Lag Phase and Nitrogen Absorption Pattern of Rice Plants in the Warm Region of Japan

By MANABU WADA

Grop Division, Chugoku National Agricultural Experiment Station
(Fukuyama, Hiroshima-ken, 450 Japan)

Comparison of length of period for each growth stage between rice plants grown in the cool northern region and those grown in the warm southern region of Japan indicates that there are great differences in the period from transplanting to the maximum tiller number stage and the period from the maximum tiller number stage to the panicle initiation stage (which is called vegetative lag phase). Duration of vegetative lag phase (hereafter referred simply to lag phase) in the cool region is short, less than 0 to about 10 days, whereas that in the warm region is usually as long as 2–3 weeks. The lag phase duration shows a high negative correlation with the duration of tillering stage in each variety group with different maturation period, and the duration of tillering stage is determined by air temperature at that stage, rate of leaf area enlargement, and nitrogen content (%) of plants[6]. Rice plants in the warm region show long lag phase durations due to rapid leaf area enlargement under high air temperature in the tillering stage, and because of photoperiod sensitivity which requires a certain day-length for panicle differentiation[5].

Nitrogen absorbed in plenty at the lag phase tends to promote the elongation of lower internodes and upper leaves, causing lodging and deterioration of ripening characteristics. Therefore, nitrogen absorption at the lag phase is strictly restrained, according to the theory of fertilizer application. In recent years, however, the risk of lodging has markedly decreased due to the use of short-culm varieties in the warm regions, particularly in Kyushu where a series of short varieties starting from Hoyoku through to the latest Nishihomare have been released. On the other hand, the spread of mechanized transplanting, which makes early planting of young seedlings, causes prolonged duration of lag phase, giving rise to a problem of nitrogenous nutrition for the prolonged lag phase. These new developments make it necessary to re-examine the effect of nitrogen absorption in lag phase of rice plants in the warm region.

Effect of nitrogen absorbed in each vegetative growth stage on leaf area and number of spikelets

In case of medium-late maturing varieties, showing the lag phase of about 3 weeks, the customary method of nitrogen application (basal dressing, and top dressing at tillering stage and at panicle initiation stage) gives a bimodal pattern of nitrogen absorption with two peaks at the late tillering stage and panicle formation stage, and a depression at the lag phase. Relative contribution of nitrogen absorbed in various growth stages to leaf area, number of panicles, and number of spikelets produced was determined by the path analysis. The result is shown in Table 1. To the leaf area, nitrogen absorbed at the lag phase gave the greatest contribution, followed by nitrogen absorbed at the late tillering stage, and almost no effect was observed with nitrogen absorbed at the early tillering stage and panicle formation stage. Relative contribution to the number of panicles/m^2 was greatest with nitrogen absorbed at the late tillering stage and the lag phase, but it was

Table 1. Relative contribution and multiple correlation coefficient (R) of nitrogen absorbed in various growth stages to maximum LAI, percentage of productive tillers, number of panicles /m², number of spikelets /panicle and /m² and number of spikelets/unit dry matter weight at heading time

	Relative contribution (%)				R
	$\triangle N_1$	$\triangle N_2$	$\triangle N_3$	$\triangle N_4$	
LAI	2	32	51	4	0.9534
Percentage of productive tillers	−2	19	38	−5	0.9605
Number of panicles/m²	15	39	35		0.9096
Number of spikelets/panicle	9	−25	34	−9	0.9674
Number of spikelets/m²	14	14	48	2	0.8797
Number of spikelets/D.W	−9	−27	14	14	0.7953

Note, 1) Relative contribution (%) was calculated from standardized partial regression coefficient.

2) $\triangle N_1$: nitrogen absorbed in the early tillering stage (from transplanting to the end of productive tiller formation).

$\triangle N_2$: nitrogen absorbed in the late tillering stage (from the end of productive tiller formation to the maximum tiller number stage).

$\triangle N_3$: nitrogen absorbed in vegetative lag phase.

$\triangle N_4$: nitrogen absorbed in reproductive phase (from panicle initiation stage to heading).

not so great with nitrogen absorbed at the early tillering stage. One of the reasons for this result is that the relative contribution of nitrogen to the percentage of productive tillers varys with the growth stage when the nitrogen was absorbed: nitrogen absorbed at the lag phase exerts a very strong influence to increase percentage of productive tillers, and hence it causes a great contribution to the number of panicles/m². This fact indicates that nitrogenous nutrition of lag phase should not be neglected in increasing number of panicles/m² in the warm region.

