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Flag Leaf Number Determination of Secondary and Tertiary Tillers and Heading Characteristics of Rice Plants*

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Abstract : When the number of leaves on the main culm is known, the number of leaves on secondary to quarternary tillers can be determined based on the following growth characteristics and procedures, even if the lower leaves are no longer on the stem. Growth characteristics : a) The leaves are located on stem alternately. b) Left tip outside and right tip outside sheath wrapping also appear alternately. c) The tillers which emerged from the node of left (right) tip outside of sheath wrapping have left (right) tip outside sheath wrapping at the first leaf. Procedures : 1) Mark the leaves of the main culm and record heading date of all tillers in a plant on the flag leaf. 2) Dig out the plant at maturity and separate it into its primary tiller groups. 3) Arrange odd-numbered primary tillers on the left side of the main culm and even-numbered tillers on the right side, in order of emergence, from outside to inside. 4) If the main culm has an odd-numbered flag leaf with right tip outside sheath wrapping, or an even-numbered flag leaf with left tip outside sheath wrapping, the first leaf of primary tillers appears on the front side of the primary tillers. 5) The first tertiary tiller points toward the main culm and in the same way, the first quarternary tiller points toward its parental primary tiller.

Investigation findings : 1) Number of leaves on secondary and tertiary tillers of Moritawase and Norin 1 increased over the number of leaves of primary and secondary tillers, respectively. 2) Main culm of Moritawase heads first, whereas, in Norin 1, primary tillers head first. 3) Heading date of secondary tillers tend to be delayed when the number of leaves increased over that of the primary tillers.
Key words : Flag leaf number, Heading date, Main culm, Rice plant, Sheath wrapping, Tillers.

水稲2, 3次分げつの止葉葉位の識別と1, 2次分げつの出穂特性 : 松崎昭夫・中元朋実・町田寛康（東京大学農学部附属農場）

要　旨 : 主稈の止葉葉位が既知であれば，下葉が枯死・脱落してしまっていても次の性質と手順により，2-4次分げつの止葉葉位を識別することができた．基本的性質：葉（分げつ芽）はほぼ互生，葉鞘の巻方向も左右交互，左（右）巻の葉鞘着生節から出現した分げつの第1葉の葉鞘は左（右）巻を示す．調査手順：1次分げつ群に分解した偶数葉位の分げつ群を主稈の右側に奇数葉位の分げつ群を主稈の左側に置くと，主稈の止葉葉位が奇数で葉鞘が右巻（または偶数葉・左巻）の個体の1次分げつの第1葉の分げつ芽は上向きに出現し，2次分げつの第1葉の分げつ芽は主稈の側（内側）を向く．同様にして，主稈の止葉葉位が偶数で葉鞘が右巻（または奇数葉・左巻）の個体の1次分げつの第1葉の分げつ芽は下向きに出現し，2次分げつの第1葉の分げつ芽は主稈の側（内側）を向く．

この方法で，森田早生および農林1号の2，3次分げつの葉数と分げつ次位・節位別の出穂日を調査した結果，高次分げつの葉数はより低次位のそれよりも多くなる傾向があること，森田早生の主稈はどの1次分げつよりも早く出穂し，農林1号の中位の1次分げつは主稈よりも早く出穂すること，2次分げつの出穂は葉数増に伴って遅れることなどが明らかにされた．
キーワード : 主稈，出穂日，水稲，止葉葉位，分げつ，葉鞘の巻方向．

The first heading tiller in a rice plant is the main culm in some varieties, and a primary tiller in others. In general, heading time depends firstly on varietal characteristics and secondarily on cultural conditions such as seeding or transplanting time, and especially on temperature during the young panicle formation stage[1].

There is a difference in heading time of individual tillers of the same plant. Namely, heading date of the individual tillers differs 4-5 days even among primary tillers. According to the synchronous leaf growth theory which was proposed by Katayama[3], all tillers in each plant will head at nearly the same time. However, it is noted that the synchronous leaf growth theory was already disturbed around the maximum number of tillers stage[7, 9]. As a result, uniform young panicle differentiation

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Table 1. The flag leaf number of main culm, primary, secondary and tertiary tillers and their direction of leaf sheath wrapping.

