Japan. Jour. Crop Sci. 58 (4) : 732—739 (1989)

Varietal Difference in Nitrogen Response of Rice Plants with Special Reference to Growth Duration*

Genshichi WADA and Pompe C. STA. CRUZ
(*The International Rice Research Institute, P.O. Box 933 Manila, Philippines*)
Received April 30, 1989

Abstract : Potential sink size was correlated with plant nitrogen (N) at late stage of spikelet initiation and flowering, and with growth duration (GD) in DS and WS. The amount of N in plant at critical growth stages increased with GD which can be attributed to N absorption pattern of plant.

Degenerated sink size and percentage of degenerated spikelets were correlated with GD, which is a function of N content in laminae during reproductive stage. The low amount of N absorption during this period resulted to high sink and spikelet degeneration as observed in long duration varieties.

Sink size was correlated with the amount of N in plant at late stage of spikelet initiation and flowering. However, the contribution of N to sink formation (S/N) differed with GD. This was manifested in the apparent association of maximum sink size with a certain GD. The optimum GD as a function of the vegetative lag phase, however, can be altered by N level.

Yield was positively correlated with sink size, and was a quadratic function of GD regardless of cropping season. The optimum GD is generally shorter than the optimum GD for sink size. This is attributed to the trend of ripening percentage that decreased with GD. Yield was also correlated with the amount of N in plant at flowering and maturity stages.
Key words : Growth duration, Nitrogen response, Rice variety, Sink, Yield.

水稲品種の窒素に対する反応とくに生育日数との関係：和田源七・ポンペサンタクルス（国際稲研究所）

要　旨：45（1986年乾期）および62（1986年雨期および1987年乾期）の改良品種／系統を用いてIRRIの水田で圃場試験を行った．

分化Sink量は頴花分化終期および出穂期の稲体の窒素量および生育期間の両方と乾期，雨期とも相関を示した．窒素吸収量の品種間差は分げつ期にのみ明らかであり，出穂期での稲体窒素量は生育期間と相関を示した．Sinkの退化率および退化量は生育期間と相関を示した．これは生育期間の長い程幼穂の生長期の窒素含有率が低いことによる．

Sinkの量は頴花分化終期および出穂期の稲体の窒素量と相関があるが，窒素量のSinkに対する貢献度は異なる．Sink量と生育期間との間には二次の相関が認められ，Sinkに対する最適生育日数は本実験の栽植密度の下では127日前後であり，栽培法とくに栽植密度が異なる場合には変動するものと考えられる．

収量は両作期とも登熟歩合に大きな差がありながらSink量と相関を示す．収量は出穂期および成熟期の稲体の窒素量と相関を示すが，Sinkの場合と同様に生育期間と二次の相関を示し，最適生育日数は122日前後となる．Sinkと収量とで最適生育日数に差を生ずるのは，登熟歩合が生育期間が長くなるにつれて低下するためである．最適生育日数より生育日数が短い場合，長い場合ともに収量は低下するが，それはSinkが少ないことによる．その原因は短い場合には吸収N量が少ないことおよび吸収NのSink分化に対する効率の低いことに，長い場合はSinkの退化の多いことにある．
キーワード：Sink，収量，生育期間，水稲品種，窒素．

Nitrogen is one of the most important element for the rice plant and a large amount is necessary to achieve high grain yield[14]. In recent years, the remarkable increase in rice yield is attributed to high-yielding varieties that are highly responsive to N ; to increased and improved water supply and ; to increased fertilizer application and better management practices. Early researches had focused on the effect of N and application method on yield and yield determining processes. Likewise, evaluation of varietal differences in response to N was conducted, but concentrated mainly on comparative analysis of traditional and improved varieties in terms of yield, carbohydrate metabolism and ripening[7,8,10,21,23]. Other studies were directed on morphological characterization of those varieties under vary-

* This work is a part of the Collaborative Project between Government of Japan and IRRI on "Low-input cultivation technology" sponsored by the Government of Japan.

ing N levels[3,23].

Limited researches however, had been done on varietal differences in N absorption ability of improved and traditional varieties[5,23], the contribution of absorbed N to sink formation and yield as function of growth duration (GD)[12,13,14,16,19,20]. Likewise, few physiological studies on the response of improved varieties to N have been carried out[2]. Hence, this study was conducted to clarify the response of improved varieties and advanced lines to N, with primary consideration on sink and yield formation in relation to GD.

Materials and Method

Forty five (45) varieties and advanced lines in 1986 dry season (DS) and 62 in 1986 wet season (WS) and 1987 DS, grouped as very early (VE, <110 days), early (E, 111—120 days), medium (M, 121—130 days) and late (L, >130 days) duration varieties were planted in lowland field, IRRI, Los Banos, Philippines. The experimental design is shown in Table 1.

