Effect of Different Temperatures Given to the Culm-Base of Rice Plant on the Emergence and Elongation of its Tiller under Controlled Environment

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Abstract : The emergence and elongation of the tiller buds of rice plants are greatly affected by the environmental temperature, especially by the temperature around the culm-bases where the tillers differentiate. Temperature switching from low to high and vice versa was carried out and varieties used were Norin 1 and Zosan 1. The experiments were conducted in growth cabinets at 25°C (light) and 18°C (dark).

The results : (1) Compared with those given no temperature treatment, tillers increased in number in low temperature treatment (15°C). On the contrary, emergence was inhibited in the high temperature treatment (33°C). (2) In Zosan 1, the emergence of secondary tillers ceased completely, while in Norin 1, there were six secondary tillers in the high temperature treatment. (3) In the temperature switching treatments in the 8th leaf stage of the main stems, the tillers which were inhibited in growth during the supply of high temperature water emerged after switching in the former treatment, and, synchronous regularity was disturbed in this case. In the latter, on the contrary, those which had emerged without interruption under low temperature conditions were inhibited in growth after switching to high temperature. The inhibition of emergence by high temperature was more conspicuous in Zosan 1 of the heavy panicle type.

Key words : Culm-base, Environment, *Oryza sativa*, Plant type, Synchronously emerging tiller, Tiller.

制御環境下で水稻稈基部の温度処理が分げつの伸長に及ぼす影響：柿崎洋生（東北大学遺伝生態研究センター）

要 旨：水稻分げつ芽の出現伸長には温度の影響が大きく、中でも分げつ芽の分化形成する稈基部温度の影響が大きい。制御環境下で直播栽培した水稻稈基部に3葉期から冷水（15°C）、温水（33°C）を通水したシリコンチューブ巻き、部分的温度処理を行い、草型の異なる2品種間で分げつ芽の出現伸長を比較した。結果、15°C 処理で生育、出葉展開は鈍るが、分げつは順次出現した。33°C 処理では生育は促進され出葉も早まるが、分げつの同調性は乱れ出現数も減少した。主稈8葉期に通水温を冷、温切り替えると33°C 処理で出現抑制を受けてた分げつが、15°C に変り本来の対応主稈葉との同調性に関係なく遅発ながら出現してきた。また、15°C 通水を33°C 通水処理に切り替えた結果、その後の分げつ出現は停止した。33°C 処理による分げつの出現抑制は少げつ型品種で顕著であった。水稻分げつ芽の出現伸長には環境温度が稲の生育の適温範囲内であるならば分げつ芽の分化着生する稈基部温度の影響が極めて強く、分げつ数の確保には比較的低い温度が効果的である。また、分げつの出現伸長の適温域も草型によって異なり、少げつ型が多げつ型に比べ高い温度域での影響を強く受け、伸長生長を休止する分げつが多かった。

キーワード：稈基部、環境、草型、水稻、同伸分げつ、分げつ。

The emergence and elongation of tillers vary to a large extent with environmental factors. Especially, the part played by light and temperature is greater than any other factor, with plant type also exhibiting different responses to the same factors as shown in the previous paper⁹⁾. In his synchronous emergence and elongation theory, Katayama clarified that tillers and main stems grow with regularity, and that there is a synchronism in emergence between main stems and tillers and further, between tillers themselves. The temperature range suitable for the elongation of tillers is narrower than that appropriate for the

development of the leaves of the main stems ; low temperature makes the growth of rice plants themselves slower, and consequently, the increase in tillers is reduced. On the contrary, high temperature causes an increase in plant height and the acceleration of leaf development, exhibiting that it takes, at low temperature, about six days to develop a single leaf of the main stem, while at high temperature only 3.5 to 4 days. As reported in the previous paper⁹⁾, synchronism in emergence between tillers and leaves is disturbed in this case.

In general, temperatures suitable for the emergence and elongation of tillers after

differentiation are known to be limited. Matsu-shima et. al.¹²⁾ report that the temperature effective for the increase of tillers is about 16°C, and Sato¹³⁾, examining the relationship between the tiller growth and air temperature, concludes that the temperature suitable for the increase in tillers is lower than that appropriate for the increase in leaf ages, exhibiting that it is 25°C (day) and 20°C (night). In the previous paper⁸⁾, the author also reports that, as the given temperature grows higher, the leaves of the main stem emerge and elongate more speedily, but that the tillers which have emerged are the largest in number at 18.5°C and the smallest at 30°C. He refers to the inhibition by high temperature, adding that as the temperature grows higher, tillering synchronizes less with the emergence of the leaves of the main stem.

