Studies on the Yield and Yield Components of Rice under Different Environmental Conditions I. On the duration of flower-bud formation and young panicle development under different conditions in rice[1]

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ABSTRACT

The process of flower-bud formation and young panicle development of rice was studied under the conditions of different varieties, crop seasons, locations and methods of fertilizer application. Twenty one developmental stages of young rice panicles reported by Matsushima and Manaka(5) were identified and thoroughly described after the detailed microscopic studies.

In the first crop, the panicle differentiation begins 47days after transplanting in Taipei (45 days in Chiayi) and is completed in 35 days (36 days in Chiayi). In the second crop, the young panicles begin to differentiate 16 days earlier than those of the first crop. Duration of panicle formation in the second crop is 38 days in Taipei (Northern Taiwan), and 33 days in Chiayi (Central Taiwan). It was noticed that the growth period of young panicle differed according to different tillers within a plant.

The high correlation coefficients (r=0.80~0.90) between growing date and developmental stage of the young panicles indicated that the growth of young panicle is in parallel to the growing days. No marked difference in the mean values of developmental stages of young panicle due to spacings was noticed.

INTRODUCTION

The flower-bud formation and the related problems in rice were first studied by Yamazaki(9) and later by Noguchi(7) and Fucke(1). Matsushima(5,6) made critical studies on young panicle formation in rice and divided the process into 21 steps, proposing that yield could be increased if the fertilizer application times were adjusted according to the

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different developmental stages of the young panicles.

Shih *et al*[8]. determined the timing of panicle initiation by light microscopic and scaning electron microscopic examination on shoot apex of rice. They indicated the positive effect of foliar application of fertilizers and growth regulators at the panicle initiation stage of the second crop rice. Lin[4] made an anatomical study on the panicle and spikelet development of rice with special emphasis on the differentiation of vascular bundle in a young panicles.

The writer[8] analyzed the yield components with the 1st and 2nd crop rices, and found the number of primary rachis was greater but the number of spikelet, percent seed setting and panicle weight were smaller in the second crop. Fertilizer application at the proper time based on the growth of young panicles was considered to be very important to promote the yield componets and grain yield. In this connection, the present experiment was aimed to study the flower-bud formation and development of young panicles under different locations, crop seasons, spacings to facilitate determining the timing of fertillizer application.

MATERIALS AND METHOD

1. Varieties:

Four rice varieties, two of the japonica type, and two of the indica type were used. The name and characteristics of the varieties are given in Table 1.

Table 1. Varieties used in the experiment

	Name of varieties	Panicle type	Classification	Growth duration (days)	
				1st crop	2nd crop
V_1	Taichung 65	panicle number	*japonica*	119	100
V_2	Chianung 242	panicle weight	*japonica*	124	105
V_3	taichung(n) 1	panicle number	*indica*	123	97
V_4	Tsai-yuan-Chung	panicle weight	*indica*	116	99

2. Planting densities:

Three planting densities were used, viz.,

S_1	22.5×22.5 cm	64	plants/2 m^2
S_2	27.0×13.5 cm	86	plants/2 m^2
S_3	18.0×18.0 cm	100	plants/2 m^2

3. Methods of fertilizer application:

Fertilizer levels; N:P:K=100:80:80 kg/ha. The same amount of fertilizer was applied in three ways. (1) fertilizer was applied twice, once as a basal dressing, and once as a top dressing (F_1). (2) One additional top dressing at the panicle formation stage was applied (F_2). (3) In addition to "panicle fertilizer" applied at the panicle formation stage,the fourth top dressing was made at the heading as "grain fertilizer" (F_3). The rate of fertilizer application is given in the following:

	Top dressing			
	Basal dressing	Tillering stage	Panicle fertilizer	Grain fertilizer
F_1	$\frac{1}{4}N+K$	$\frac{3}{4}N$		
F_2	$\frac{1}{4}N+\frac{1}{2}K$	$\frac{1}{2}N+\frac{1}{2}K$	$\frac{1}{4}N$	
F_3	$\frac{1}{4}N+\frac{1}{2}K$	$\frac{2}{5}N+\frac{1}{4}K$	$\frac{1}{4}N+\frac{1}{4}K$	$\frac{1}{10}N$

4. Experimental design:

Both variety and spacing were designed as a small sub-plot, fertilizer as large plot basis. They were arranged in split-plot design with three replications resuling in a total plot size of 4×3×3×3=108. The size of one small sub-plot was 1.3×2.7 m, the other 2.7×5.2 m, and that of the large block 5.2×8.1 m.

5. Locations: Taipei and Chiayi

Before transplanting, the main stem of each seedling was marked with ink so as to identify the plants from which the young panicle would be collected for microscopic study. Leaf-age index, plant height, etc. were examined in the field, while counting of the grain number, panicle length, panicle weight, as well as observation of young panicle differentiation were made in the laboratory.

RESULTS AND DISCUSSION

1. Process of flower bud-formation and young panicle differentiation

The main stem of each plant which had previously been marked with ink were collected from each plot. The stem enclosing young panicles were cut into 5~10 cm, and then fixed with FAA fixatives. Paraffin sections cut at a thickness of 20 micra were made, using an hand operated microtome. The specimens were stained with 1% water solution of fast green. The panicle developmental stages were then determined according to Matushima's scheme of stage determination[6]. The typical stages of panicle development were photographed. More than 5,000 slides were made during this experiment.

The 21 developmental stages of young rice panicles described by Matsushima and manaka[5,6] and observed in the present studies are as follows:

Stage I: Differentiating stages of the flag-leaf

Appearance of upper-most leaf primodium, and the upper part of the prototuberance which will develop into a panicle (Fig. 1).