In 1986 DS, pre-germinated seeds were sown on wet seedbeds at 60 g per m^2 and transplanted in the field, 19 days after seeding at 20×20 cm spacing with two plants per hill. In 1986 WS and 1987 DS, seeds were sown in seedling trays at 2 seeds per cm^3 soil and transplanted in the field, 14 days after seeding at 20×20 cm spacing.

Plants were collected at 3 weeks after transplanting (WAT), 5 WAT (approximately maximum tiller number stage), panicle primordia initiation stage, flowering and maturity. Dry weights of leaf blade, sheath/culm, and panicle were determined. N was determined by Micro-Kjeldahl method. Yield and yield components including spikelet degeneration were recorded. The number of degenerat-

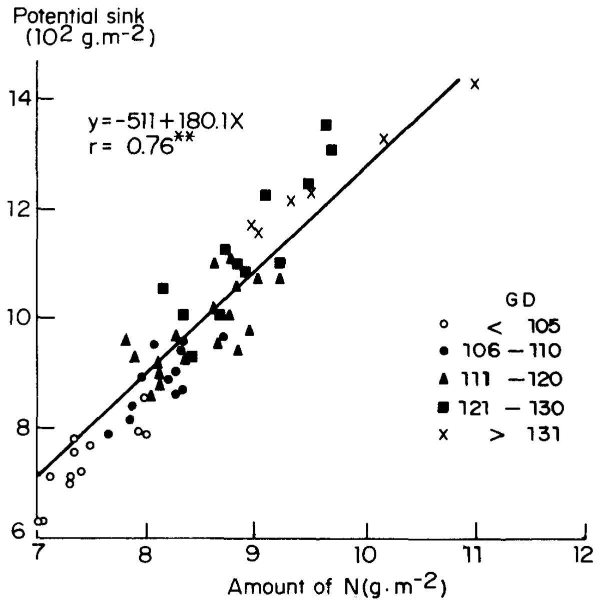

Fig. 1. Relationship between potential sink and the amount of N in plant at flowering (1987 DS).

Table 1. Design of Experiment.

Planting season	No. of Varieties	Amount of N (g·m^{-2})	Seeding date	Transplanting date
1986 DS	VE 20 E 10 M 5 L 10	0.9*	Jan. 11, 86	Jan. 30, 86
1986 WS	VE 24 E 10 M 16 L 12	0.9*	June 11, 86	June 26, 86
1987 DS	VE 24 E 10 M 16 L 12	0.9*	June 16., 87	Jan. 30, 87

Phosphorus and potassium were applied as basal at the rate 5 g·m^{-2}. Plot size is 10 m^2 with three replications in 1986 DS and two replications in 1986 WS and 1987 DS.

* Six grams of N is applied as basal and 3 g as top-dressing at panicle primordia initiation stage.

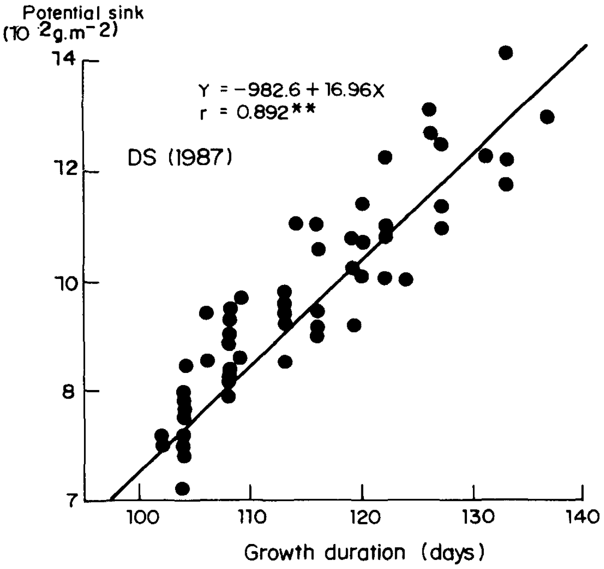

Fig. 2. Relationship between potential sink and growth duration.

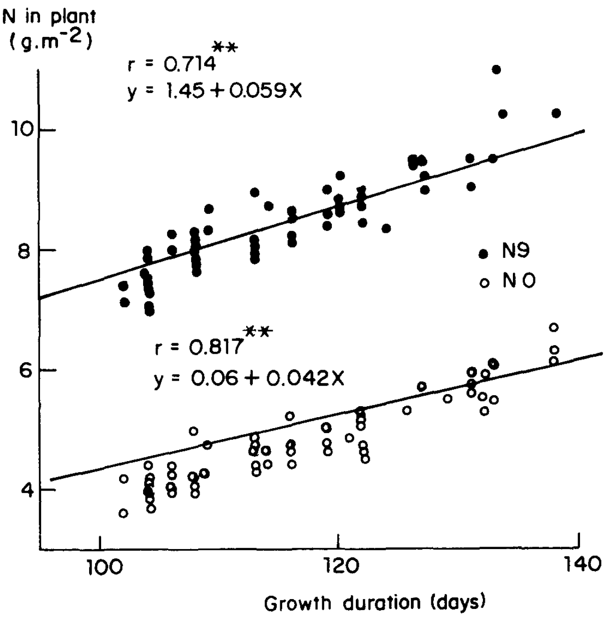

Fig. 3. Relationship between the amount of N in plant at flowering and growth duration (1987 DS).