For this study, series of experiments were made to examine whether the environmental temperature surrounding a whole plant body or the temperature around its basal part where tiller bud differentiates has a greater effect on the emergence of tillers. The effects were traced by using growth cabinets, where temperature were controlled so as to be suitable for the growth of rice plants and the increase in their stems, and, at the same time, temperature treatments were given to their culm-bases. The results indicated that temperature around the culm-bases had marked effects on the emergence of tillers.

Fig. 1. Temperature treatment of culm-bases.

A : Silicone tube. B : vermiculite.

C : pot. D : water bath. E : water circulation. F : water level.

Materials and Methods

Experiments were made in two growth cabinets (KG-206 Type, Koito manufacturing Co.) under a 12h light and 12h dark cycle at 25°C (light) and 18°C (dark). Varieties used were Norin No. 1 (many panicle type) and Zosan No. 1 (heavy panicle type). These were chosen to make clear the differences in responses between plant types. The culture was vermiculite added with ammonium sulphate, superphosphate of lime and potassium chloride prepared so that N.P.K. might be 0.3 g respectively. After the fertilizers were dissolved in the water, the solution was mixed with the vermiculite. Then the culture was put into pots 10 cm in diameter and 15 cm in depth. Sterilized and forced to sprout, the seeds were sown (Oct. 23, 1989) and raised in the cabinets. When they completed the first two leaves respectively, the plants, uniform in growth, were left as they were, one plant per pot, and for removal the rest were cut off at the surface of the culture. Figs. 1 and 2. show the experimental equipment.

The basal parts were encircled with a penrose drain, a silicon tube used for clinical purposes, with a 12 mm lumen and 0.2 mm thickness, supplying a constant flow of water, cooled or warmed at the desired temperatures by a Coolnics Circulator. The treatments were begun at the time of the emergence of the 3rd leaf. Fig. 3. shows microscopic photos of the basal parts treated. Five kinds of treatments were adopted ; (1) water at 33°C was supplied throughout the experiment (H), (2) water temperature was 15°C during the same period as in H (L), (3) switching water temperature from 33°C to 15°C was carried out when the

Fig. 2. Plants undergoing temperature treatment in the growth cabinet.

8th leaf appeared from the surrounding leaf sheath (HL), (4) the temperature was switched from 15°C to 33°C, the other conditions being nearly the same as in HL (LH), (5) no temperature treatment was given throughout the whole period (C) (Fig. 4.). The plants were divided into separate groups, each consisting of 10 plants. Daily observations were made on the emergence of a tiller and a leaf on the main stem at every node and leaf position. The temperature at basal parts was also read every 3 hours after the onset of irradiation.

Results and Discussion

At first it must be mentioned that temperature treatments to basal parts by this method should have effects on the shoot apices of the main stems themselves, because the plants are too short soon after the beginning of the experiments, as shown in Fig. 3.

The temperature at the basal parts (Fig. 5.) under the H and L treatments indicated that the water circulated almost properly in the tube, keeping the desired temperature.

Since the development of the main stems was affected by the temperature treatments around the basal parts, the relation in number

between days after seeding and the emergence of leaves of the stem was exhibited in Fig. 6. The emergence of leaves was earlier in the high temperature treatment (H) than where no temperature treatment was given (C). On the 52nd day from seeding, Norin No. 1 and Zosan No. 1 had 11 leaves in the C treatment. On the same day, both the varieties showed that in the cool treatment throughout the experiment (L) the growth of leaves was slow in speed; the 9th leaf was developing in Norin No. 1 and the 10th in Zosan No. 1, revealing that growth was slower in the L treatment than in the H and C treatments. In the HL treatment, the emergence of leaves was faster during the warm-water-supplying period, though the speed slowed down after temperature switching. In the LH, however, the speed of leaf emergence was slow in the cool-water supplying period, though it was accelerated in response to the change from low to high.

