

Characteristics Relating Young Panicle Development and Heading of Closely Related Calrose Rice Genotypes

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Abstract : Seven near-isogenic lines which were derived from rice cultivar “Calrose” were sown on June 8, 1985, and transplanted on June 25 at the fourth leaf stage in rice facility of the University of California, Davis. Each plant was marked by a felt pen on every even leaf of main culm to count the number of flag leaf. At leaf number index (LNI) 85 to 95, young panicle length was investigated. At heading stage, all panicles of about 50 plants per genotype were dated their heading date on their flag leaf, and at harvest each panicle was recorded its node location from which it emerged.

A high correlation coefficient between LNI and logarithm of young panicle length was obtained in all genotypes, so it was considered that LNI was an excellent index to estimate young panicle developmental stage, when the total number of leaves of genotype was known already. In ES-201, panicle of main culm and tillers headed nearly the same time, whereas in the other 6 genotypes, heading date of main culm was later than that of the first headed tiller panicle. Especially main culm heading of S-201 was delayed more than 2 weeks than that of the first headed tiller panicle. Primary tiller which emerged from 6th node on main culm headed at first in the genotype excluding ES-201. As the 6 genotypes other than ES-201 showed the most advanced young panicles in their 6th node at LNI 85 to 95, above-mentioned behavior seems to be a characteristic of these genotypes. Heading date of main culm in M-302 and S-201 was prolonged by low temperature compared to that of Calrose 76 and M7, respectively. This might be based on their tolerance to low temperature for the uppermost internode elongation. An early heading genotypes showed less number of flag leaf (M-101) or higher leaf emergence rate (ES-201) than that of later ones (M7 and S-201), respectively.

Key words : Distance between collars, Heading date, Leaf number index, Main culm, Tillers panicle, Young panicle length.

水稻 Calrose 近縁品種の幼穂发育と出穂特性 : 松崎昭夫・RUTGER J.N. (東京大学農学部附属農場・カリフォルニア大学, USDA-ARS.)

要 旨 Calrose 76 を中心とするアイソジェニック 7 品種を 1985 年, カリフォルニア大学 (Davis) の水田で栽培し, 葉齢指数と幼穂发育程度との関係, 主稈と分げつの出穂日を調査した。

主稈と 6 号分げつの葉齢指数と幼穂長の関係は主稈のみの場合と同様であり, 止葉の葉数が確定したあとの幼穂の发育段階は葉齢指数から高い精度で推定できることが確認された。

調査個体 200 株の平均値でみた場合, 品種 ES-201 の主稈の出穂日は 1 株の中で最初に出穂した分げつの平均出穂日とほぼ同時であったが, 他の 6 品種の出穂日は主稈よりも分げつのほうが早かった。とくに, 品種 S-201 の主稈の出穂日は最初に出穂した分げつの平均出穂日より 2 週間も遅れた。1 株のなかで最初に出穂した分げつは ES-201 を除き 1 次分げつの 6 号分げつ (主稈の 6 葉から出た分げつ) であったが, 2 次分げつが最初に出穂した個体もみられた。これら 6 品種では葉齢指数 85-90 の時期の幼穂長は 6 号分げつが最大値を示し, しかも主稈よりも大きい値を示していたので, これら 6 品種の分げつの出穂日が主稈よりも早い性質はこれら 6 品種の特性であると考えられる。

M-302 と S-201 の主稈の出穂日が Calrose 76 と M7 に比較して低温に遭遇した場合に遅延程度が大きかった理由のひとつにこれらの品種の穂首節間の低温による伸長抑制が指摘された。また, M-101 と ES-201 が M7 と S-201 よりも出穂が早いのは, M-101 では止葉葉数が少ないこと, ES-201 では葉の展開速度が早いことによるものと推定された。

キーワード : 主稈, 出穂日, 分げつ, 葉耳間長, 幼穂長, 葉齢指数。

Shifting time of growth phase from vegetative to reproductive and heading time are

important for rice culture improvement. The former is characterized by young panicle differentiation, which is in general determined by basic vegetative growth, photoperiod sensitivity and thermosensitivity^{16,17)}. The latter is

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directly brought about by the uppermost and second internode elongation which largely depends on temperature during elongation periods.