ed spikelets was determined by the number of vestiges of degenerated primary and secondary rachis branches and spikelets[4]. Sink size and potential sink size were calculated as follows: Sink size = yield ÷ percent ripened grains, or (number of spikelets × 1000 grain weight); Potential sink size = Sink size ÷ (1.00 − percent degenerated spikelets), or (number of differentiated spikelets × 1000 grain weight).

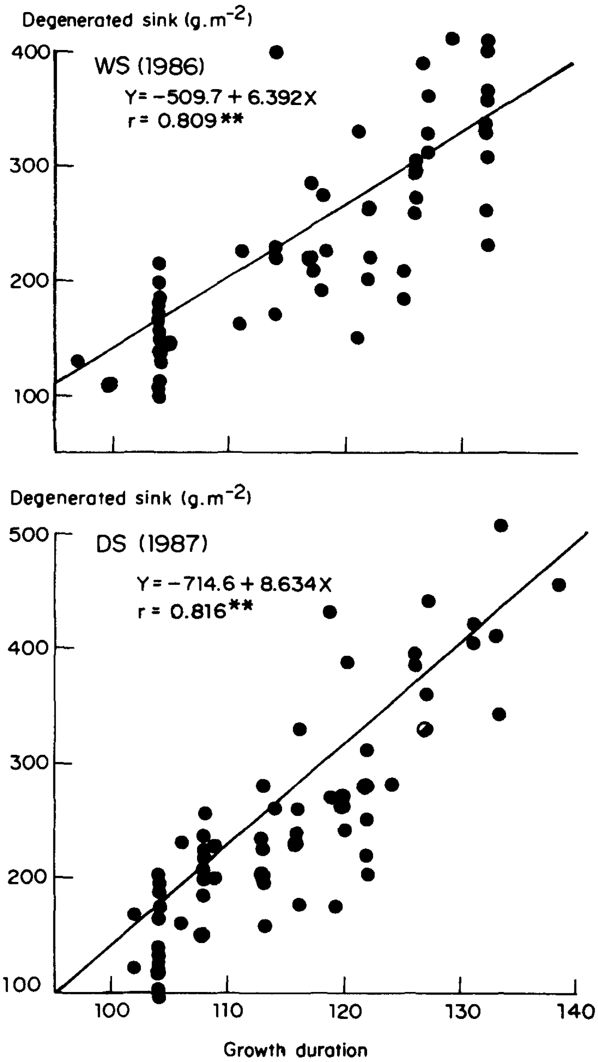

Fig. 4. Relationship between degenerated sink and growth duration.

Results and Discussion

1. Sink size

1) Potential sink size Potential sink size was correlated with the amount of N in plant at late stage of spikelet initiation ($r=0.811^{**}$, $Y=-201.9+166.6X$) and at flowering (Fig. 1). Likewise, potential sink size was positively correlated with GD (Fig. 2). The amount of N in plants at the critical growth stage were also correlated with GD under high and low N levels (at late stage of spikelet initiation $r=0.815^{**}$, $Y=-1.94+0.078X$, at maturity, $r=0.789^{**}$, $Y=2.07+0.069X$, in N_9, Fig. 3).

Varietal differences in N absorption were apparent during tillering stage, while insignificant differences were noted after maximum tiller number stage (Table 2). The

Table 2. Varietal differences in nitrogen absorption of short duration varieties/lines at different growth stages (1986 DS).