Between the two varieties, differences were observed in the number of days from seeding until the emergence of the 8th leaf blade out of

Fig. 3. Cross section of the part of culm-base under temperature treatments.

Fig. 4. Experimental design.

Fig. 5. Temperature at the culm-base and its measuring point.

Fig. 6. leaf age of main stem.

the 7th leaf sheath. In Norin No. 1, the leaf tip appeared on the 28th day in the C treatment, on the 27th day in the H, and on the 35th (7 days later than in the C treatment) in the L. In Zosan No. 1, the emergence was observed on the 26th day in the C and H, and on the 31st day (5 days later than in the C and H treatments) in the L. The delay of leaf emergence in the L treatment is thought to be due to the effect of the cool water in the early growth stage on the shoot apexes with the result that the development of the leaves of the main stems was inhibited.

Since the speed of leaf emergence varies, as given above, with the temperature adopted for the treatments, it is not reasonable to compare the numbers of tillers based on the numbers of days after seeding. Therefore, the tillers which were observed to emerge in response to their corresponding leaf positions on the main stem are shown according to Katayama's theory (Fig. 7.). The leaf positions of the main stem, are given on the horizontal line in the lower part of the figure and, on the left side, are shown from down upwards primary, secondary, and tertiary tillers. Chain lines denote the leaf positions at which the corresponding

tillers should emerge in Katayama's theory. Tillers whose emerging positions are shown on the left side of the chain lines have appeared earlier, and those on the right later than the regular ones in the theory. Tillers which have not emerged outside the leaf sheaths owing to dormancy are not given in this figure. In Fig. 7. A (Norin No. 1) and B (Zosan No. 1), the results of the L and H treatments are placed for comparison on those of the C; in Fig. 7. C and D, the results of the HL on those of the H treatment and in Fig. 7. E and F, the results of the LH on those of the L. Table 1 shows differences in emerging time between the tillers and leaves of the plants treated and those in the theory. According to the theory, the primary tillers which emerge synchronously until the 7th leaf stage of the main stem are 4 in number, nos 1 to 4, and the secondary one is one, No. 1-1. Until the 7th leaf stage, most of them emerged as in the theory with the exception of tiller No. 1, revealing synchronism with the development of the leaves of the main stem. Because of the dormancy of the tiller No. 1 on the mother stem, it was not thought in this case that the secondary tiller No. 1-1 could emerge, though the other tillers emerged almost to support the theory. The tiller No. 1, which should have emerged in theory synchronously with the 4th leaf stage, was scarcely observed in the experiments; there was only one example in the case of Norin No. 1 in the L treatment, and the emergence was in the stage for the tiller No. 2 to appear one leaf stage later. In Zosan No. 1 there was no emergence of the tillers nos. 1 and 2, which did not appear to support the theory. Differences between the results obtained and the tillering in the theory did not exceed more than the one leaf stage in both the varieties.

In Zosan No. 1 H treatment, the primary tillers to emerge decreased in number due to the supply of high temperature water, showing only five, nos. 3 to 7, and there was no secondary tiller in contrast to four secondary ones, nos 3-1, 4-1, 4-2, 5-2 in the case of C. With regard to Norin No. 1 in the H treatment, there were thirteen tillers, seven primary and six secondary tillers. In rice plants of the many panicle type, high temperature given to the culm-bases had conspicuous effects on the emergence of tillers, though there was little difference in number between emerging tillers

Fig. 7a. Differences in emergence time between the leaves and tillers treated and those in the theory.

Fig. 7b. Differences in emergence time between the leaves and tillers treated and those in the theory.

in the high temperature treatment and those in the C, revealing that high temperature produces a different effect on rice plants of many panicle type from the effect on those of heavy panicle type, which are markedly inhibited in growth by high temperature.

In Fig. 7, C and D are shown the results of the HL treatment. In the case of primary tillers of Norin No. 1 they emerged at nodes corresponding to those in the H treatment, showing no difference. However, tillers emerged at high node order as well, after the supply of the water of low temperature (15°C), being four tillers more than those in the H treatment. There was no emergence of secondary tillers in the case of Zosan No. 1 in the H treatment. In the HL treatment, however, after temperature switching, the tillers whose emergence had been inhibited assumed full activity, and primary tiller No. 2, which had differentiated but stayed dormant, also appeared; they summed up to thirteen, including seven secondary tillers and the primary tiller No. 2, which emerged three leaf-stages later, being 2.6 times as many as those in the H treatment.