To know young panicle developmental stage accurately is important for nitrogen top dressing to increase the number of spikelets per square meter⁷⁻¹¹). Heading time is also an important index in cultural practices, not only representing ripening stage as “number of days after heading”, but also young panicle developmental stages as “number of days before heading”. On the other hand, it is known that leaf number index, which is the relative leaf number to the total leaf number at any growth stage, is a useful index representing young panicle developmental stage⁶).

So, using isogenic lines which have similar genetic background except heading^{14,15}), the authors tried to clarify the relation between leaf number index and young panicle developmental stages, to search heading variations of individual plants in a genotype and of individual tillers in a plant.

Materials and Methods

In order to minimize the influence based on different genetic background, seven closely related lines which have nearly the same genetic background except heading time were chosen and classified into three groups according to their genetic relationships to Calrose 76 and each other as shown in Table 1^{14,15}).

Seeds were sown on June 8, 1985, in jointed paperpot (15 mm square, 30 mm depth) and grown in glasshouse until 4th leaf stage. After

marking each 4th leaf by a felt pen, each seedling was transplanted on June 25, in 10×25 cm, at the Rice Research Facility of the University of California, Davis.

Each genotype, which consists of 2 rows of 25 plants per row, was arranged by randomized method with 4 replications. After transplanting, each plant was marked by a felt pen on every even leaf to count flag leaf number, and the length of young panicles of all tillers was investigated by direct dissection as well as the main culm at the stage of 85 to 95 in leaf number index (LNI), which was defined as the percentage of leaf number at that time to flag leaf number⁶).

Heading date was recorded on flag leaf of main culm and of tillers which headed at first in the plant. Especially on one plot in each genotype, the heading date of all panicles of

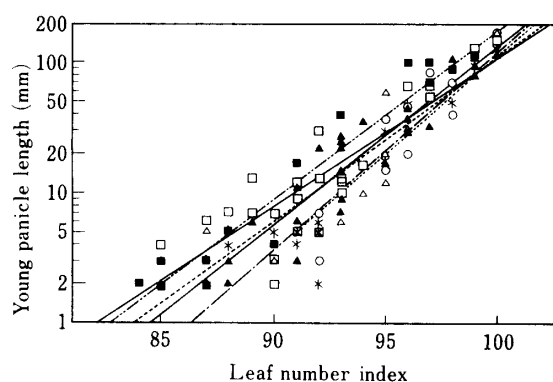


Fig. 1. Relation between leaf number index (LNI) and young panicle length (YPL).
 $\text{Ln (YPLmm)} = 0.286 \times (\text{LNI}) - 23.94$,
 $R^2 = 0.841$ ($n = 139$)

ED7 Calrose 76 M-101 M7 ES-201 S-201

Table 1. Genetic background and characteristics of genotypes.

Group	Genotype	Coefficient of percentage with :			No. of days to heading	
		Calrose	Last number of group	No. of plants	sown 6/9	sown 5/9
A	ED7	1.000	1.000	191	89	97
	Calrose 76*	1.000	1.000	196	102	115
B	M-101	0.922	0.850	198	87	95
	M-302	0.766	0.850	195	96	105
	M7*	0.844	1.000	195	104	114
C	Early S-201	0.625	1.000	169	84	95
	S-201	0.625	1.000	194	94	102

* Photoperiod sensitive cultivar.