To the number of spikelets/panicle, nitrogen absorbed at the lag phase showed a high positive contribution, while nitrogen at the late tillering stage gave a negative contribution. Nitrogen absorbed at the early tillering stage and panicle formation stage showed a small contribution. Relative contribution to the number of spikelets/m² was greatest with the nitrogen absorbed at the lag phase, reflecting the contribution of that nitrogen to each of the number of panicles/m² and number of spikelets/panicle. It was considerably higher than the combined contribution of the whole tillering stage. On the other hand, a parabolic curve regression between the number of spikelets/m² and the rate of nitrogen absorption at the lag phase was found as shown in Fig. 1. The maximum number of spikelets/m² was obtained at the rate of nitrogen absorption of 364 mg/m²·day. The number of spikelets produced per unit dry weight of plant also showed a positive relation to the nitrogen absorbed at lag phase or panicle formation stage, while it showed a high negative rela-

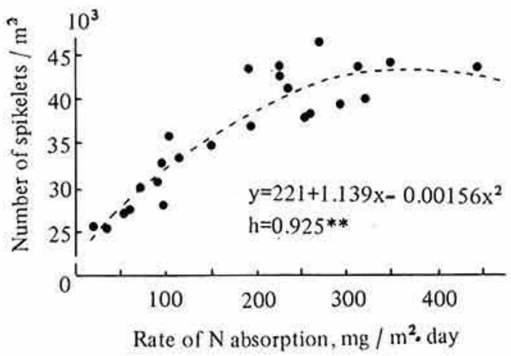
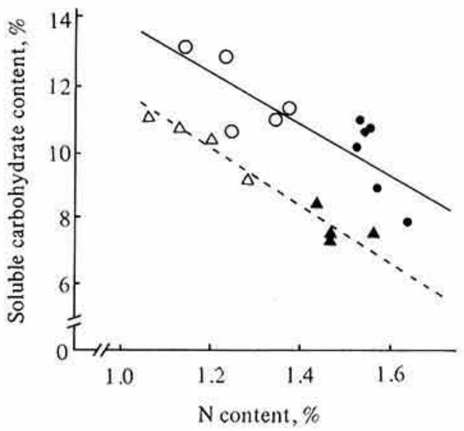


Fig. 1. Relationship between number of spikelets and rate of N absorption in vegetative lag phase

tion to the nitrogen of the tillering stage, especially of the late tillering stage.

The above result of analysis indicates clearly that the effect of nitrogenous nutrition of lag phase on number of spikelets is very large with medium-late maturing varieties in the warm region. It is necessary, therefore, to increase the rate of nitrogen absorption at the lag phase to a certain extent. However, with the usual practice of fertilizer application, the rate of nitrogen absorption at the lag phase is extremely low in general: in most cases it is 50–150 mg/m^2 · day, though it varys depending on soil fertility. Therefore, a method of fertilizer application enabling to reduce nitrogen absorption at the late tillering stage to some extent and increase nitrogen absorption at the lag phase, without causing excessive increase in plant dry weight and leaf area is needed. Nitrogen applied at the lag phase shows an extremely high rate of recovery in plants as compared with basal dressing and top dressing at the tillering stage, and it is comparable to that of top dressing at the panicle initiation stage. Thus, the nitrogen application at the lag phase can save the nitrogen required to get a given number of spikelets.

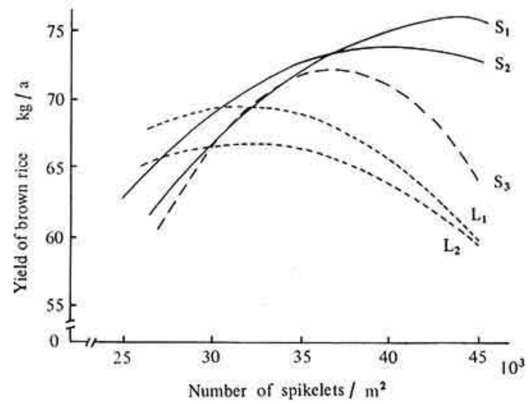


○: Short varieties in standard plot
●: Short varieties in top-dressed plot
△: Medium-tall varieties in standard plot
▲: Medium-tall varieties in top-dressed plot
Solid line shows regression line of short varieties ($y=21.4-7.59x$, $r=-0.811^{*}$) and broken line shows regression line of medium-tall varieties ($y=20.4-8.55x$, $r=-0.970^{**}$).