In Fig. 7, E and F are shown the results of the LH treatment. Temperature switching caused the primary tiller No. 8 to stop growth

in Norin No. 1, though it emerged in the L treatment. However, the tillers, nos. 6 and 7 to emerge synchronously with the 9th and 10th leaves of the main stem were observed in the 8th leaf stage. With regard to this, the following reasoning was possible: when the 8th leaf was observed from outside, the tiller buds had differentiated inside in accurate correspondence to the 9th and 10th leaves and had been elongating, though at a very slow speed, and as a result of accelerated growth in response to high temperature, appeared outside the leaf sheaths. After temperature switching, secondary tillers numbered 10 in contrast to thirteen in the L treatment, excluding four tillers thought to have been elongating and emerged soon after the switching. Zosan No. 1 exhibited the same tendency; the tiller No. 7, which did not emerge during the supply of the water of low temperature, entered into dormancy, and in addition secondary tillers nos. 3-3, 4-2, 5-1 and 5-2 which should have emerged in the theory, did not appear as a result of inhibition by high temperature. They were four tillers less than those in the L treatment.

As revealed by the above-mentioned facts, at low temperature (15°C), tiller buds continue to grow, though at a very slow speed,

Table 1. Differences in emergence time between the leaves and tillers treated and those in the theory.

Table 1-A		Norin 1 H. HL.									
leaf position on the stem		3	4	5	6	7	8	9	10	11	12
primary tiller		1	2	3	4	5	6	7	8	9	
H		—	—	5.1	5.5	6.6	7.8	9.1	10.6	11.5	—
HL		—	—	5.1	5.6	6.6	8.0	8.9	9.8	10.6	—
	secondary tiller				1-1	1-2	1-3	1-4	1-5	1-6	
					—	—	—	—	—	—	
					—	—	—	—	—	—	
					2-1	2-2	2-3	2-4	2-5		
					8.5	9.6	—	—	—		
					8.4	9.0	9.9	10.6	—		
					3-1	3-2	3-3	3-4			
					8.7	9.9	—	—			
					9.1	10.0	10.6	—			
					4-1	4-2	4-3				
					9.9	11.3	—				
					9.8	10.4	—				
					5-1	5-2					
					—	—					
					10.5	—					
					6-1						
					—						
					—						

Table 1-B		Norin 1 L. LH.									
leaf position on the stem		3	4	5	6	7	8	9	10	11	12
primary tiller		1	2	3	4	5	6	7	8	9	
L		—	5.1	5.0	5.6	6.1	6.7	7.6	8.1	8.9	—
LH		—	5.0	5.2	5.6	6.2	6.8	7.4	7.7	—	—
	secondary tiller				1-1	1-2	1-3	1-4	1-5	1-6	
					—	—	—	—	—	—	
					—	—	—	—	—	—	
					2-1	2-2	2-3	2-4	2-5		
					6.1	6.7	7.4	8.0	—		
					6.2	6.8	7.3	8.1	—		
					3-1	3-2	3-3	3-4			
					6.8	7.6	8.1	8.4			
					6.8	7.4	8.1	—			
					4-1	4-2	4-3				
					7.4	7.9	8.5				
					7.3	8.4	—				
					5-1	5-2					
					7.9	8.4					
					8.7	—					
					6-1						
					—						
					—						

Table 1-C		Zosan 1 H. HL.									
leaf position on the stem		3	4	5	6	7	8	9	10	11	12
primary tiller		1	2	3	4	5	6	7	8	9	
H		—	—	—	5.9	6.8	7.9	8.7	10.0	—	—
HL		—	—	7.8	5.7	6.8	8.1	8.9	9.7	—	—
	secondary tiller				1-1	1-2	1-3	1-4	1-5	1-6	
					—	—	—	—	—	—	
					—	—	—	—	—	—	
					2-1	2-2	2-3	2-4	2-5		
					—	—	—	—	—		
					9.7	10.2	—	—	—		
					3-1	3-2	3-3	3-4			
					—	—	—	—			
					8.9	9.5	—	—			
					4-1	4-2	4-3				
					—	—	—	—			
					9.7	10.1	—				
					5-1	5-2					
					—	—					
					10.0	—					
					6-1						
					—						
					—						