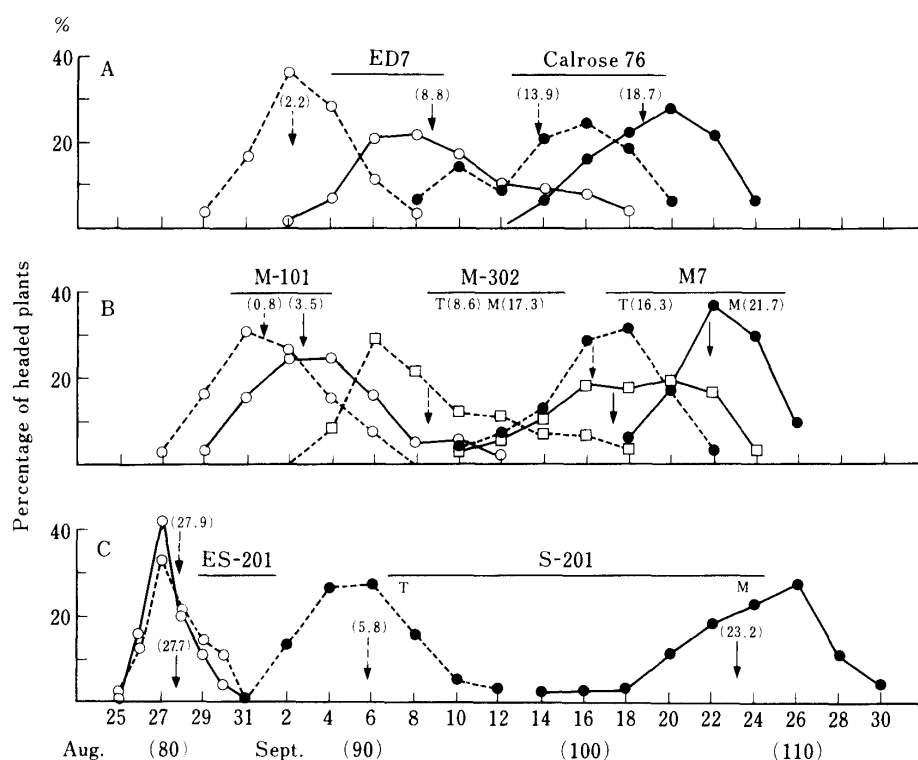


Fig. 2. Trend of heading percentage of main culm (solid line) and tillers panicle (broken line). Numerals in parenthesis indicate an average heading date.

the plant was recorded. At 30 days after heading, the originating node locations of each panicle and the internode length of main culm were investigated.

The distance between collars (DBC) of flag leaf and the penultimate leaf on main culm was also recorded to estimate the temperature effect on the uppermost and the second internode elongation at booting stage.

Results and Discussion

Estimation of young panicle length

A young panicle showed slower growth by the stage around 90 in leaf number index (LNI), and after that grew exponentially. A high correlation was obtained between LNI and a logarithm of young panicle length (YPL) of main culm and tillers which emerged from 6th node on main culm as shown in Fig. 1. No difference was detected in regression coefficient between LNI and YPL among genotypes. Based on these relationships, we can estimate the young panicle length from LNI without dissecting rice plant. As the number of flag leaf can be confirmed by naked eyes at the stage of primary rachis

branch differentiation, about 80 in LNI⁶⁾, it was considered that LNI had been more reliable index to estimate young panicle developmental stage than other indices such as the number of days before heading (DBH), because LNI was determined on the basis of leaf number expanded at that time.

When no information is available on flag leaf number, it is, of course, necessary to dissect the rice plant directly in order to determine young panicle developmental stage. As a result of it, if white bract hairs around growing point were recognized and if flag leaf length was less than 5 mm at that time, young panicle developmental stage is regarded as secondary rachis branch differentiation, that is, LNI 85–86. After this stage, 2.0–2.3 leaves must be expanded in case of flag leaf number being 14–16.

Heading characteristics

Heading time of main culm and tillers panicle: Heading date of each plant was recorded on main culm and the first heading tiller in the plant. Fig. 2 has shown the ratio of headed plants each two day intervals to all plants of 4 replications in each genotype. In ES-201, main