Stages II: Differentiating stage of first bract primodium

Apperance of annular protuberance of the first bract primodium on the axis side or left side

of the figure, cells differentiate more rapidly than on the other side. At the beginning of its appearance, it is difficult to distinguish from an ordinary primodium, but its development is not as fast as that of ordinary leaf primordium. The first bract development is not as fast as that of ordinary leaf primordium. The first bract developes into the panicle neck and its trace remaines, though sometimes it later develops into a flag-leaf. Even so, it still functions as the first bract and will differentiate primary rachis from there. After the vegetative differentiation stage, the rice reaches stages of sextual differeneiation (Fig. 2).

Stage III: Increasing stage of bract primordia

The second, third and fourth bracts successively appear in divergence of 2/5 or at angles of 144°. They are always found at the base of the second primary rachis-branch on the 2 nd bract. Similarly, the third bract always appear at the base of the primary rachis branch (Fig. 3)

Stage IV: Early differentiating stage of primary branch primordia

Primary rachis-branches differentiation begins. From the points of attachment on the second and third bracts, the second and third primary rachis-branches are differentiating respectively (Fig. 4).

Stage V: Middle differentiating stage of primary branch primordia

The successive differentiation of the primary rachis branches advances upwards rapidly (Fig. 5).

Stage VI: Late differentiating stage of primary branch primordia

The differentiation is advanced and then the primordium of a primary rachis branch appear near the top of the developing rachis. The differentiation will be soon completed (Fig. 6).

Stage VII: Differentiating stage of secondary rachis-branches

(a)Early differentiating stage of secondary rachis-branch primordia. The growing point located at the tip of the developing panicle stops its growth and the primary rachis begin to grow, and on their dorsal side the secondary rachis-branch primordia differentiate alternately, in two rows (Fig. 7a).

(b)A later differentiating primary rachis-branch which is located near the top of the cone, is more vigorous in growth than the earlier differentiating primary rachis-branches located at the base of cone, in particular the primary rachis-branch which is located nearest the tip of the developing panicle is higher than the tip of the growth point of the panicle (Fig. 7b).

Stage VIII: Late differentiating stage of secondary branch primordia

The differentiation proceeds upward to the tip of each primary branch primordium and the young panicle is completely enveloped in bract hairs which are more easily discernible with the naked eye than at the stage VIII (Fig. 8)

Stage IX: Beginning stage of flower primordia differentiation

Thereafter near the top of each primary branch empty glume and rudimentary glume primordia appear, from now on spiklete differentiate successively. In this stage, the length of the young panicle reached 1 mm, and this stage is the stage of “beginning of panicle initiation” (Fig.

9).

Stage X: Early differentiating stage of flower primordia

In the spiklets differentiated near the tip of each rachis-branch the lemma primordia and palea primordia begin to appear (Fig. 10).

Stage XI: Middle differentiating stage of flower primordia

Stamen primordia and lodicule primordia appear and on the lower part each rachis the differentiation of spikelets begins (Fig. 11).

Stage XII: Late differentiating stage of flower primordia

The stamen is divided into an anther and a filament. The pollen mother cell is not yet visible. The ovule primordium differentiates and generally a lodicule can be clearly distinguished. The lemma and palea primordia grow to envelop completely the internal organs. The bract on the lower part of the axis does not degenerate and can be clearly seen (Fig. 12).

Stage XIII: Differentiating stage of pollen mother cell

Pollen mother cells are mature enough to display their contents, the length of the young panicle reaches 1.2 to 4.0 cm.

Stage XIV: Early stage of reduction division of pollen mother cell

This corresponds to the early stage of meiosis of the pollen mother cell. The length of spikelet is about 3 mm and when the top most spikelet reaches this stage, the length of the young panicle is 5 mm.

Stage XV: 1st meiotic division

At this stage, the length of the panicle is 70% of its full length.

Stage XVI: 2nd meiotic division

Stage XVII: Tetrad stage

Stage XVIII: Beginning stage of extin formation

At this time the spikelets are 85% of their full length.

Stage XIX: Extin formation stage

The length of the spikelets nearing full length

Stage XX: Early rice stage of pollen

The spikelet reaches its full length

Stage XXI: Stage of pollen maturity

The pollen grains are completely mature.

2. Relation between the developmental stages of young panicles and growth duration

Generally, the young panicle begins to differentiate 29-47 days after transplanting. In the first crop, the panicle differentiation begins 47 days after transplating in Taipei, (45 days in Chiayi) and is completed in 35 days (36 days in Chiayi). There is no difference in duration of panicle formation in the two locations. In the second crop, the young panicles begin to differentiate 16 days earlier than those of the first crop. This is due to the high temperature at the initial stage of rice growth which accelerates the initiation of the young panicles. Duration of panicle formation in the 2nd crop is 38 days in Taipei, and 33 days in Chiayi (Table 1). Matsushima[5,6] reported that the growth duration of rice panicles was 32.6~37.4 days varying slightly from year to year.

