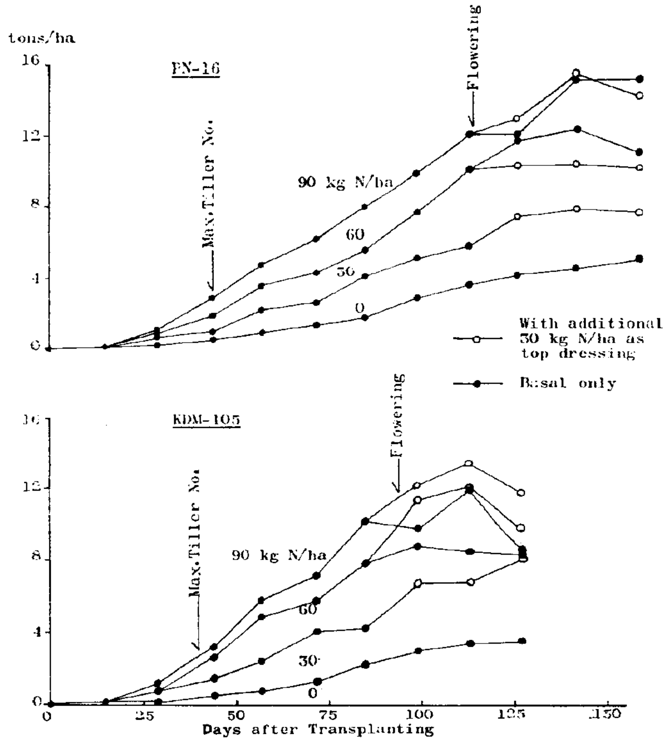

Fig. 9 Dry Matter Production of PN-16 and KDM-105 at Successive Growth Stages (1967)

flowering was almost equal to the panicle number at harvest. The so-called vegetative lag phase was the critical period for the death or survival of tillers. As mentioned before, this lag phase was two months for PN-16 and one month for KDM-105.

Plant height became greater as growth proceeded. (Fig. 8) The height of both varieties at harvest was 105–170 cm depending on nitrogen level. The increasing rate of plant height in accordance with the proceeding growth stages became greater around flowering time, probably resulting from an internode elongation as well as longer leaves. While KDM-105 increased its height rapidly before flowering, PN-16's height increase took place after flowering. After this period, plant height was practically unchanged.

The total dry matter weight at successive growth stages in 1967 was shown in Fig. 9. Dry matter increased while growth proceeded and the increase at higher nitrogen levels was greater than at lower nitrogen levels, at least until flowering. The stagnation of the increasing rate of total dry matter was not observed during vegetative lag phase. At low nitrogen levels, the increases in dry matter weight after flowering were small in both varieties. At higher nitrogen levels, this increase was observed in some cases with or without top dressing.

Generally speaking, dry matter production during the ripening period is important for grain production. Figure 10 shows the relation between plant weight at flowering and dry weight increase or decrease between flowering and harvesting. This figure was based on the records of all the treatments reported in this paper. PN-16 planted at the spacing of 40×40 cm in 1966 showed a relatively smaller plant weight at flower-