Table 1-D		Zosan 1 L. LH.									
leaf position on the stem		3	4	5	6	7	8	9	10	11	12
primary tiller		1	2	3	4	5	6	7	8	9	
L		—	—	5.7	6.2	6.5	7.0	7.6	8.5	—	—
LH		—	—	5.7	6.2	6.7	7.2	7.7	—	—	—
	secondary tiller				1-1	1-2	1-3	1-4	1-5	1-6	
					—	—	—	—	—	—	
					—	—	—	—	—	—	
					2-1	2-2	2-3	2-4	2-5		
					6.9	7.6	—	—	—		
					6.9	7.7	—	—	—		
					3-1	3-2	3-3	3-4			
					7.3	7.9	—	—			
					7.5	8.1	—	—			
					4-1	4-2	4-3				
					7.9	8.5	—				
					7.8	—	—				
					5-1	5-2					
					8.3	8.7					
					—	—					
					6-1						
					—						
					—						

and emerge outside the leaf sheaths as grown-up tillers under favorable conditions. And once tillers begin to grow and elongate after differentiation, they seldom stop the activity, and their growth and elongation are not inhibited but promoted all the more by high temperature, though tiller buds shortly after differentiation, especially in secondary tillering, are inhibited. Norin No. 1 is different in response to high temperature from Zosan No. 1, suggesting their hereditary properties due to plant type.

By using the specimens prepared by the

paraffin method, microscopic observations were made on tiller buds in the state of dormancy under unfavorable conditions, such as high temperature after their differentiation at the leaf axils of the mother stems. The results are shown in Table 2. They neither withered nor suffered from yellowing as reported in the previous paper¹⁰⁾ and were about 3 to 4 mm in length. Many of them had four, and some five differentiated leaves, including prophylls. There was little difference in this tendency between the two varieties.

Matsushima et. al.¹²⁾ mention it in their

Table 2 Differentiated tiller in dormancy observed under microscope

differentiated leaves		primary tiller			secondary tiller					
		1	2	8	2-3	3-1	3-2	3-3	4-1	4-2
Zosan 1	number length (mm)	3 2.7	4 3.4	4 3.2		4 3.8	4 3.9	3 3.4	4 3.5	3 3.2
Norin 1	number length (mm)	4 3.7			4 3.2			4 3.4		

F.A.A fixed Paraffin method

report that the number of tillers is the smallest at 31°C and the largest at 16°C around the culm-base, and that the temperature there produces more marked effects than that around the roots. Furthermore, after examining the positions where tillers emerge, they add that at 16°C, the node order where tillering can be observed is low but that at 31° and 36°C no tiller emerges at low node order, suggesting that the tiller bud which has stopped elongation, though differentiated, reopens its activity, when the culm-base is given low temperature. In this study as well, the points they took notice of were examined by switching temperature around the culm-bases at the 8th leaf age and it was ascertained that the tiller buds which had been in dormancy after differentiation under high temperature conditions, reopened growth and elongation, when low temperature was given, and that the tiller buds which continued to emerge in regular succession under low temperature conditions stopped growth under high temperature conditions. And it was also made clear that the buds which did not appear, did not wither at once, but reopened growth and elongated under the low temperature conditions with the result that leaf-tiller synchronous emergence was disturbed, and that the high temperature condition strongly inhibited the emergence of high-order tillers.

From the above results can be drawn the following: Although the environmental temperature surrounding plant bodies is, without doubt, a factor of great importance in their growth, the temperature around the culm-bases, where tiller buds differentiate at nodes, has marked effects on the elongation after differentiation. Providing that the environmental temperature is favorable to the growth of rice plants, high temperature conditions

around the culm-bases causes the elongation of the leaves of the main stems without bringing about the growth of tiller buds, each of which, having differentiated into 4 to 5 leaves, remains dormant. Though in the state of dormancy, they do not wither in a short time, and when conditions become favorable, some of them begin their delayed growth, disturbing tiller-leaf synchronism, and grow up to be complete tillers.

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