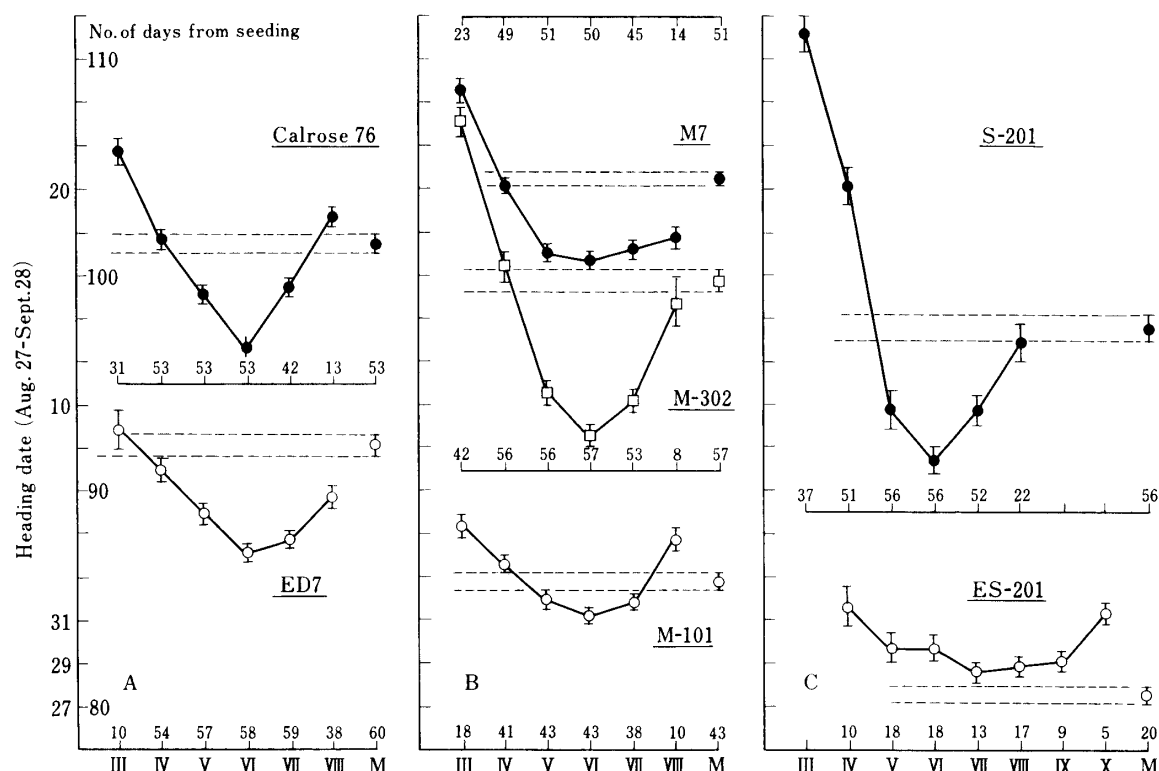


Fig. 3. Heading date of main culm and primary tillers emerged from 3rd-10th nodes on main culm. Numerals on horizontal axis indicate the number of plants investigated.

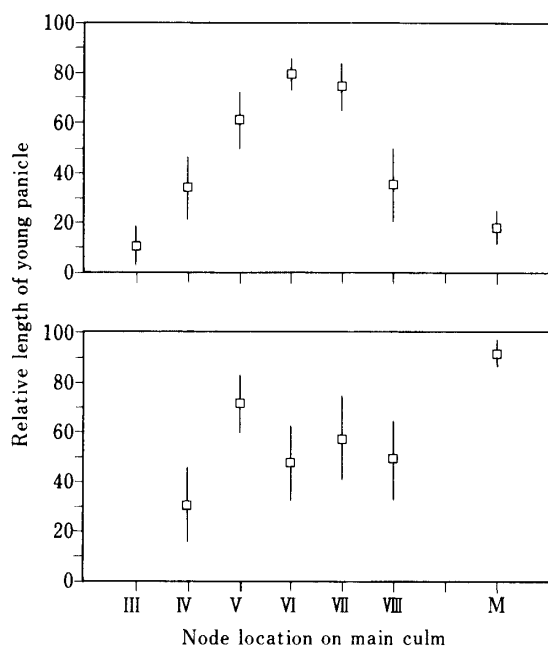


Fig. 4. Relative length of young panicle at LNI 90 on main culm and primary tillers emerged from 3rd-8th nodes on main culm. Vertical line at each point indicates the standard deviation. (upper S-201 n=11, lower ES-201 n=6)