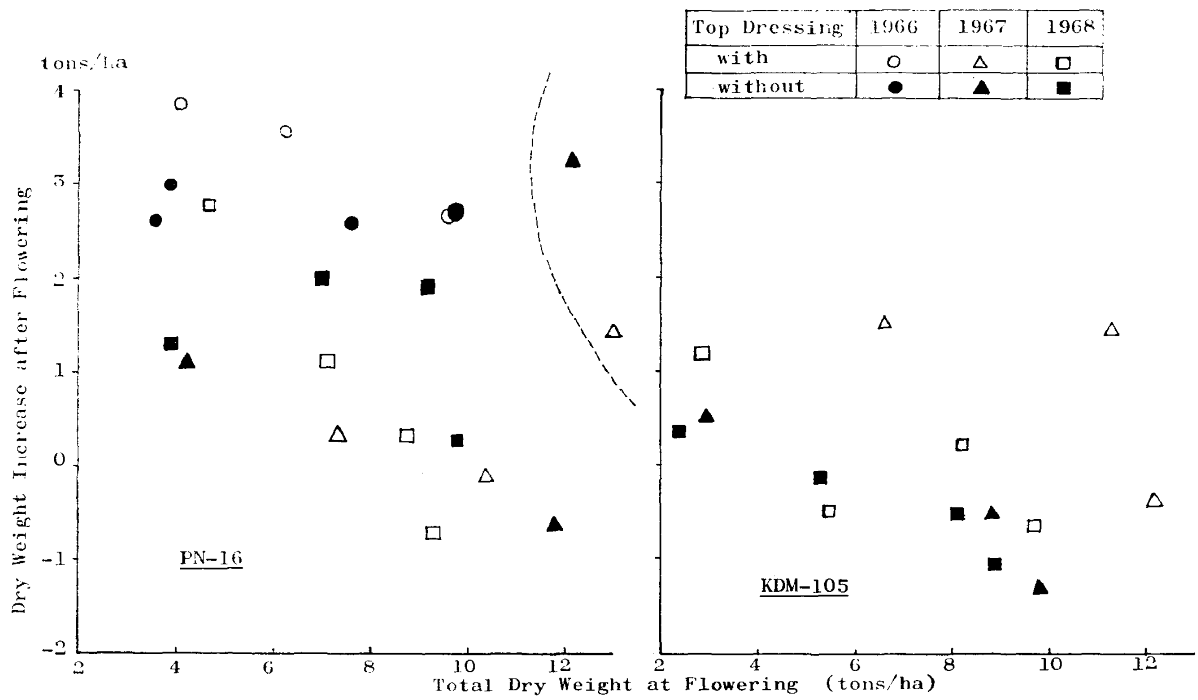

Fig. 10 Relation between Total Dry Weight at Flowering and Dry Weight Increase after Flowering (PN-16 and KDM-105 in 1966–1968)

ing and a greater increase in dry weight after it. In 1967, there were two plots which showed over 12 ton/ha dry weight at flowering and yet showed a considerable increase in dry weight after it. These two plots received 90 kg N/ha as basal, the highest dose for 1967. If the two points indicating these two treatments in Fig. 10 could rationally be omitted, a negative correlation between the two items under discussion might be observed. The dry weight increase of KDM-105 after flowering was generally less than that of PN-16. However, the plants having greater total dry weight at flowering still increased their weight after it when nitrogen was top-dressed. Without a top dressing, negative correlation seems significant. Under the conditions of the present study, the dry matter increase after flowering tended to be small when plant weight at flowering was great. However, it was not necessarily small if either a large amount of basal nitrogen or top dressing of this element was applied. It seems that the factor limiting dry matter production after flowering was the nitrogen rather than the light condition. The relation between grain yield and dry matter production after flowering was not obvious for either varieties. (Fig. 11)