Fig. 2. Regressions of carbohydrate content in leaf sheaths and stems on nitrogen content in leaves and stems at panicle intiation stage

Differences in effectiveness of nitrogen applied at the lag phase according to varietal characteristics

By the new method of nitrogen application, which reduces nitrogen absorption at the tillering stage and increases nitrogen absorption at the lag phase, CGR in the tillering stage was lowered, but CGR, NAR and RLGR were increased after the lag phase, as compared with the case of usual method of fertilizer application. Extent of these increases differs with plant type: small increases with short varieties while great increase with tall varieties. The increase in dry

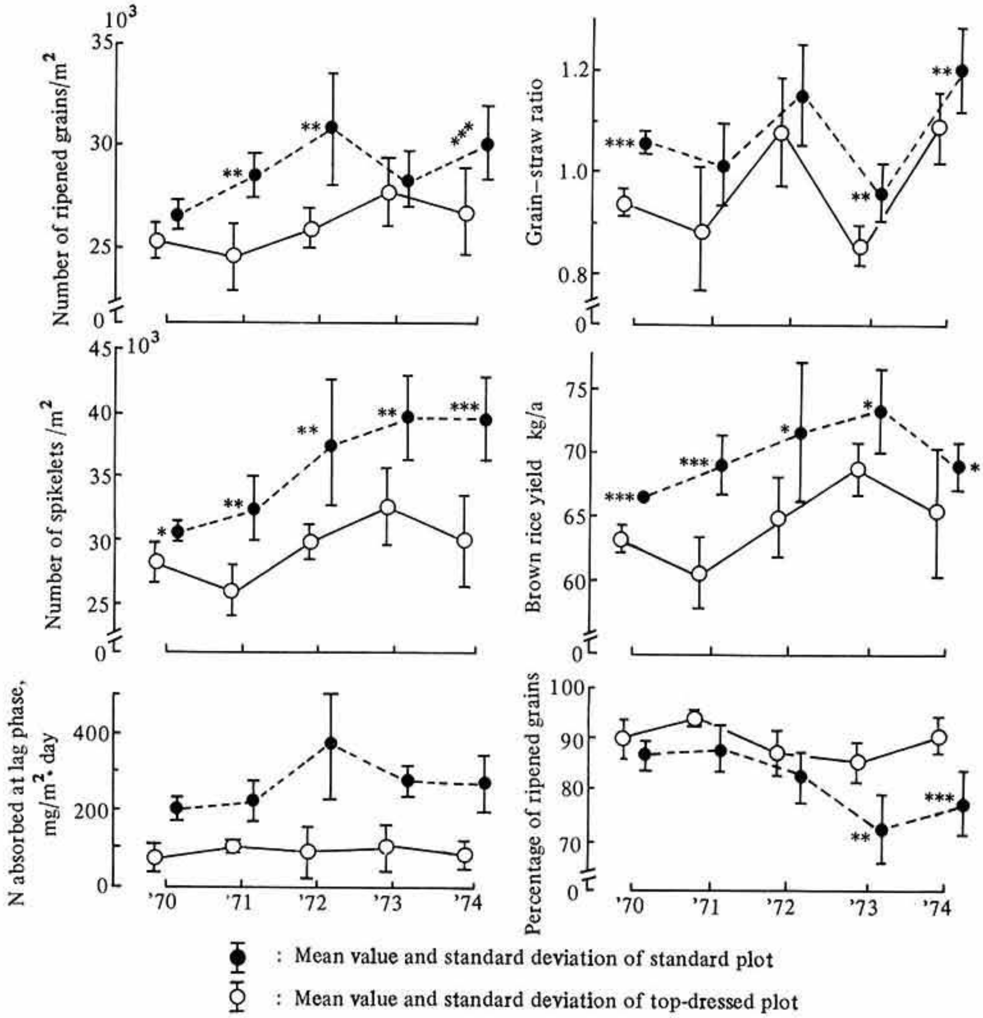


S_1: Tsukushibare (extremely short variety) $y=-16.9+4.17x(10^{-3})-0.0473x(10^{-3})^2$, $h=0.970^{***}$
S_2: Saikai No. 113 (extremely short variety) $y=-4.0+3.88x(10^{-3})-0.0483x(10^{-3})^2$, $h=0.930^{**}$
S_3: Toyotama (short variety) $y=-95.5+9.10x(10^{-3})-0.123x(10^{-3})^2$, $h=0.885^{*}$
L_1: Sendai (medium-tall variety) $y=13.6+3.50x(10^{-3})-0.0550x(10^{-3})^2$, $h=0.921^{**}$
L_2: Ariake (medium-tall variety) $y=21.1+2.84x(10^{-3})-0.0442x(10^{-3})^2$, $h=0.776^{*}$

Fig. 3. Varietal differences of regressions of grain yield on number of spikelets/m^2

matter production occurred after the lag phase induced the decrease of soluble carbohydrate content, and this decrease was more with tall varieties than short varieties (Fig. 2) as same as the result of Takahashi et al.[3] Extent of the increase in number of spikelets/panicle caused by nitrogen at the lag phase was also greater with tall varieties than short varieties, and the increase in number of spikelets/m² also showed a similar tendency. Such differences in the response of dry matter production and number of spikelets no nitrogen by plant type brought about differences in ripening characteristics through the light-intercepting characteristics during the ripening stage.