culm and the first heading tillers headed almost the same time. In other 6 genotypes, however, tiller panicles (broken lines) headed earlier than that of main culm (solid line). An average heading date of main culm delayed 2.7 days in M-101, 4.8 in Calrose 76, 5.4 in M7, 6.6 in ED7, and 8.7 in M-302 from that of the first heading tillers, especially 17.4 days in S-201. It seems that the difference of heading date between main culm and the first heading tillers was larger in the genotype which had low temperature during their heading period (Table 3) and that it was controlled by varietal characteristics and enhanced by environmental conditions, such as low temperature in heading period.

Node location of the first heading tiller panicle: Heading date of all panicles in the plants was recorded for about 50 plants of each genotype. Fig. 3 has shown the average heading date of main culm and of panicles which originated from each node on main culm. In ES-201, in which only 20 plants were investigated, the average heading date of main culm (M) was earlier than that of tiller panicles. On the other hand in another 6 genotypes, tiller panicles which originated from 6th node on main culm

Table 2. Percentage of main culm, primary and secondary tillers which emerged first in a plant.

Group	Genotype	No. of panicles*	Percentage of					
			Main culm	Primary tillers	Secondary tillers			
					Total	IV	V	Others
A	ED7	107	0.9	45.7	52.9	19.5	28.9	4.5
	Calrose 76	69	2.9	69.5	27.7	10.3	17.4	0
B	M-101	83	6.0	79.5	14.4	4.8	6.0	3.6
	M-302	77	1.3	63.7	35.1	23.4	9.1	3.6
	M7	72	2.8	55.6	41.7	13.9	20.8	7.0
C	ES-201	47	34.0	51.0	15.0	4.3	10.7	0
	S-201	72	0	65.0	35.0	5.6	21.0	8.4

* Two or more panicles in the plant emerged at the same time.

Table 3. Estimation of number of days to heading from distance between collars.

Group	Geno- type	No. of		Measure- ment date of DBC*	Ave- rage DBC	No. of days before heading (DBH)	Average daily max. temp. **	Regression of DBH to DBC	
		Flag leaf	Plants					Con- stant ***	Coef- ficient ****
						mm	°C		
A	ED7	14	100	Aug. 27	33	13	28.7	16.7	−1.71
	Cal 76	15	114	Sep. 3	29	16	25.7	19.8	−1.27
B	M-101	14	120	Aug. 22	16	13	32.7	13.0	−0.96
	M-302	14	120	Aug. 30	25	18	26.6	20.3	−1.12
	M7	15	141	Sep. 4	33	18	26.1	21.0	−0.83
C	ES-201	15	133	Aug. 18	29	10	32.6	10.4	−0.38
	S-201	15	117	Sep. 3	11	20	26.6	21.5	−0.92

* Contraction of "Distance between collars".

** Average temperature from measurement date of DBC to average heading date of main culm.

*** Number of days to heading when DBC is zero.

**** Number of days required to elongate 10 mm of DBC.

(VI panicle) headed at first, and then tillers from 5th (V panicle) or 7th (VII panicle) node on main culm followed. Main culm headed after heading of V, VI and VII panicles in these 6 genotypes.

Fig. 4 has shown relative young panicle length at the stage of LNI 85-95. S-201 represents other 5 genotypes except ES-201. It was obvious that tillers originated from the 6th node on the main culm had most advanced young panicles except for ES-201. So, we can consider that the pattern as shown in Fig. 3 and 4 is mainly based on genotype characteristics.

Table 2 shows the percentage of main culm,

primary and secondary tillers which head at first in the plant. In this instance, node locations of secondary tillers on primary tillers from which they originated, were estimated by the synchronous leaf growth theory⁵⁾. As expected from Fig. 3 and 4, the main culm of ES-201 showed a higher percentage than the other genotypes. It was also observed that some secondary tillers emerged at first. Especially in ED7, more than half of the panicles which emerged at first, belonged to secondary tillers. As for the node location of secondary tillers, it seems that panicles originated from IV and V primary tillers have a greater chance to head first in the plant. A definite tendency

was not observed among the groups or earliness in each group. However, percentage of the first headed secondary tillers was low in genotypes which headed at an earlier date, for example, in ES-201 and M-101.