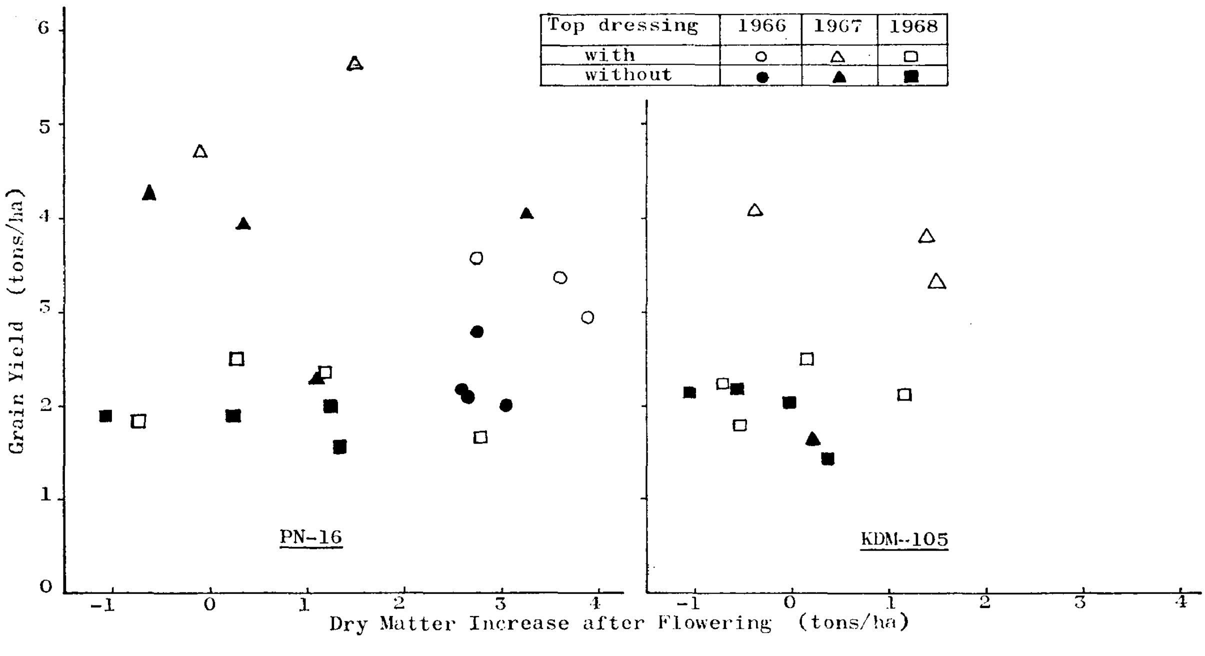

Fig. 11 Relation between Grain Yield and Dry Matter Increase after Flowering (PN-16 and KDM-105 in 1966–1968)

III Discussion

Though various experiments on rice are being carried out extensively in Southeast Asia, usually only grain yield is reported. One of the few examples of studies on yield components in this part of the world is in the works of OTA and YAMADA in Ceylon. According to these, the maximum tiller number of an active-tillering variety can be increased by nitrogen application which, however, does not necessarily result in greater panicle number at harvest because of death of tillers. (OTA, 1964) Some *Indicas* such as M-302 of Ceylon (OTA, 1964) and Century Patna-231 of U.S.A. (TANAKA *et al.*, 1964) do not show significant increase in maximum tiller number with nitrogen application. The poor tillering ability of these *Indica* varieties may be the factor limiting the response to nitrogen. However, if maximum tiller number can be regarded as index of tillering ability, the factor limiting panicle number of active-tillering varieties is not the tillering ability itself but death of tillers after the maximum tiller number stage.

As top dressing of nitrogen at four weeks before flowering increased the degeneration rate of spikelets, so top dressing at two weeks before flowering which suppressed the degeneration was recommended. (OTA, 1964) The significant effect of top dressing 2–3 weeks before flowering on spikelets number per panicle observed in the experiments reported in this paper is considered to be accounted for by this reason.

The percentage of sterility became great if light intensity was weakened by sheltering around the time of flowering stage under the conditions of pot culture in Ceylon. (OTA and YAMADA, 1965a) Increase in sterility percentage was also caused by nitrogen supply during the reproductive growth stage under the conditions of a water culture experiment. (OTA and YAMADA, 1965b) These studies on sterility problems were taken up because: "It is well known that rice plants growing in tropical countries are usually troubled with high sterility percentage and increasing use of fertilizers in future might certainly bring about a serious increase in sterility." (OTA and YAMADA, 1965a, p. 14) However, under field conditions, according to the same authors, the high sterility percentage caused by nitrogen application 4 to 6 weeks after transplanting was not caused by an increasing number of spikelets but caused by lodging. (OTA, 1964) The would-be increase or decrease of sterility percentage of unlodged plants under the field conditions is still not certain.