VARIETY/LINE	Amount of nitrogen absorbed ($g \cdot m^{-2}$)						
	Active tillering (N1)	dN1 (N2-N1)	Maximum tillers (N2)	dN2 (N3-N2)	Flowering (N3)	dN3 (N4-N3)	Maturity (N4)
IR 36	1.4 bc	1.2 c	2.6 c	7.3 ab	9.9 bc	2.7 a	12.6bc
IR 25588-7-3-1	1.6 b	1.6 b	3.2 b	7.2 ab	10.4 b	2.8 a	13.2b
IR 25261-135-1-1	2.0 a	2.4 a	4.4 a	7.5 a	11.9 a	2.5 a	14.4a
IR 29658-69-2-1-2	1.5 b	1.3 bc	2.8 bc	7.2 ab	10.0 bc	2.4 ab	12.4c
IR 29692-94-2-1-3	1.4 bc	1.1 cd	2.5 cd	7.2 ab	9.7 c	2.6 a	11.3d
IR 29725-109-1-2-1	1.3 c	1.3 bc	2.6 c	7.3 ab	9.9 c	2.7 a	12.6bc
IR 31868-64-2-3-3-3	1.3 c	1.2 c	2.5 cd	7.3 ab	9.8 c	2.7 a	12.5c
IR 32419-81-2-3-3	1.2 c	0.9 d	2.1 e	7.1 b	9.2 d	2.4 ab	11.6cd
IR 32429-47-3-2	1.3 c	0.9 d	2.2 de	7.6 a	9.8 c	2.2 b	12.0c
IR 32429-122-3-1-2	1.5 b	1.1 cd	2.6 c	7.4 ab	10.0 bc	2.4 ab	12.4c

Growth duration : 111 days.
Common letters are not significantly different by DMRT at $p=0.05$.

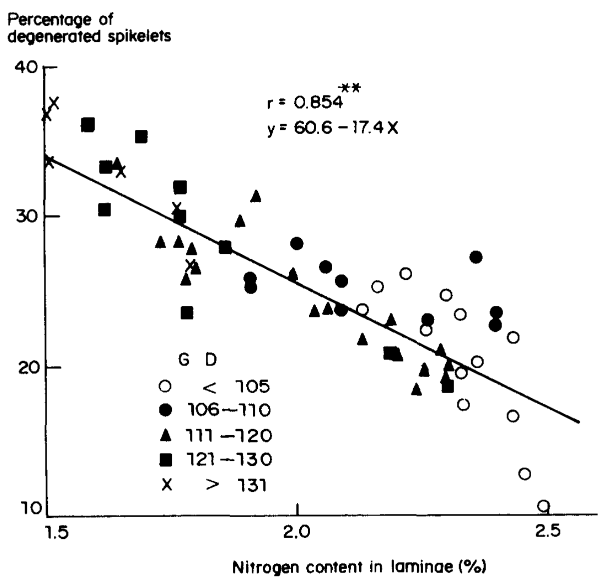

Fig. 5. Relationship between percentage of degenerated spikelets and N content in laminae at flowering (1987 DS).

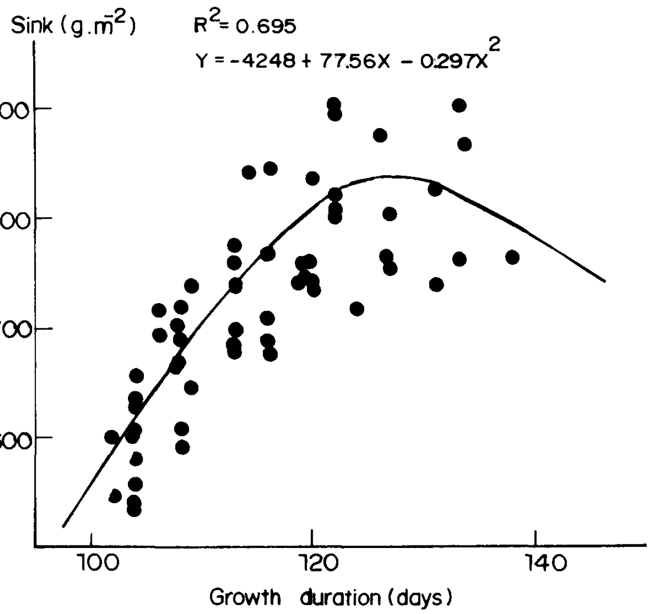

Fig. 6. Relationship between sink size and growth duration (1987 DS).

maximum tiller number stage occurred simultaneously in short, medium, and long duration varieties grown under the same cultural practice[4]. The observed increase in the amount of N in plant at critical growth stage with increased GD, can be explained by N absorption pattern of plants[18]. After the maximum tiller number stage, there is no difference in N absorption rate of plants grown under an identical field[18]. The longer the GD, the higher the amount of N absorbed by plants.

2) Degenerated sink size. It was reported that degenerated sink size and percentage of degenerated spikelets were correlated with GD[15]. Degenerated sink increased with decrease in N content in laminae during reproductive stage. This was attributed to lower amount of N during this period for every differentiated spikelet[14,16]. In the present experiment, the degenerated sink size was correlated with GD and the percentage of degenerated spikelets was correlated with N content in laminae at flowering stage (Figs. 4