Low temperature effect on heading: A few genotypes in this experiment were hit by low temperature during their heading periods. It

was 5°–13°C lower in daily maximum temperature than that of the average from 1951 to 1980, during the periods from September 5 to 14. At that time, the tillers of M-302 and main culm of ED7 were just heading, and the tillers of Calrose 76 and M7, main culm of M-302 and Calrose 76 were beginning to head. In these genotypes, prolonged heading and drops in heading percentage were observed (Fig. 2).

In genotypes which headed before September 5th, an average heading date, indicated by arrows, was located at or after the peak of heading curve, whereas it appeared before the peak in genotypes which headed after that time. Tillers average heading date of M-302 or S-201 located after or at the peak, however, an average heading date of main culm appeared before the peak, and these two genotypes showed much more differences in average heading date between main culm and tillers. Judging from these facts, it seems that the degree of sensitivity to low temperature was higher in M-302 and S-201 than in Calrose 76 and M7, respectively.

The distance between collars of the flag and penultimate leaves (DBC) of main culm was recorded at booting stage, and regression of the number of days till heading to DBC was calculated from DBC and heading date of main culm which had the same flag leaf number in each genotype (Fig. 5 and Table 3). The number of days to heading from zero DBC showed a high correlation with average daily maximum temperature during the period

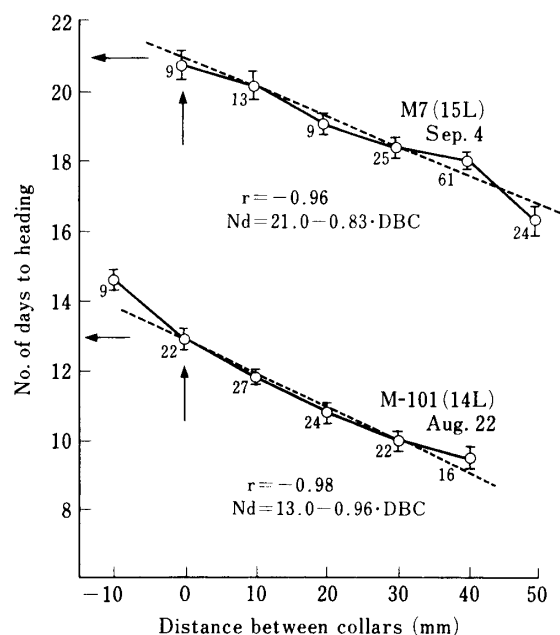


Fig. 5. Relation between number of days (Nd) to heading and distance between collars (DBC). Numerals under the curves indicate the number of plants investigated and vertical line at each point indicates the standard deviation.

Table 4. Decreasing rate of culm and internode length differing seeding date.

Group	Genotype	Culm length*	Relative culm length**	Internode length (cm)			
				Upper-most*	Relative uppermost**	Second*	Relative second**
		cm	%	cm	%	cm	%
A	ED7	57	90	19.8	71	14.2	82
	Calrose 76	54	87	20.0	76	12.9	76
B	M-101	57	89	22.3	82	14.6	85
	M-302	50	77	19.1	70	14.1	79
	M-7	50	83	18.7	71	13.1	77
C	ES-201	62	98	24.0	92	18.2	101
	S-201	49	85	18.7	80	12.1	82

* Averages of 20–60 main culm described in Fig. 3, which sown on June 8.

** Relative values of June data to May, averaged of 12 main culms which sown on May 9.

Table 5. Factors relating to early heading of ED7, M-101 and ES-201.