The conclusion of the nine various experiments reported in Technical Bulletin 3, Part II, I.R.R.I., 1964., by TANAKA *et al.*, was as follows: low nitrogen-responsive *Indica* varieties absorb and metabolize nitrogen rapidly and show vigorous growth at an early stage of growth resulting in mutual shading. Mutual shading becomes more significant in the cases of less responsive varieties, higher nitrogen doses, closer spacings,

Table 3 Effect of Mutual Shading on Yield Components after TANAKA *et al.*

Nitrogen-responsiveness of variety	Growth stage when mutual shading sets in	Yield components			
		Panicle Number	Spikelet Number per Panicle	Percentage of Filled Grain	1,000 Grain Weight
Low	Tillering	no increase	decrease	decrease under some conditions	not affected
	Ear-initiation		decrease	decrease	no or slight decrease if any
High	Later			decrease	decrease

TANAKA *et al.*, 1964. Technical Bulletin 3, pp. 74–75. I.R.R.I., the Philippines.

and/or wet season planting. The effect of mutual shading on yield components depends on the growth stage at which mutual shading sets in and can be summarized as in Table 3. The yield components of the two varieties used in the present study in Thailand showed similar tendencies to those of the "low nitrogen-response" varieties in that table.

The result of the present study, a large percentage of non-effective tillers as the cause of the leveling off of panicle number at higher nitrogen levels, coincides well with the results obtained in Ceylon as well as with those at I.R.R.I. This suggests severe mutual shading was occurring in the plant population of the two varieties at least during early growth stage under the conditions of the present study in Thailand.

In this study the decrease in spikelet number per panicle was found in plants which received large amounts of nitrogen and no top dressing. At I.R.R.I. the decrease occurred when mutual shading set in earlier than the ear-initiation stage. Among the nine experiments reported in Technical Bulletin 3 by TANAKA *et al.*, five were the experiments under field conditions. Only one of them (Experiment 7) was reported with data showing spikelet number per panicle. For the other field experiments, data on yield components was not reported at all or was shown merely as average values by treatment even when more than two factors under examination were found to be significantly correlated. Three varieties, Tainan-3, Peta, and BPI-76 were compared at six different spacings in Experiment 7. Number of spikelets per panicle of Peta which is a typical leafy tropical variety popular in the Philippines, was found to be 112 at the spacing of 10×10 cm, the narrowest among all treatments employed in that experiment. At the wider spacing from 20×20 up through 60×60 cm, it was between the range of 142 to 162 without significant correlation between spikelet number and spacing. Under the conditions of Experiment 7, "At spacings of 10×10 to 30×30 cm, lodging occurred 2 weeks before flowering. ..." (TANAKA *et al.*, 1964. p. 55)

Lodging seems to be common when leafy tropical varieties were grown at I.R.R.I. with some amount of nitrogen during wet season. In the experiment on the variety× planting season study, "Peta (with 40 kg N/ha as basal) was inclined to lodge heavily before flowering, except in the October planting." (TANAKA *et al.*, 1964, p. 15) And "Whenever there was danger of lodging, four hills were tied together to keep the plants standing." (*ibid.* p. 6) In their studies, Peta was most commonly used as a typical tropical variety and nitrogen levels employed were often higher than 40 kg N/h. The data on Peta plants which were grown with heavy nitrogen application in wet season seem to be obtained under conditions in which otherwise lodging plants were supported physically after reproductive growth stage.

The lodging of Peta planted at I.R.R.I. seems to be caused by the exceptionally high inherent soil fertility of the I.R.R.I. field rather than by the varietal characteristics of Peta. As shown in Table 4, the grain yield of no nitrogen plots was nearly

Table 4 Grain Yield and Total Dry Weight of *Peta* Planted in Wet Seasons (TANAKA *et al.*, 1964. Technical Bulletin 3, I.R.R.I., the Philippines)