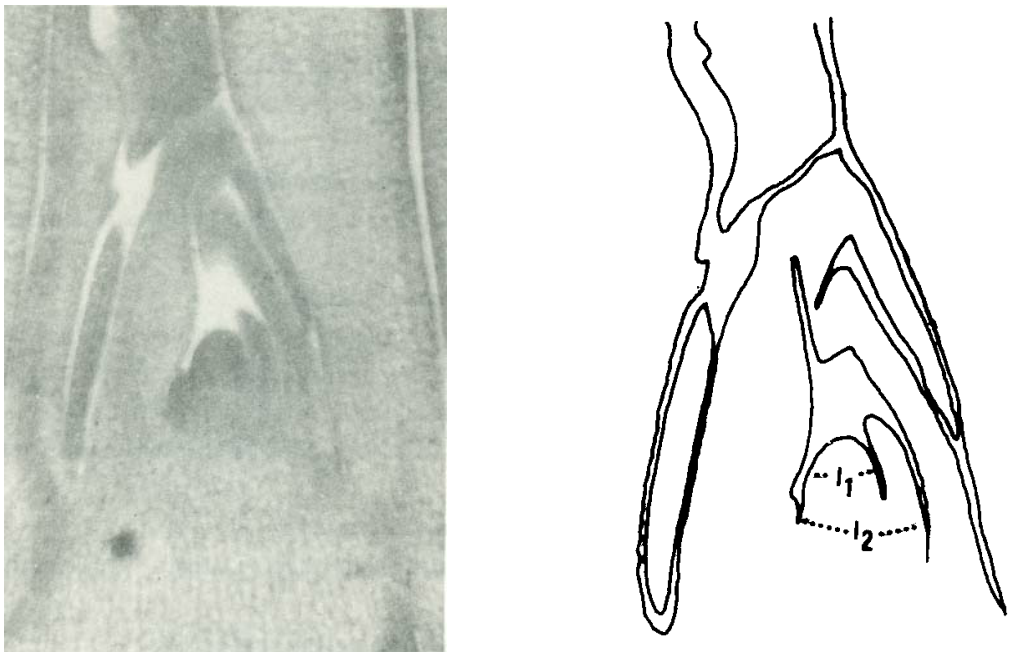


Fig. 1. I. Differentiating stage of upper-most leaf primordium.
L_1……upper-most leaf primordium.
L_2…..2nd leaf primordium.

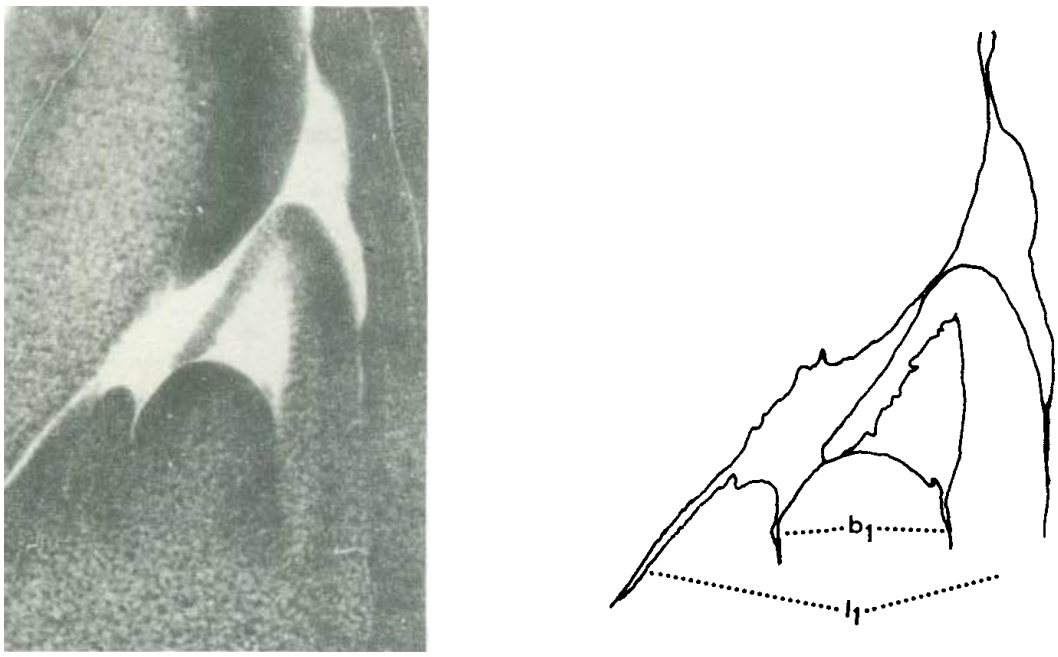


Fig. 2. II. Differentiating stage of first bract primordium.
b_1….First bract primordium

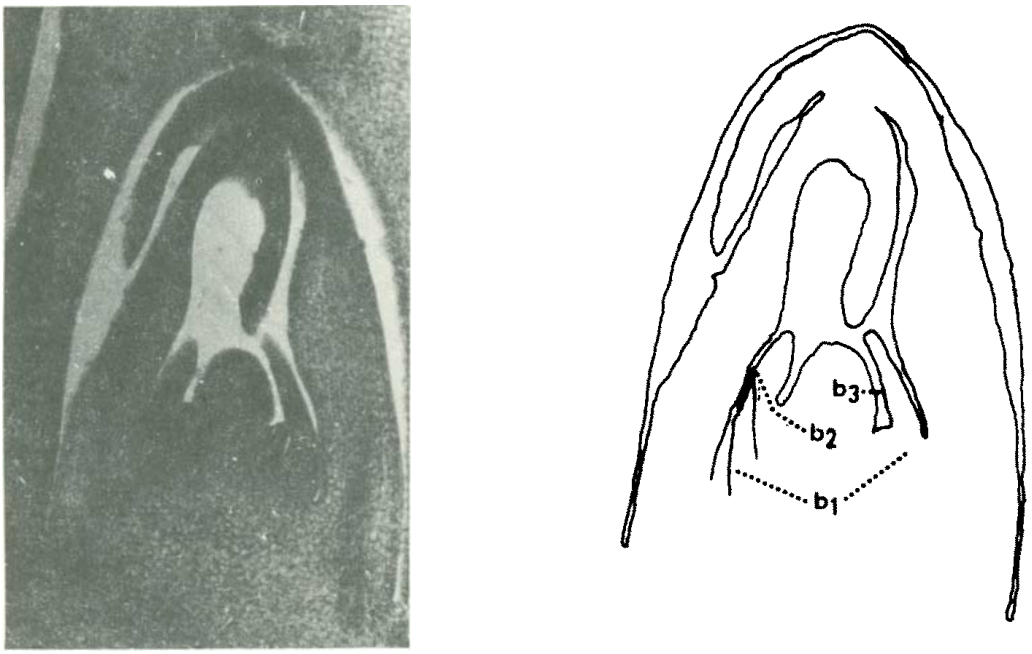


Fig. 3. III. Increasing stage of bract primordia.
b_2, b_3….2nd, 3rd bract primordium.