Group	Geno- type	Flag leaf number	Leaf emergence rate from Jul. 5-Aug. 8 (per day)	DBH at 50 mm DBC*	Average daily max. temp. **	Ff- fective temp.	Degree days (Nd*Te)	Second internode elonga- tion*** (mm)
				(Nd)	(Tm)	(Te=Tm-20)		
A	ED7	14.4	0.18	8.1	28.0	8.0	65	2.2
	Cal 76	14.7	0.18	13.4	24.9	4.9	66	2.0
B	M-101	13.9	0.18	8.2	31.3	11.3	93	1.6
	M-302	14.1	0.18	14.7	25.4	5.4	79	1.8
	M7	14.9	0.19	16.8	25.8	5.8	97	1.4
C	ES-201	15.0	0.22	8.5	33.0	13.0	111	1.6
	S-201	15.1	0.19	16.9	26.3	6.3	106	1.1

* Calculated from regression in Table 3.

** During the period from 50 mm DBC to heading.

*** Second internode length in Table 4 was divided by degree days.

from measurement date of DBC to average heading date of main culm. This means that low temperature delayed heading some extent through decreasing the uppermost internode elongation.

Extremely delayed heading of main culm in S-201: Although the main culm of Calrose 76, M7 and S-201 began to head at nearly the same time, the main culm of S-201 showed extremely delayed heading (Fig. 2). Low temperature during that period, of course, must be a cause of it. Delaying in S-201, however, was too much to be explained by only temperature effect compared to Calrose 76 and M7.

On one hand, S-201 main culm has had shorter young panicles at the stage of LNI 85-95 than that of tiller panicles (Fig. 4) and the uppermost and second internode length of S-201 were nearly the same as that of Calrose 76 and M7. However, the ratio of the uppermost and second internode length to that of May sown plants in S-201 was larger than that of Calrose 76 and M7, because the uppermost and second internode length of May sown plants in S-201 was less than that of them (Table 4). Moreover, it was observed that more than half of the plants showed delayed heading of main culm even in May sown plants. Judging from these results, delayed heading of main culm of S-201 seems to be a unique genotype characteristic.

Morphological characteristics in relation to heading: As stated above, earliness of genotype is

explained by basic vegetative growth, photosensitivity and thermosensitivity^{16,17)}. In general, short day length was accompanied by high temperature under field conditions, and rice plants have combined effects of them. In this experiment, only heading date observation was recorded in May sown plants (Table 1). So, the authors tried to approach to the earliness of the genotype from the viewpoint of morphological aspects.

Table 5 shows the flag leaf number, the leaf emergence rate and the second internode elongation rate. In group A, Calrose 76 is photoperiod sensitive^{3,13)}. So, differences in heading date between ED7 and Calrose 76 are mainly explained by photosensitivity^{3,12)} and partly by thermosensitivity of ED7. Pinheiro et al¹²⁾ found that ED7 headed in 23 days earlier in the glasshouse than in the field, compared to two day less for Calrose 76 in the same conditions. According to Wada's idea¹⁷⁾, it was considered that early heading of ED7 in glasshouse was mainly based on thermosensitivity. In morphological aspects, little difference was recognized in the flag leaf number and the leaf emergence rate. In group B, late genotype M7 is also photosensitive, but M-101 and M-302 are not photosensitive^{1,4)}. Therefore, the difference in heading date of M-101 and M7 was mainly ascribed to that of photosensitivity, and partly to the difference in the flag leaf number and the second internode elongation rate. However, in M-101 and M-302, no

difference was detected in any of them. In group C, both genotype are not photosensitive²⁾, and have the same flag leaf number. So, earliness of ES-201 was ascribed to higher leaf emergence rate during the period from July 5th to August 8 and to higher second internode elongation rate than that of S-201.

Differences among groups were noticeable in the degree days which were induced as the product of the number of days before heading at the stage of 50 mm in DBC and effective temperature which was defined as temperature higher than 20.0°C. The degree day was largest in Group C, smallest in group A, and intermediate in group B. It was considered that the larger the degree days, the longer period was required when they were hit by low temperature. So, deficit of effective temperature may be one of reasons that heading date of main culm of S-201 was delayed as compared to Calrose 76 and M7.

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