	Calrose 76					Norin 8						
	1	2	3	4	5	1	2	3	4	5	6	7
Main culm	17R	16L	17R	17L	17L	21L	21R	21L	20R	21L	20R	21L
Primary tillers												
12								22L		21R		
11						21R	21L	22L		22L	21R	21R
10				17R		21R	20R	22L	20L	22L	20L	21R
9	17L	16R	17L	17R	17R	21R	21L	22L		22L		
8	17L	16R	17L	17R	17R	21R	21L	22L	19R		20L	21R
7	17L	16R	17L	17R	17R	21R	19L	22L	19R		19R	20L
6	17L	16R	17L	18L		21R	19L		19R			21R
5	17L	17L	17L	17R	17R		20R				19R	
Secondary tillers												
92								23L				
91						22R		23L		22R		
9P						22R				21L		
83								23L				
82						22R	22L	22R			20R	21L
81				18R		22R	22L	21L			21L	21L
73						22R		22R				22R
72						22R	21R	22R			20R	20R
71	18L		17R	18R		22R	20L	22R	19L		20R	21L
7P	18L	17R			17L						20R	
64												21L
63						22R						20R
62	17R			18R		22R	20L		19L			20R
61	17R	17R	17R	18R		21L	20L		19L			20R
53				17L								
52	(18R)	17R		18R	17L							
51	(18R)	17R	17R	18R	17L							
5P		17R										
Tertiary tillers												
612							22R					
611							21L					21R
412			(19R)									

1. Flag leaf number of tillers was converted into the corresponding leaf position of main culm based on the synchronous leaf growth theory. As to "L" and "R", see Fig. 1.
2. Parentheses indicate that they did not obey the regularity of leaf arrangement.

and heading time among individual tillers can not be expected even in the same plant.

In this report, the authors tried to investigate the difference of heading time among varieties and determine the number of leaves on secondary to quarternary tillers, when the flag leaf number of the main culm was known.

Materials and Methods

Cultivars Moritawase and Norin 1 were

sown on April 17, 1987, in a conventional style nursery bed, and transplanted as 6 leaf age seedlings on May 29 at a plant density of 30×15 cm, with one plant per hill. To ascertain the flag leaf number of the main culm, every even-numbered leaf on the main culm was marked by a felt pen or an acrylic color paint. Heading date of each individual tiller was also recorded on flag leaf on the day when the tip of the panicle emerged a little from its leaf sheath. At maturity, individual plants were dug out and separated into primary tiller groups. Then heading date of tillers was totaled across different plants for the main culm and for the corresponding primary tillers and secondary tillers in each plant. Between 35 and 40 plants per cultivar were investigated. Flag leaf number of Calrose 76, Norin 8 and other cultivars were also investigated to ensure there was regularity of leaf sheath wrapping arrangement.

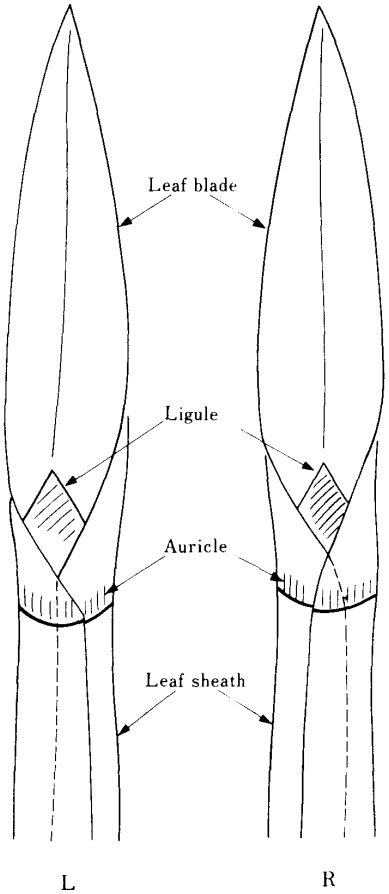

Fig. 1. A schematic expression of wrapping direction of leaf sheath, where L=Left tip outside (right tip inside) and R=Right tip outside (left tip inside).

Results

Determination of flag leaf number on secondary and tertiary tillers:

Based on previous knowledge[5, 6, 10~12] and on the results of preliminary investigations, the authors were able to determine the flag leaf number of secondary to quarternary tillers at maturity under the following conditions and procedures, if the flag leaf number of the main culm was known.

1. Fundamental characteristics of leaf development:

1) Leaves or tiller buds attached almost alternately on the stem[4, 5].

2) Expressing "L" as the left tip outside of the leaf sheath wrapping and "R" as the right tip outside of the leaf sheath wrapping (Fig. 1.), "L" and "R" appeared also alternately[5].