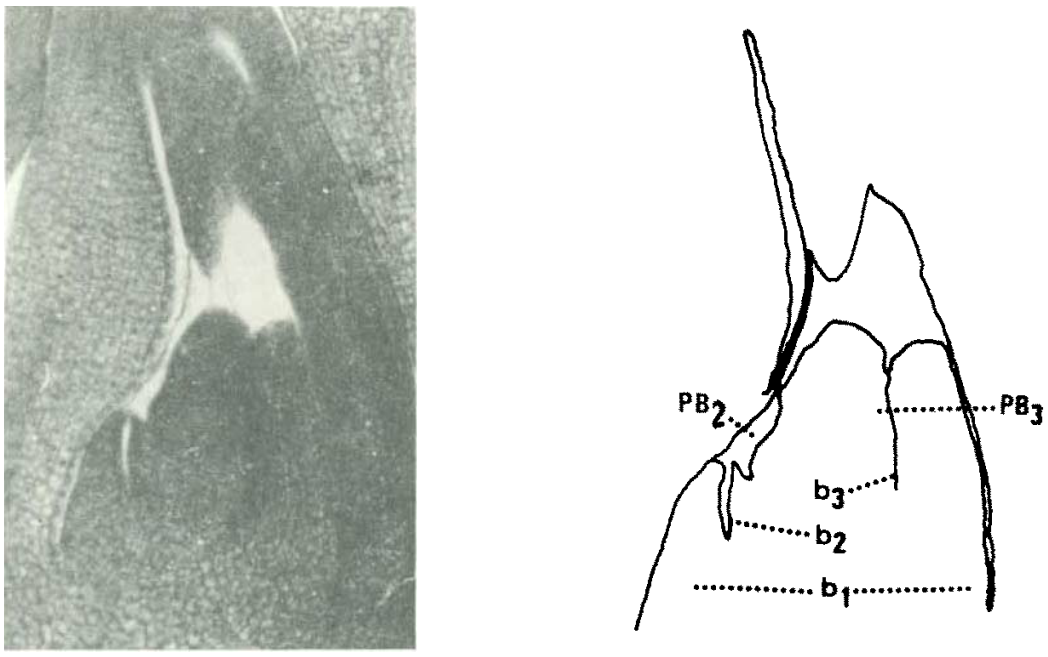


Fig. 4. IV. Early differentiating stage of primary branch primordia.
PB_2, PB_3… 2nd, 3nd primary branch primordium.

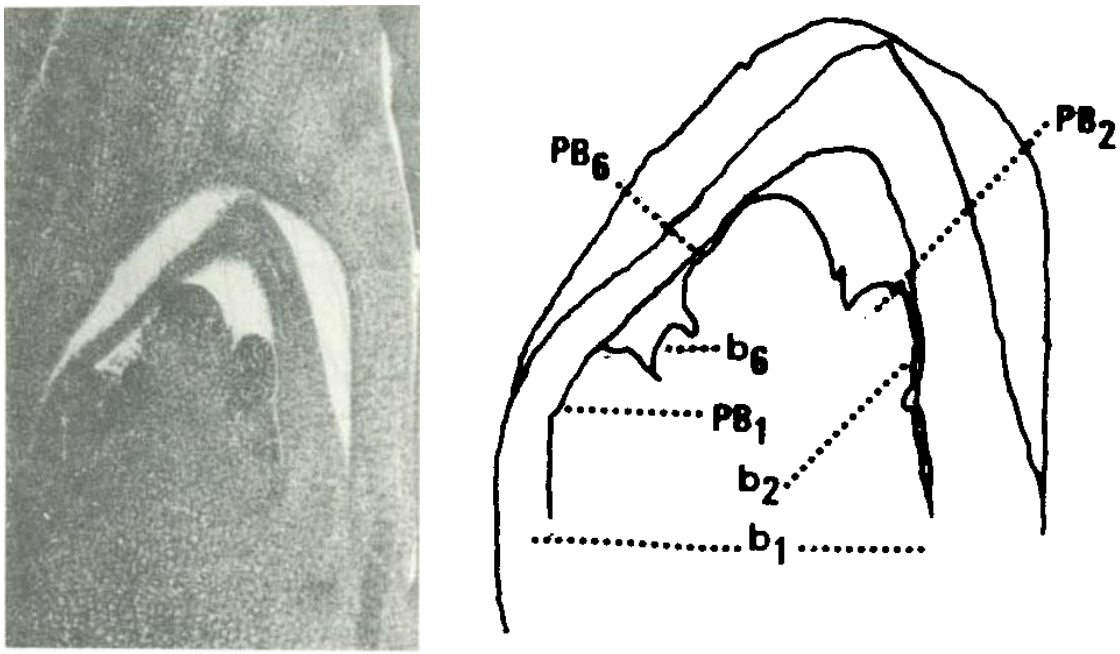


Fig. 5. V. Middle differentiating stage of primary branch primordia.