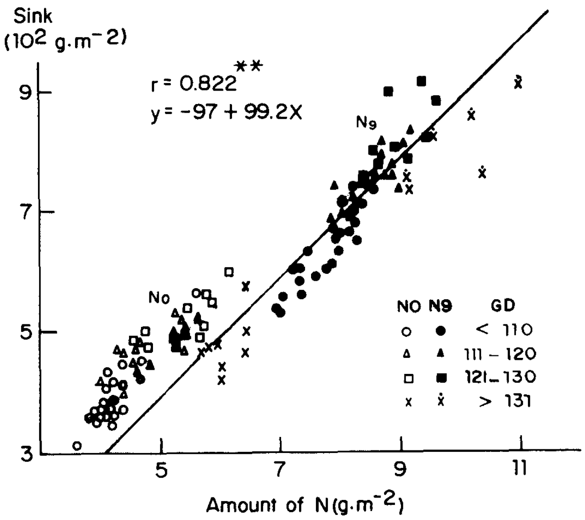

Fig. 7. Relationship between sink and the amount of N in plant at flowering (1987 DS).

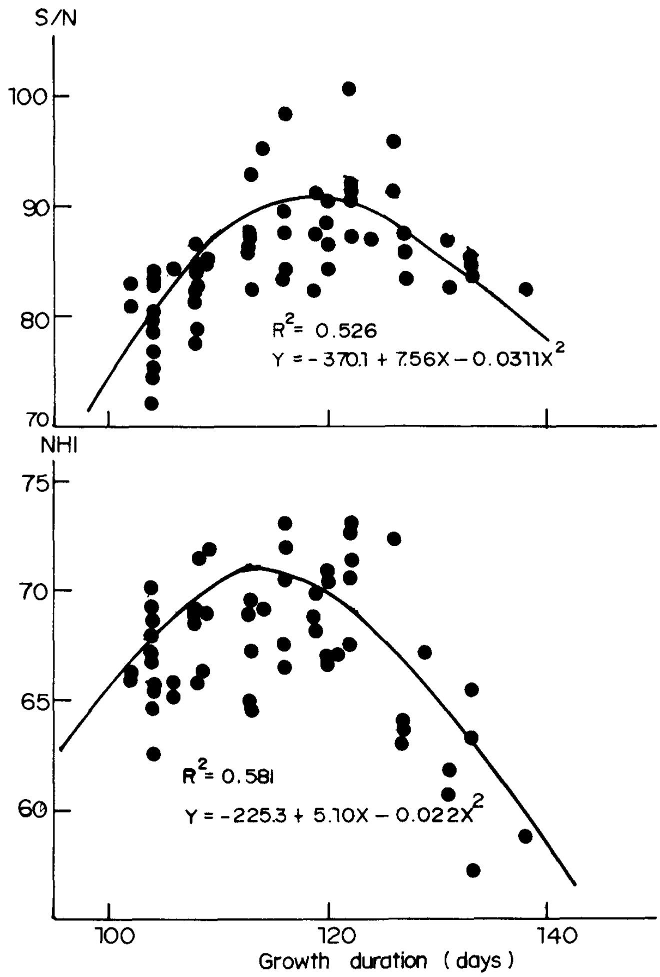

Fig. 8. Effect of growth duration on the contribution of nitrogen (N) in plant to sink (S) and nitrogen harvest index (NHI) (1987 DS).

and 5). Variations in degenerated sink size and percentage of degenerated spikelets were obtained within varieties of the same GD group. The variation in degenerated sink size was smaller in short duration varieties than long duration varieties. Currently, details of varietal differences in sink and spikelet degenerations are under investigation.

Using photoperiod to vary the GD of a variety, Vergara et al[12] reported that the number of spikelets per panicle decreased when GD exceeded 120 days. Wada[15] obtained similar result using a long duration variety, but attributed the observation to increased degenerated spikelets. The longer the GD, the lower the N content in the laminae. The percentage of degenerated spikelets of long duration varieties can be reduced by shortening the GD in the field excluding the nursery days[16].

3) Sink size. Sink size is closely related with GD. Results showed that sink size was represented as a quadratic function of GD (Fig. 6). Sink size was also correlated with the amount of N in plant at late stage of spikelet initiation ($r=0.845^{**}$, $Y=73+91.83X$) and flowering stage. However, the contribution of N in plant to sink formation differed with GD (Fig. 7). For instance, the lower contribution of N to sink formation in very short and long duration varieties was apparent (Figs. 7 and 8).

Maximum sink size was associated with certain GD. The average optimum GD for sink size was 127 days (CV=8.7% for 3 seasons and 2 N levels). Variation in optimum GD between DS and WS was 2—3 days, while 7 days between N levels. Optimum GD was shorter in DS and high N level compared with WS and low N level. Optimum GD was also observed in one variety with different GD in paddy field or pot when nursery days were altered or the panicle initiation was induced by short-day treatments[12,16].