	Sowing	Spacing cm	Nitrogen kg/ha	Grain Yield tons/ha	Total Dry Weight tons/ha
Part 1	Average of Mar., May & Jul.	30×30	40	3.78	14.11
Exp. 6	June	30×30	0	ca. 3.8	
			30	3.0	
			60	3.0	
			90	2.7	
			120	2.0	
Exp. 7	June	10×10		ca. 2.0	ca. 15.4
		20×20		2.6	16.5
		30×30		2.7	17.7
		40×40		2.9	16.6
		50×50		3.3	16.2
		60×60		3.3	16.3
Exp. 9	May	50×50	0	ca. 3.5	
			30	4.2	
			60	3.9	
			90	3.2	
			120	3.3	

Table 5 Solar Radiation in Wet and Dry Seasons at I.R.R.I., 1962–63 (For Variety *Peta*)

	Transplant		Ear-initiation*		Flowering		Harvest
Dry season crop							
Date	Dec. 2		Feb. 3		Feb. 28		Mar. 27
Radiation per day		273		368		456 (cal/cm^2/day)	
Wet season crop							
Date	Jun. 5		Aug. 16		Sep. 10		Oct. 8
Radiation per day		346		306		325	

* Supposed 25 days before flowering.
Source : TANAKA *et al.*, 1964. Tech. Bull. 3, I.R.R.I., Philippines.

equal to the highest yield obtained by increasing the nitrogen. Increasing the amount of nitrogen application often had a negative effect on the grain yield. This situation is far different from that at the Rangsit Station in Thailand.

The difference in climatic conditions between I.R.R.I. and Rangsit is considered to be another possible reason for different experimental results. In a field experiment concerning planting density×variety×planting season interaction at I.R.R.I. in 1962–1963, Peta planted in the dry season greatly outyielded that planted in the wet season. The average solar radiation per day during various growth stages of the two rice crops in the different seasons was reported to be the cause of the seasonal difference in grain yield. (Table 5) For the wet season crop, solar radiation after flowering was not significantly larger than in the foregoing growth stages. Because of the lack of data on solar radiation in Thailand, direct comparison between the two places is impossible. However, dry weather sets in late October in the Central Plain of Thailand, about the time of, or one month earliar than the time of flowering of KDM-105 or PN-16, respectively. Ripening of the rice plant in this plain proceeds under dry season condition with abundant solar radiation.

The results observed in the present study concerning spikelet number, percentage of filled grain, and 1,000 grain weight do not contradict the results obtained in Ceylon and the Philippines.

The reasons are:

(1) Poor ripening of *Indicas* is not a commonly observed phenomenon. Hampered ripening is reported to occur when plants lodge before flowering. The authors failed to meet a report which clearly showed the decrease in the percentage of filled grain of the leafy tropical variety with such an amount of nitrogen application that does not cause lodging.

(2) The percentage of filled grain and/or 1,000 grain weight may decrease by heavy nitrogen application in the case of short and not-typically-tropical varieties even if they do not lodge. In these cases, plants have more than enough spikelets and the further effort to increase spikelets adversely affects the ripening.

(3) The data indicating a negative effect of nitrogen on spikelet number per panicle of low nitrogen-response varieties is also scarce. Negative effect may be observed when the plants lodge or when they are supported physically to prevent lodging. It may also occur when mutual shading does not set in at an early growth stage and panicle number is not suppressed. In some cases, as in the present study, a top dressing of nitrogen at proper time is effective in avoiding the otherwise occurring reduction of spikelet number per panicle.

IV Summary and Conclusion

From the results of the present study and comparison with other works in Ceylon and the Philippines, it can be concluded that: under the conditions at the Rangsit Experiment Station, both of PN-16 and KDM-105 responded to some extent to nitrogen. This is due firstly to the increase of panicle number and secondly to the increase of spikelet number by top dressing of nitrogen. Insignificant response to nitrogen in some years or at higher nitrogen levels was caused by the failure in increasing the panicle number rather than by the adverse effect of nitrogen on the other components. The leveling off of panicle number at higher nitrogen levels is considered to be caused by the mutual shading during long vegetative lag phase of these two varieties. However, the commencement of mutual shading at the early growth stage did not necessarily affect the yield components which are determined at later growth stages. In the present study, the factor limiting dry matter production at the later growth stage was not light condition but nitrogen.

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