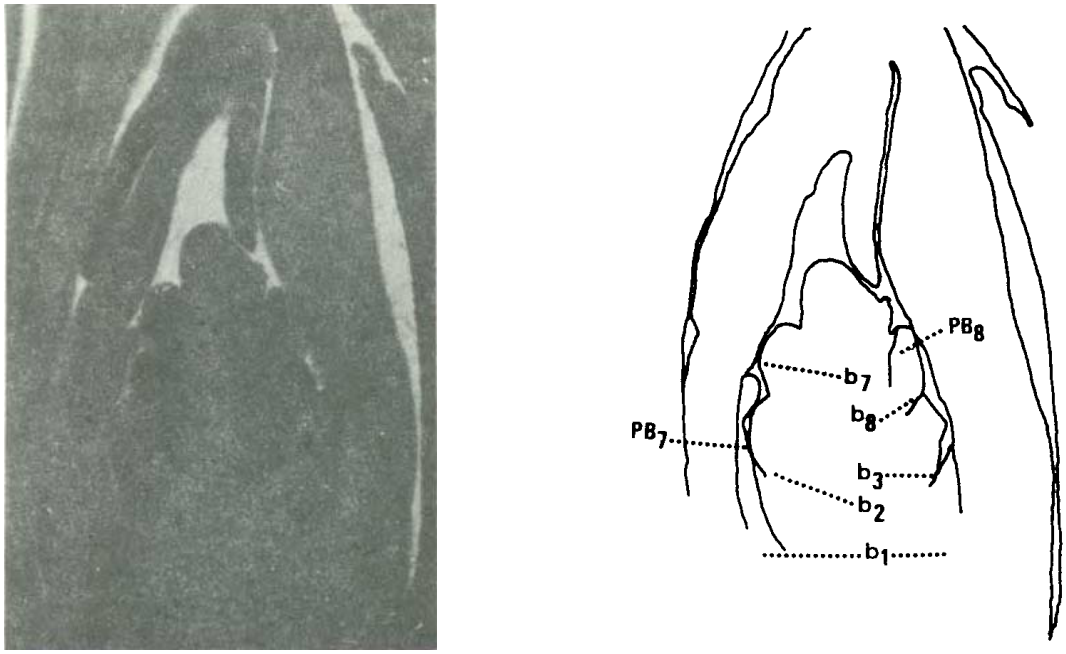


Fig. 6. VI. Late differentiating stage of primary branch primordia.

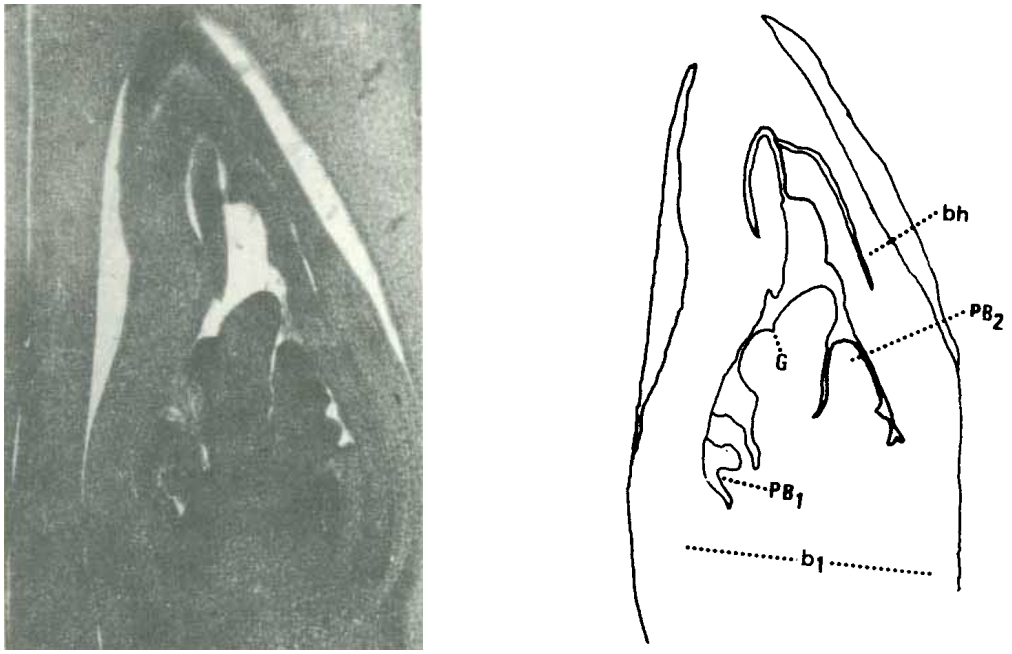


Fig. 7a. VII. Early differentiating stage of secondary branch primordia.
SB……secondary branch primordia.
bh……bract hair.

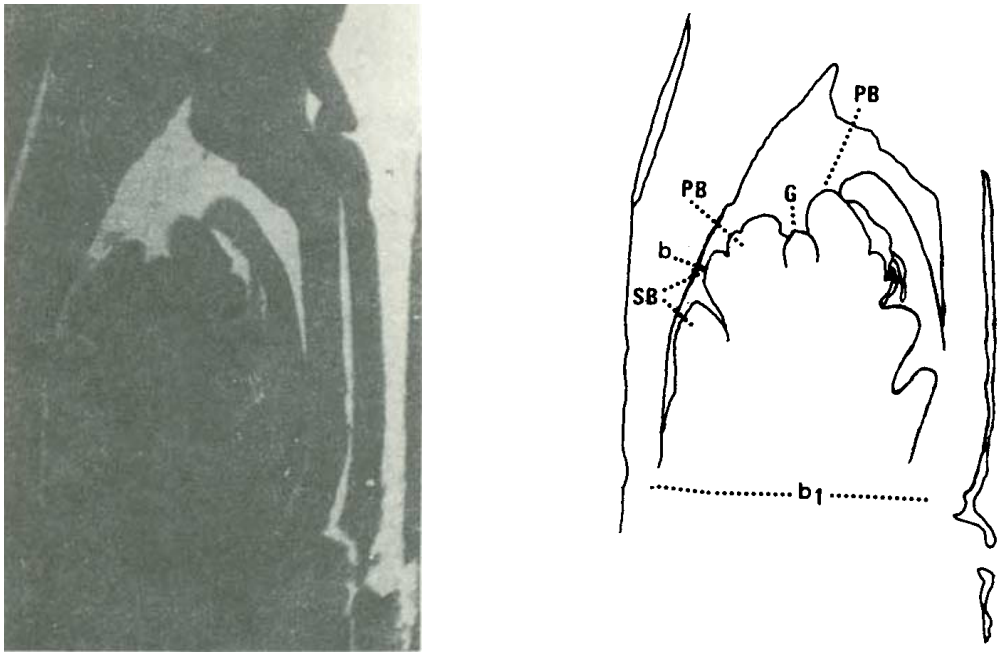


Fig. 7b. VII. Middle differentiating stage of secondary branch primordia.
G……growing point.