Generally, the maximum tiller number stage occurs simultaneously in short, medium and long duration varieties[3]. Furthermore, no significant differences in the duration of reproductive and ripening stages among varieties were observed in the tropics. Therefore, differences in GD are determined by the duration of vegetative lag phase (VLP), which is defined as the difference in days, between the occurence of panicle primordia initiation and maximum tiller number stage. In such case, the optimum GD might be a function of VLP. The optimum VLP for maximizing sink size can be assumed at around 10—15 days. In the case of direct seeding (broadcast seeding, 200 plants per m^2, no nursery days), the optimum GD is 95 days[1]. In a variety, VLP was found to be affected by spacing. Cropping season however, has minimal effect[18].

Optimum GD was shorter under high N than low N level. The high number of differentiated spikelets observed under high N level can be attributed to large amount of N absorbed by the plants. However, it was reported earlier that there were small differences in the amount of N absorbed from late stage of spikelet initiation to flowering stage (dN) between two N levels[18]. Therefore, when dN per differentiated spikelet was taken into account, lower values were obtained under high N due to high differentiated spikelets resulting to high number of degenerated spikelets[14]. The effect of spikelet degeneration on sink size was more apparent in high N than low N level.

When GD is shorter than the optimum, the observed low sink size is mainly due to less differentiated sink size caused by low amount of N in plant at late stage of spikelet initiation. Another possible cause is the low contribution of N to sink formation (Figs. 7 and 8). This can be explained by the contribution of N absorbed by plant at different growth stages and N absorption patterns in plants. The panicle primordia initiation stage of short duration varieties, occured before or simultaneously with the maximum tiller number stage. Therefore, large amount of N is still absorbed from panicle primordia initiation stage to late stage of spikelet initiation[18]. The N absorbed after panicle primordia initiation until late stage of spikelet initiation has less effect on differentiation of spikelets than the N absorbed before the panicle primordia initiation stage[4,14]. Results suggest the importance of increasing N absorption at early growth stage or inducing longer VLP by manipulating some cultural practices to increase the contribution of plant N to spikelet differentiation, particularly in short duration varieties. When the GD is longer than the optimum, the low sink size is attributed to the increase in

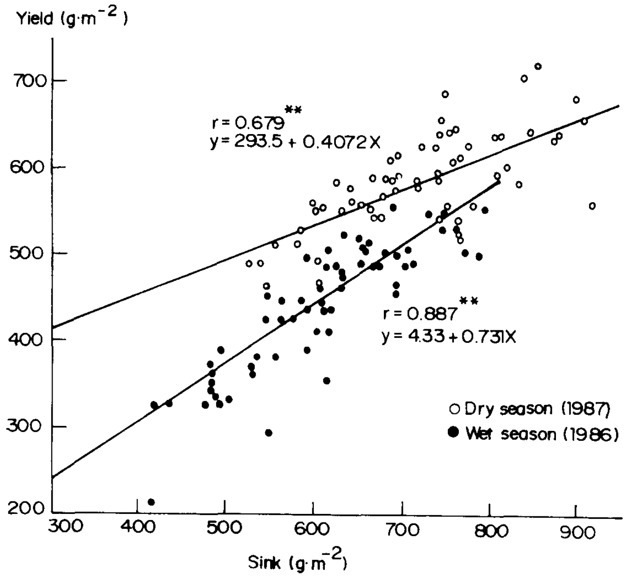

Fig. 9. Relationship between yield and sink.

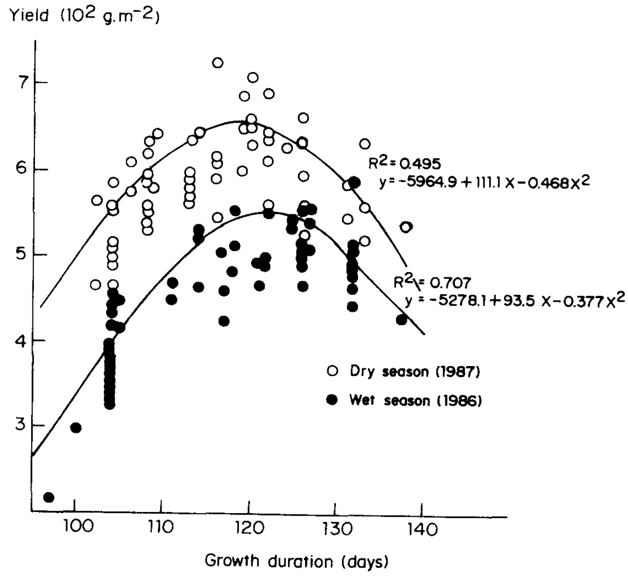

Fig. 10. Relationship between yield and growth duration.

degenerated spikelets in spite of high differentiated spikelets, which is associated to low ratio of dN to differentiated sink. To increase sink size, it is necessary to prevent the spikelet degeneration by increasing N absorption from late stage of spikelet initiation to flowering[14,15].