Relative contributions of yield components to yield was determined by path analysis. Contribution of number of spikelets/m² to yield was 55% with short varieties, and only



*, **, *** indicates significant differences at 5, 1, and 0.1%, respectively, in top-dressed plot against non top-dressed plot.

Fig. 4. Comparison of number of spikelets, ripened grains, percentage of ripened grains, grain yield and grain-straw ratio between standard plot (not top-dressed) and top-dressed pilot (top-dressed at lag phase) of short varieties.

29% with tall varieties. On the contrary, that of ripening characteristics (percentages of ripened grains and 1000 kernel weight) was only 17% for short varieties and as much as 54% for tall varieties. As to the tall varieties, this result well agrees with the current theory of fertilizer application[2] that percentage of ripened grains is most important among yield components[1], and hence nitrogen absorption in the middle growth stage should strictly be prevented. However, for short varieties, this result suggests that the theory may not be applicable. This is apparently shown by the relation between yields and number of spikelets. The parabolic curve regression exists between yields and number of spikelets/m^2, but the pattern of the curves differed apparently by plant type (Fig. 3). The number of spikelets required to obtain the maximum yield (the optimum number of spikelets) was about 32,000 for medium-long culm varieties (Sendai and Ariake), whereas it was 37,000 for a short variety (Toyotama), and more than 40,000 for extremely short varieties (Tsukushibare and Saikai 113).

These results suggest that the nitrogen absorption pattern of short varieties is different from that of tall varieties, and that the customary method of nitrogen application intending to promote initial growth and to prevent nitrogen absorption in the lag phase has to be modified for short varieties.

To verify this idea, an experiment with plots different in nitrogen application during the vegetative growth period was carried out, using short varieties (extremely short type and short type) for 5 years. In the standard plot, nitrogen was applied as basal dressing with or without top-dressing at the tillering stage, while in the top-dressed plot, amount of basal dressing was reduced and top dressing was applied at the lag phase. The result is shown in Fig. 4. In the top-dressed plot, rate of nitrogen absorption in the lag phase was increased 2–3 times that of the standard plot, and number of spikelets/m^2 was significantly increased in all the years. In this plot, percentage of ripened grains showed a tendency to decrease, and especially in 1973 and 1974 it decreased significantly due to remarkable increase in number of spikelets and slightly less solar radiation during the ripening period. Nevertheless, brown rice yield of this plot was significantly higher than the standard plot in all the years, due to the increased number of ripened grains. Grain-straw ratio was also relatively higher in the top-dressed plot than the standard plot in all the years. This result indicates that the nitrogen absorption pattern with limited absorption during the tillering stage and promoted absorption in the lag phase is superior to the standard bimodal pattern for short varieties with the lag phase duration of about 3 weeks. The former is a monomodal type with a peak at the panicle formation stage or lag phase.

In early maturing varieties with short lag phase duration of about 1 week, dry matter production in lag phase was less and nitrogen content at the panicle initiation stage was higher than medium-late maturing varieties. In this case, NAR, RLGR at the panicle formation stage became high, resulting in decreased carbohydrate content, so that increased number of spikelets caused by nitrogen absorption in the lag phase tended to reduce percentage of ripened grains to an extent more than the case of medium-late maturing varieties.

In general, varietal improvement has taken the direction to enlarge the sink, and then to improve the plant type in order to avoid the increase of LAI and decrease of NAR, both associated with the enlargement of sink[4]. The present study showed a possibility to increase rice yield with stability in the warm regon of Japan by enlarging the size of the sink so as to enable full manifestation of characteristics of varieties with improved plant type in an efficient way from the view point of economy of plant substances.

References

1) Matsushima, S.: Analysis of developmental factors determining yield and yield production in lowland rice. *Nat.Inst.Agr.Sci.Bull., Series* A 5, 1–271 (1957) [In Japanese with English

summary].
2) Matsushima, S.: V-shape theory for high yielding of rice and its application. *Nōgyo oyobi engei*, **42**, 144–150 (1967) [In Japanese].
3) Takahashi, Y., Iwata, I. & Baba, O.: Studies on the 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 (1959) [In Japanese with English summary].
4) Tanaka, A.: Analysis of high yielding based on source-sink. relationship. *Recent progress of breeding science in Japan*, No. 15, 29–39 (1975) [In Japanese].
5) Wada, E.: Studies on the response of heading to day-length and temperature in rice plants. 1. Response of varieties and its relation to their geographical distribution in Japan. *Jap. J. Breeding*, **2**, 55–62 (1952) [In Japanese with English summary].
6) Wada, M.: Studies on the vegetative lag phase of rice plants in the warm region of Japan—In relation to nitrogen absorption pattern of rice plants—. *Bull. Kyushu Agr. Expt. Sta.*, **21** (2), 113–250 (1981) [In Japanese with English summary].

(Received for publication, October 3, 1980)