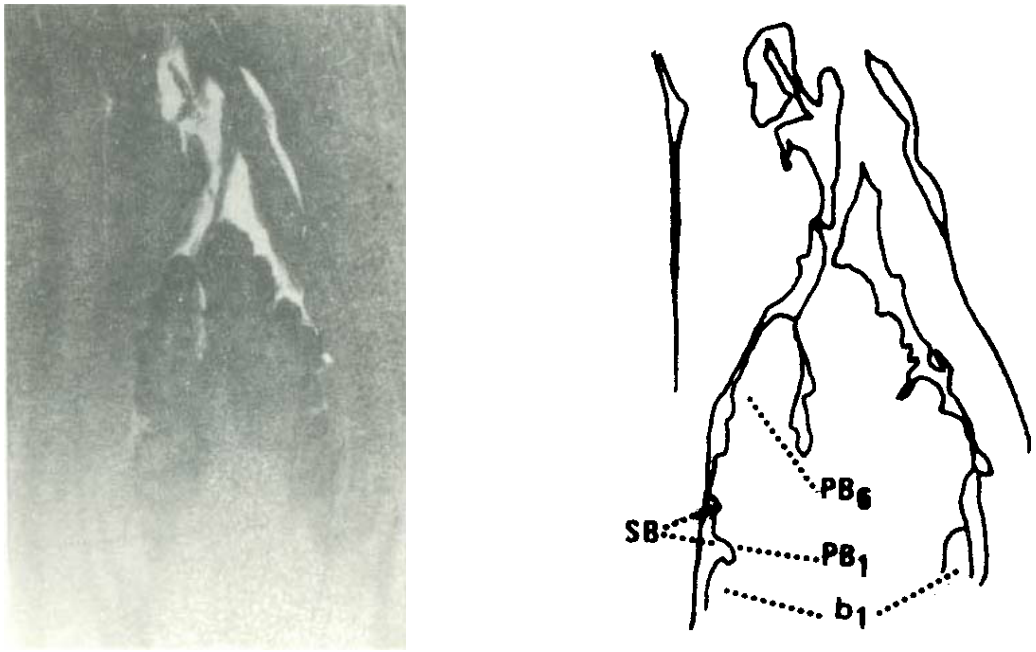


Fig. 8. VIII. Late differentiating stage of secondary branch primordia.

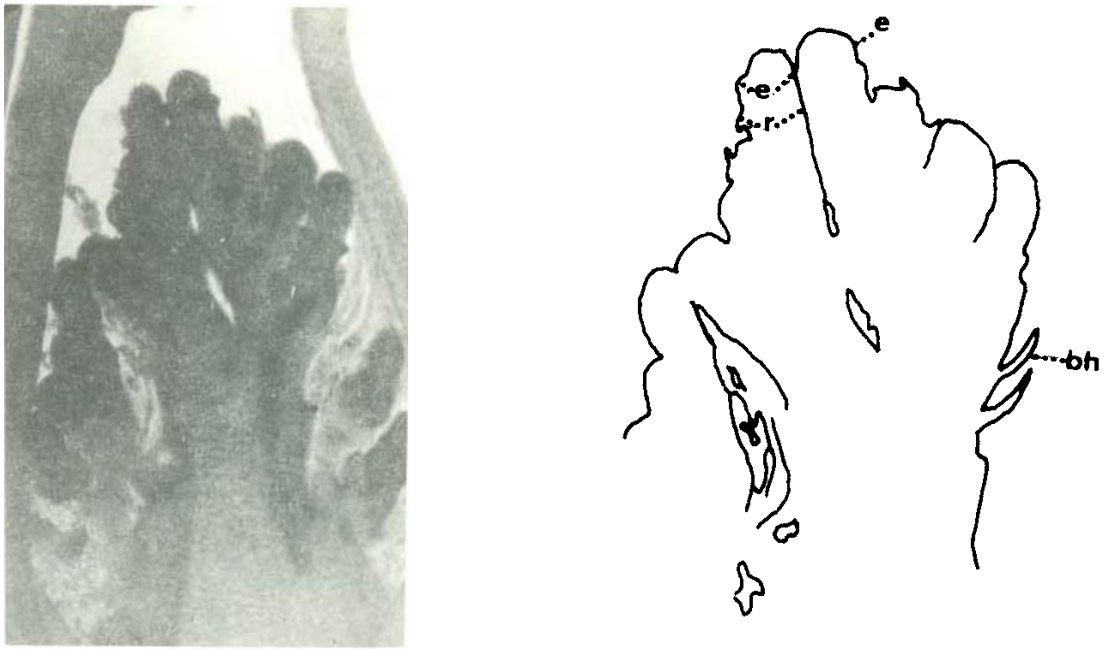


Fig. 9. IX. Beginning stage of flower primordia differentiation.

e……empty glume primordia.

r……rudimentary glume primordia.