3) An example of the flag leaf number and

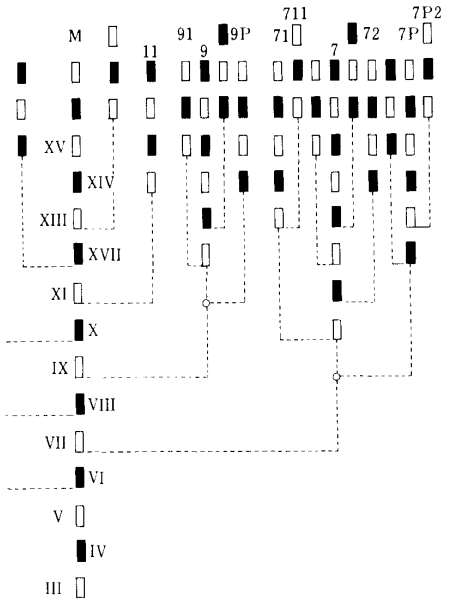

Fig. 2. A schematic expression of node position and wrapping direction of leaf sheath in individual tillers of a rice plant, where white column=left (or right) tip outside of sheath wrapping and black column=right (or left) tip outside of sheath wrapping.
For example, the first leaf of every tiller has the same wrapping direction (left or right tip outside of sheath) as the leaf at the node from which the tiller came, and leaves in the same nodal positions of same ordered tillers also showed the same direction of sheath wrapping.

the sheath wrapping direction was shown in Table 1. From the data of Table 1, alternate sheath wrapping direction[5] and the fact that the sheath wrapping of the first leaf of each tiller showed the same direction as the leaf sheath originating at the same node from which the tiller appeared, the following relationships were recognized (Fig. 2.) ; The sheath wrapping of synchronous growth leaves of tillers which appeared from the same parental tiller, for example, synchronous leaf positions 7, 9 and 11 in primary tillers and 7 P, 71 and 72 in secondary tillers, showed the same direction. Moreover, in the case of the main culm (M) and secondary tillers (7 P, 71, 72, 9 P, 91 and so on), and primary tillers (7, 9, 11 and so on) and tertiary ones (7 P 2, 711, and so on), the sheath wrapping of synchronous leaves also showed the same direction. However, opposite direction of sheath wrapping in synchronous growth leaves was found between the main culm and primary tillers, primary and secondary tillers, and secondary and tertiary tillers.

2. Procedures to determine flag leaf number :

1) Separate tillers into primary tiller groups.

2) Then arrange primary tiller groups which originated from even-numbered nodes on the main culm on the right side of the main culm, and primary tiller groups which originated from odd-numbered nodes on the left side of the main culm, in order of emergence, from outside to inside as shown in Fig. 3.

3) Tiller buds which emerged from the first node of primary tillers appeared on the front side of primary tillers as shown in Fig. 4, when the main culm had an odd flag leaf number with "R" sheath wrapping or an even flag leaf number with "L" sheath wrapping.

4) Tiller buds which emerged from the first node of primary tillers appeared on the back side of primary tillers when the main culm had an odd flag leaf number with "L" sheath wrapping and an even flag leaf number with "R" sheath wrapping.

5) Tiller buds which emerged from the first node of secondary tillers pointed toward the main culm.

6) Tiller buds from the first node of tertiary tillers pointed toward their parental primary tiller which corresponded to the relationship between the first tiller buds of secondary tillers

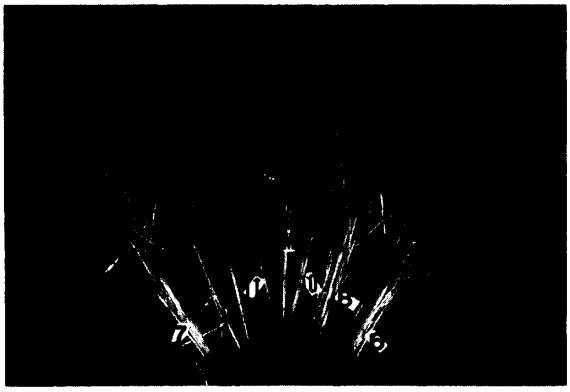

Fig. 3. An arrangement of primary tillers of the same plant to determine the flag leaf number of secondary to quarternary tillers. Odd-numbered primary tillers were placed on the left side of the main culm (M) and even-numbered ones on right side, in order of emergence, from outside to inside.