2. Grain yield

Grain yield was positively correlated with sink size in WS and DS croppings (Fig. 9), despite the varying trends of ripening percentage in the two seasons. Generally, yield was higher in DS in varieties with similar sink size.

Table 3. Relationship between the percentage of ripened grains and growth duration.

Season	Amount of N		
1986 DS	0	$r=-0.535^{*}$	$y=11.9-0.189x$
	9	$r=-0.250^{ns}$	
1986 WS	0	$R^2=0.318^{*}$	$y=-512.0+9.97x-0.041x^2$
	9	$R^2=0.338^{*}$	$y=-414.1+8.295x-0.0345x^2$
1987 DS	0	$r=-0.604^{*}$	$y=129.8-0.409x$
	9	$r=-0.774^{*}$	$y=151.4-0.581x$

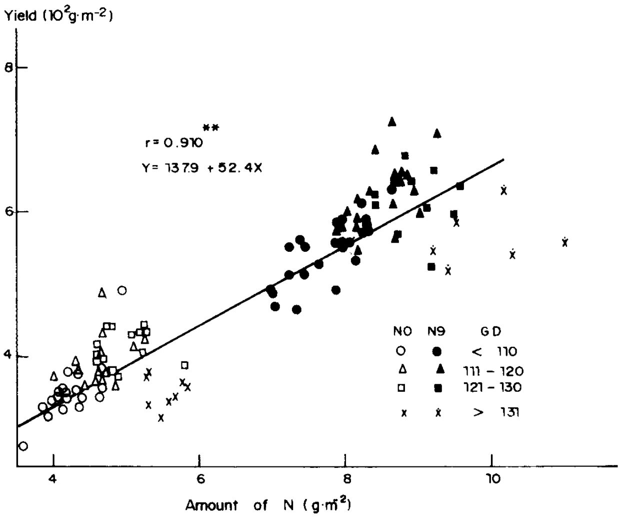

Fig. 11. Relationship between yield and the amount of N in plant at flowering (1987 DS).

These observations are in agreement with previous findings of Wada[14], Yoshida and Parao[22], Wada[16] and Tsuchiya et al[11].

Yield was a quadratic function of GD in both DS and WS (Fig. 10). The optimum GD for yield was 122 days (CV=9%, for 3 seasons and 2 N levels). Variation in optimum GD between DS and WS was 6 days, while, between N levels was 5 days. The optimum GD for yield was generally shorter than sink in DS and WS croppings as well as high and low N levels. This observation is related to ripening percentage which decreased with GD (Table 3).

Yield was correlated with the amount of N in plant at flowering (Fig. 11) and maturity stages ($r=0.612^{**}$, $Y=162.7+42.2X$). However, the contribution of N in plant to yield and nitrogen harvest index (NHI) varied with GD. Lower yields were observed in short and long duration varieties, hence, occurence of optimum GD.

Previous researches identified the presence of optimum GD. Vergara et al[12,13] reported 120 days in pot and 140 days in field condition at 25×30 cm spacing during DS. However, no observation was made during WS. Kawano and Tanaka[3] in their field experiment at IRRI observed 120 days for high N level and 140 days for low N level at 30×30 cm spacing during DS and WS. Similarly in Malaysia, Nozaki[6] reported 130 days in DS and WS at 25×25 cm spacing, while Takita[9] observed 130—135 days during DS and WS at 25×25 cm spacing. Likewise, Yamakawa and Nishiyama[20], reported an optimum GD in temperate area.

Researches in 1960's involved improved and traditional varieties of indica and japonica types. Varietal differences in yield potential, N response and morphological characters were observed. However, optimum GD was not identified during WS due to inclusion of varieties prone to lodging under adverse WS condition that resulted to decreased yield. In the report of Kawano and Tanaka[3] long duration varieties (traditional) were mostly non-responsive to N while short and medium duration (improved) varieties were responsive to N. It can be assumed that this is one of the reasons why there is a big difference in optimum GD among plants grown under high and low N levels. The main reason for the differences in optimum GD obtained by Nozaki[6], Takita[9] and this experiment is attributed to the differences in plant density.

Under tropical condition, yield is primarily governed by sink size[16]. Hence, the optimum GD should be primarily discussed from the viewpoint of sink formation. Yamakawa and Nishiyama[20] and Vergara et al[12,13] pointed out that when GD is shorter than the optimum, the low yield is caused by shortage of vegetative growth, less number of panicles and less number of spikelets. In this experiment, low yield is explained by relatively lower sink size particularly in varieties with low potential sink size. This is due to low amount of N in plants at late stage of spikelet initiation. Vergara et al[13] also reported that when GD is longer than optimum, low yield is caused by less number of spikelets per panicle. From the results of this experiment, the observation can be explained by higher spikelet degeneration.