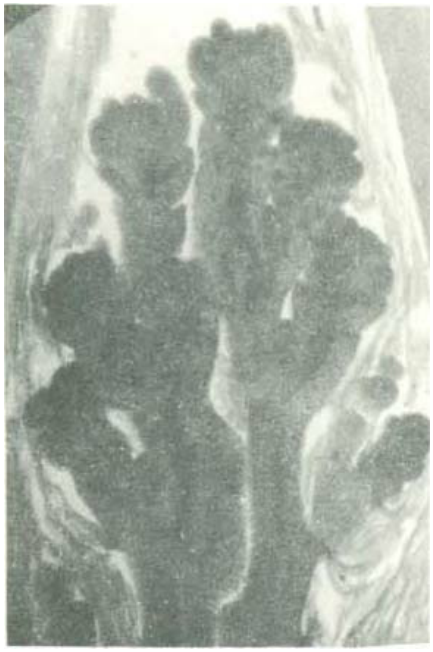
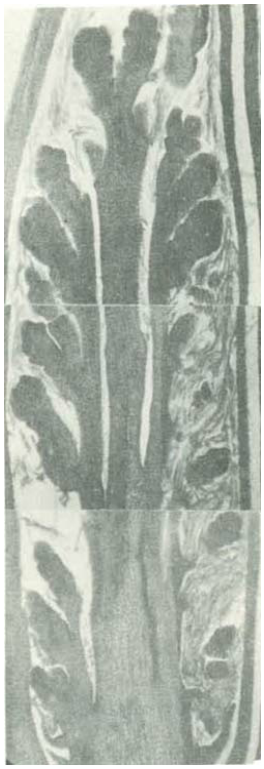


Fig. 10. X. Early differentiating stage of flower primordia.
p……palea primordia.
f……lemma primordia.



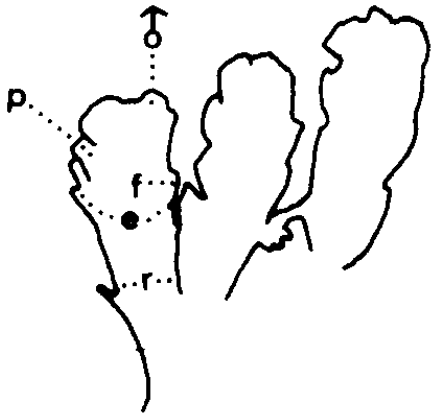
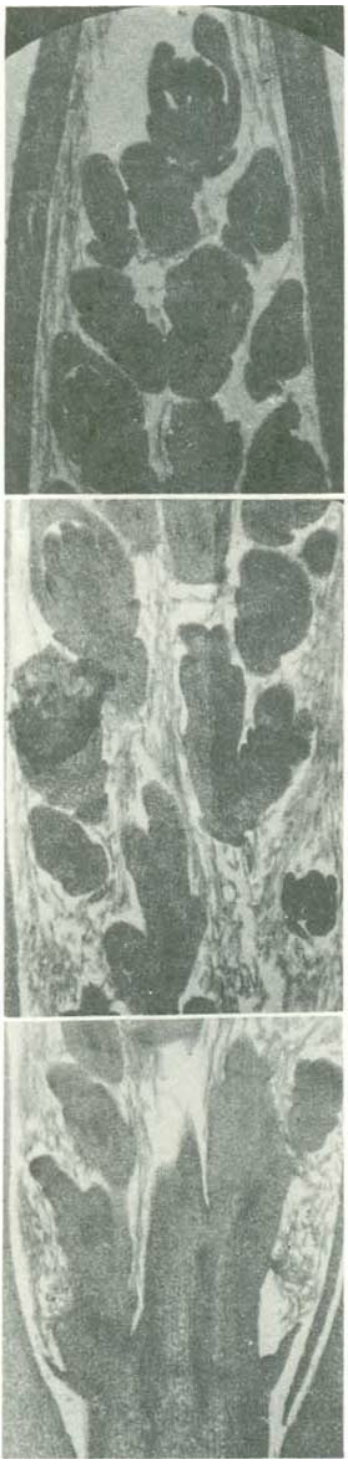
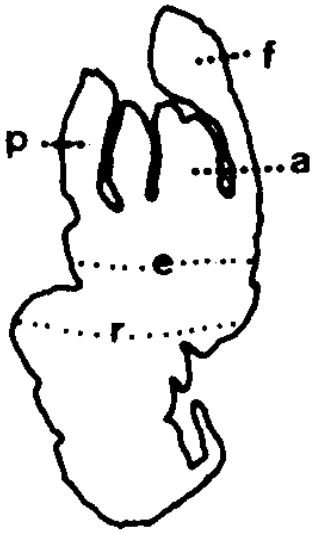


Fig. 11. XI. Middle differentiating stage of primordia.
♂……Stamen primordia.





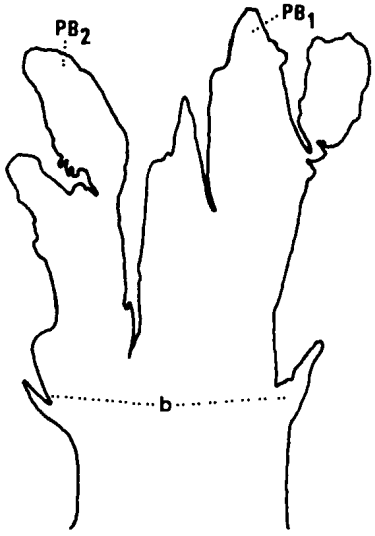


Fig. 12. XII. Late differentiating stage of flower primordia.
a……anther.

The 33~38 days panicle growth duration in the present study, then, is in close agreement with Matsushima's finding in Japan.[5,6]

Table 2. Difference in Duration of panicle formation due to different crop seasons

Crop seasons	Locations	Days after transplanting		Duration of panicle formation
		Initiation of young panicle formation (a)	Initiation of panicle formation (b)	(b)–(a)
1st	Taipei	47	82	35
	Chiayi	45	81	36
2nd	Taipei	31	69	38
	Chiayi	29	62	33

In order to know whether there is a difference in panicle growth duration between crop seasons and locations, the whole duration of panicle formation is grouped into seven periods, and the length of each period is compared in Table 2 and Figure 13.