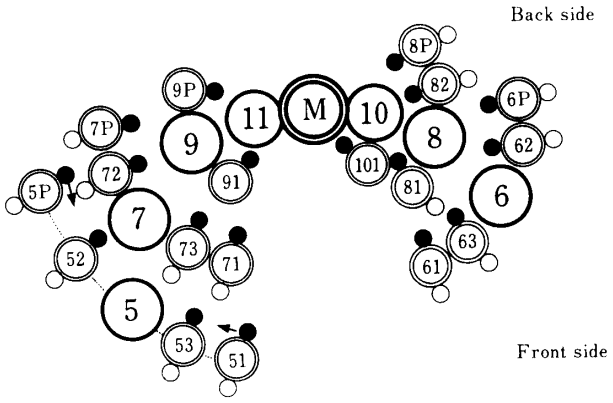

Fig. 4. A schematic arrangement of the tillering system in a rice plant with an odd-numbered flag leaf and right tip outside of sheath wrapping (or an even-numbered flag leaf and left tip outside of sheath wrapping). In this case, the first leaf of primary tillers appeared on the front side of primary tillers which were arranged as shown in Fig. 3.
M = Main culm ; 5, 6------11 = Primary tillers ;
51, 61------101 = First leaf (or tiller bud) of primary tillers ;
Black circle = First leaf (or tiller bud) of secondary tillers ;
Arrow = First leaf (or tiller bud) of tertiary tillers.

Table 2. Error of the proposed method to the traditional ring method to investigate the leaf and shoot development.

Node Position on main culm	Primary tillers	Secondary tillers					
		P	1	2	3	4	Total
11	0/15						
10	1/44						
9	1/47	0/3	0/18				0/21
8	1/47	3/32	1/38	1/12			5/82
7	2/42	1/13	1/39	0/36	0/8		2/96
6	2/22		4/16	0/19	0/12		4/47
5	0/23		0/12	0/20	0/19	0/9	0/60
Total	7/240	4/48	6/123	1/87	0/39	0/9	11/306
Error %	2.92	8.33	4.88	1.15	0	0	3.59
Grand total							18/546
Error %							3.30

1. A numerator shows the number of tillers in which the flag leaf number did not accord with the number counted by traditional method and a denominator the number of tillers investigated.
2. A single plant of Norin 1 was transplanted in a/2000 wagner pot at 6th leaf age on June 8. Two plants were raised in a pot with 24 replications.

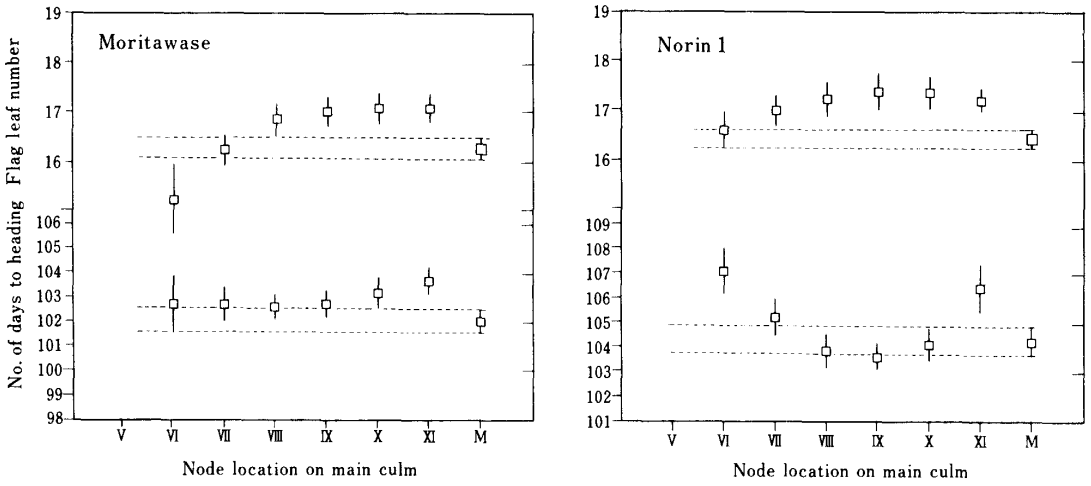

Fig. 5. Flag leaf number and number of days to heading from seeding of primary tillers (VI-XI) and main culm (M) of cultivars Moritawase and Norin 1. Longitudinal bars show the confidence limit at the 95% level.

and the main culm. In other words, tiller buds from the first node of secondary through quarternary tillers pointed toward their great grandparents, i.e., the main culm through secondary tillers, respectively. These results agreed with the leaf arrangement which was reported by Kawashima et al.[4].