The abovementioned evidences suggest that low yield of varieties having shorter or longer GD than optimum is explained primarily by low sink size. Moreover, the optimum GD for yield as a function of different cultural practices can be attributed to sink size.

References

1. Aragones, D.V. and G. Wada 1989. Physiological aspects of direct seeded (broadcasting) rice cultivation. Japan. J. Crop Sci. 58 (Extra 1) : 22—23.
2. Broadbent, F.E., S.K. de Datta and E.V. Laureles 1987. Measurement of nitrogen utilization efficiency in rice genotypes. Agron. J. 79 : 786—791.
3. Kawano, K. and A. Tanaka 1968. Growth duration in relation to yield and nitrogen response in plant. Japan. J. Breed. 18 : 46—61.
4. Matsushima, S. 1966. Crop Science in Rice. p. 22—23, 75. Fuji Publ. Tokyo.
5. Miyagawa, S. 1981. Nitrogen balance in paddy field planted with different indica varieties. Japan. J. Trop. Agric. 25 : 107—114*.
6. Nozaki, M. 1984. Studies on rice double cropping culture in Muda irrigation area, Malaysia. p. 208. A report of Muda Agricultural Development Authority, Malaysia and Tropical Agriculture Research Center, Japan.
7. Osada, A. 1966. Relationship between photosynthetic activity and dry matter production in rice varieties, especially as influenced by N-supply. Bull. Natl. Inst. Agric. Sci. D14 : 117—188*.
8. Takahashi, Y., I. Iwata and I. Baba 1959. Studies on varietal adaptability for heavy manuring in rice. 1. Varietal differences in nitrogen and carbohydrate metabolism affected by different supply of nitrogen. Proc. Crop Sci. Soc. Japan 28 : 22—24*.
9. Takita, T. 1986. Studies in breeding for resistance to green leafhopper, varietal adaptability to local environments and high yield of rice in Malaysia. IV. Relationship between maturation period and yield and the breeding strategy for short maturation rice varieties. 28—31. Malaysian Agricultural Research and Development Institute and Tropical Agriculture Research Center, Japan. Cooperative study report.
10. Tanaka, A., K. Kawano and J. Yamaguchi 1966. Photosynthesis, respiration and plant type of tropical rice plant. IRRI Tech. Bull. 6 : 1—46.
11. Tsuchiya, M., B.S. Vergara and G. Wada 1986. Nitrogen response of rice varieties grown under low N level. Japan. Jour. Crop Sci. 55 (Extra 1) : 50—51**.
12. Vergara, B.S., R. Lilis and A. Tanaka 1964. Relationship between length of growing period and yield of rice plants under a limited nitrogen supply. Soil Sci. Plant Nutr. 10 : 59—65.
13. ——, A. Tanaka, R. Lilis and S. Puranabhavung 1966. Relationship between growth duration and grain yield of rice plant. Soil Sci. Plant Nutr. 12 : 31—39.
14. Wada, G. 1969. The effect of nitrogenous nutrition on yield determining process of rice plant. Bull. Natl. Inst. Agric. Sci. A16 : 27—157*.
15. ——, 1985a. Rice cultivation in Sabah, Malaysia. 1. Yield and yield components in major paddy area. JARQ 18 : 331—335.
16. —— 1985b. Rice cultivation in Sabah, Malaysia. 4. Effect of the seedling age on the growth and yield of rice. Presented at 57th Meeting of Trop. Agric. Res. Assoc. Japan Proceeding 60—61**.
17. ——, S. Shoji and T. Mae 1986. Relationship between nitrogen absorption and growth and yield of rice plant. JARQ 20 : 135—145.
18. ——, D.V. Aragones and R.C. Aragones 1989. N-absorption pattern of rice plant in the tropics. Japan. Jour. Crop Sci. 58 : 225—231.
19. Wada, M. 1981. Studies on the effect of nitrogenous nutrition at the vegetative lag phase on growth and yield of rice plant in Southern Japan. Bull. Natl. Kyushu Agric. Exp. Stn. 21 : 113—250*.
20. Yamakawa, Y. and H. Nishiyama 1958. Studies on the cultivation period on rice plant in warmer district of Japan. I. Effect of changes of cultivating period on rice plant and its varietal differences. Saga Univ. Fac. Agric. Bull. 5 : 1—48*.
21. Yoshida, S. and S.B. Ahn 1968. The accumulation process of carbohydrate in rice varieties in relation to their response to nitrogen in tropics. Soil Sci. Plant Nutr. 14 : 153—161.
22. —— and F.T. Parao 1972. Climatic influence on yield and yield components of lowland rice in the tropics In Climate and Rice. 471—494. IRRI, Los Baños.
23. —— 1981. Fundamentals of Rice Crop Science. p. 235—237. IRRI, Los Baños.

* In Japanese with English summary.

** In Japanese.