7) According to the procedures mentioned above, the flag leaf number of all tillers in a plant could be determined at maturity, even if the lower leaf blades were dead and detached already. The reliability of this method was confirmed by the fact that 96.7% of investigated tillers accorded well with the results obtained from the traditional one (Table 2.).

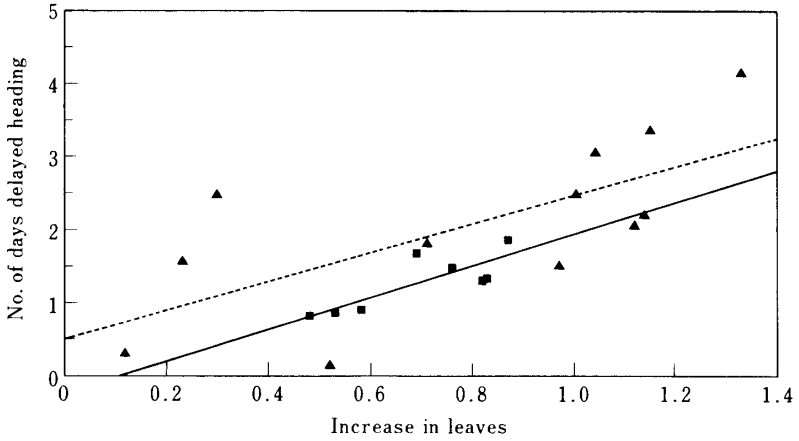

Fig. 6. Relationship between the increase in leaf number of secondary tillers over primary tillers and delayed heading of secondary over primary tillers.
Solid line with the square ; Moritawase $Y=2.16X-0.23$, $r=0.820^*$
Dotted line with the triangle ; Norin 1 $Y=1.95X+0.53$, $r=0.696^*$

Relation between the flag leaf number and heading date of primary tillers :

The flag leaf number and heading date of primary tillers of cultivars Moritawase and Norin 1 were shown in Fig. 5. The flag leaf number of primary tillers on node number VIII-XI was higher than that of the main culm in both cultivars, and the flag leaf number tended to increase as the node number increased. Heading date of primary tillers differed between cultivars. The main culm of Moritawase headed earlier than all primary tillers, and heading of primary tillers which originated from higher nodes along the main culm tended to be delayed. In Norin 1, on the other hand, heading of primary tillers which were located at intermediate nodes along the main culm was earlier than that of the main culm. However, primary tillers located above and below the intermediate nodes headed later than the main culm. Consequently, the difference in heading date between the earliest and last headed tillers was more than 4 days.

In general, tillers originating at higher node levels had fewer leaves than tillers originating at lower node levels on the same maternal tillers[3]. However, the authors observed that headed tillers had at least two leaves, not counting prophyl.

The flag leaf number and heading date of secondary tillers :

In both cultivars, the flag leaf number of secondary tillers was higher than that of parental primary tilllers. Heading date of secondary tillers in both cultivars tended to be delayed in proportion to the increase in leaf number of secondary tillers over parental primary tillers, and a high correlation was found between them (Fig. 6).

The flag leaf number of tertiary tillers also tended to increase over that of parental secondary tillers[2, 8], though only a few tertialy and quarternary tillers were observed.

Discussion

If the number of leaves on the main culm was known by marking with a felt pen or something similar, the flag leaf number of all tillers in an individual plant could be determined, even if lower leaves were already detached from their culms at maturity.

Previously, a ring method which tagged newly appeared tillers with a colored ring or similar was usually applied to distinguish individual tillers in a plant. This procedure was so laborious that the number of plants in an experimental plot had to be limited. The method described in this paper does not need to trace individual tiller emergence, so a great number of plants can be investigated for better results. The authors could separate and investigate 40-60 plants per day, depending on the number of available panicles per plant. As for the variation of heading date among

primary tillers, it appeared sufficient to deal with 40 plants per cultivar, judging from the confidence limit of 95% as shown in Fig. 5. Regarding the flag leaf number of primary tillers, 40 plants were sufficient for many other cultivars because there was less variation in flag leaf number as compared with heading date.

Delayed heading of secondary tillers compared with primary tillers depended on their increased number of flag leaves. However, the first heading of IX node tillers in Norin 1 could not be explained by the flag leaf number, because it showed a maximum number among primary tillers (Fig. 5.). The same phenomenon was observed in Moritawase. It is possible that these phenomena was due to the difference of young panicle differentiation time of tillers as pointed by Asakuma[1].

Differences in young panicle initiation among individual tillers still remains a problem to be solved at a future date.

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