Days after transplanting

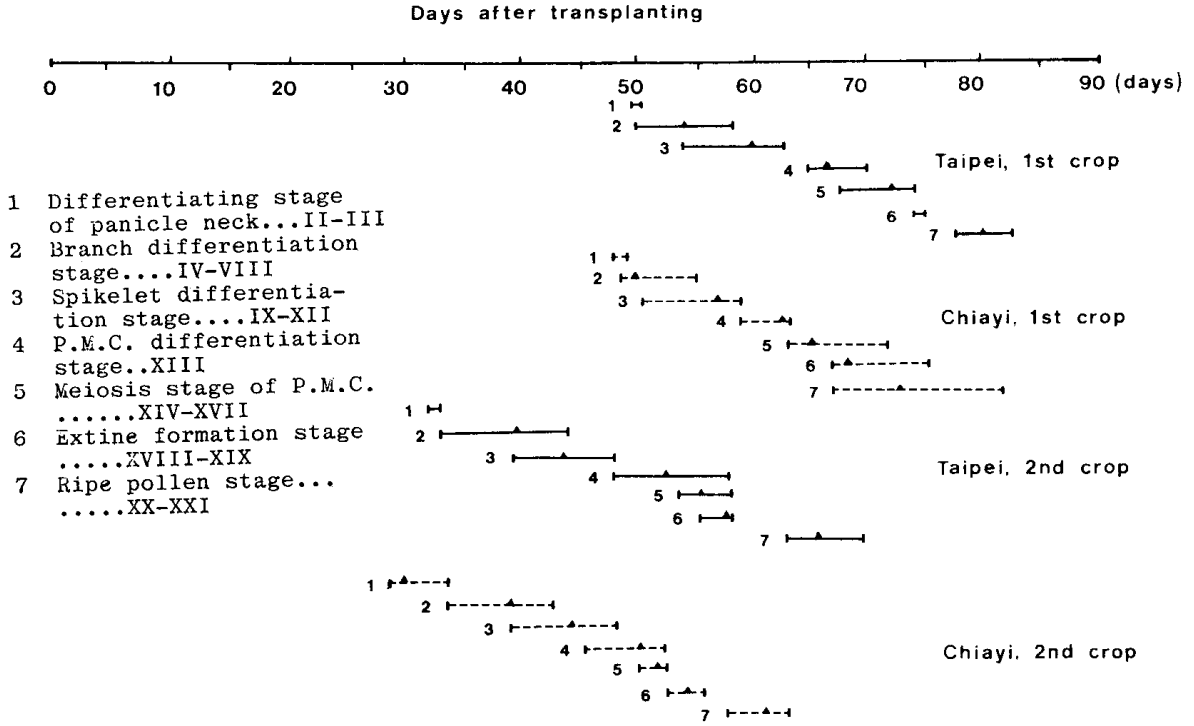


Fig. 13. Difference in duration of the main developmental stages of young panicle due to the different crop seasons and locations.

Table 3. Duration of panicle developmental stage in days

	Developmental stages	1st crop		2nd crop	
		Taipei	Chiayi	Taipei	Chiayi
Young panicle formation perid	1 I – II	2	2	1	1
	1 II – III	1 → 3	1 → 3	1 → 2	1 → 2
	2 III – IV	1	1	2	2
	2 IV – VIII	4 → 5	5 → 6	6 → 8	4 → 6
	3 VIII – IX	1	1	1	1
	3 IX – XIII	9 → 10	8 → 9	7 → 8	6 → 7
		18	18	18	15
Panicle pregnancy period	4 XII – XIII	3	5	5	4
	4 XIII – XIV	1 → 4	1 → 6	1 → 6	1 → 5
	5 XIV – XVII	2	2	2	1
	5 XIV – XVIII	1 → 3	1 → 3	1 → 3	2 → 3
	6 XVIII – XIX	4	3	4	3
	6 XIX – XX	2 → 6	3 → 6	2 → 6	3 → 6
	7 XX – XXI	4 4	3 3	5 5	4 4
		17	18	20	18
	Total days	35	36	38	33

As shown in Table 2 and figure 13, periods 1-3 belong to the young “panicle formation period” which takes 15-18 days to complet, while periods 4-7 belong to the panicle pregnancy period, which needs 17-20 days to complete. There is 1-2 days difference in terms of the panicle pregnancy period due to different crop seasons and locations. There is also 1~2 days modification in each of seven periods according to different crop seasons and locations. This may be due to environmental modification. Further, as is shown in Table 2, the differentiating stage of the panicle neck needed 2~3 days to complete, while the spikelet differentiation stage needed 7~10 days, the longest period in the panicle development stage.

Variation of the young panicle developmental stages, the growth rate with regard to different methods of fertilizer application, spacing, and varieties are plotted in Figures 14~16. the vertical bars in Figures 14~16 show the range of developmantal stages which appeared on the same days, and o,x marks show the stages which frequently appeared. As shown in Figures 13~16, there is an overlapping of stages. Two to three stages overlapped on the same day in the majority of the cases; however, sometimes 7~8 stages overlapped. This means that the main stem growth periods varied among different plants. It is then inferred that the growth period of the young panicle may differ according to different tillers within a plant.

The correlation coefficient between growing dates and developmental stages of the young panicle is very high, being r=0.80~0.90, showing that the growth of the young panicle is in

parallel to the growing days. As indicated in Figune 14, there was no marked difference in the 1st crop, at both locations. (Figure 15.)

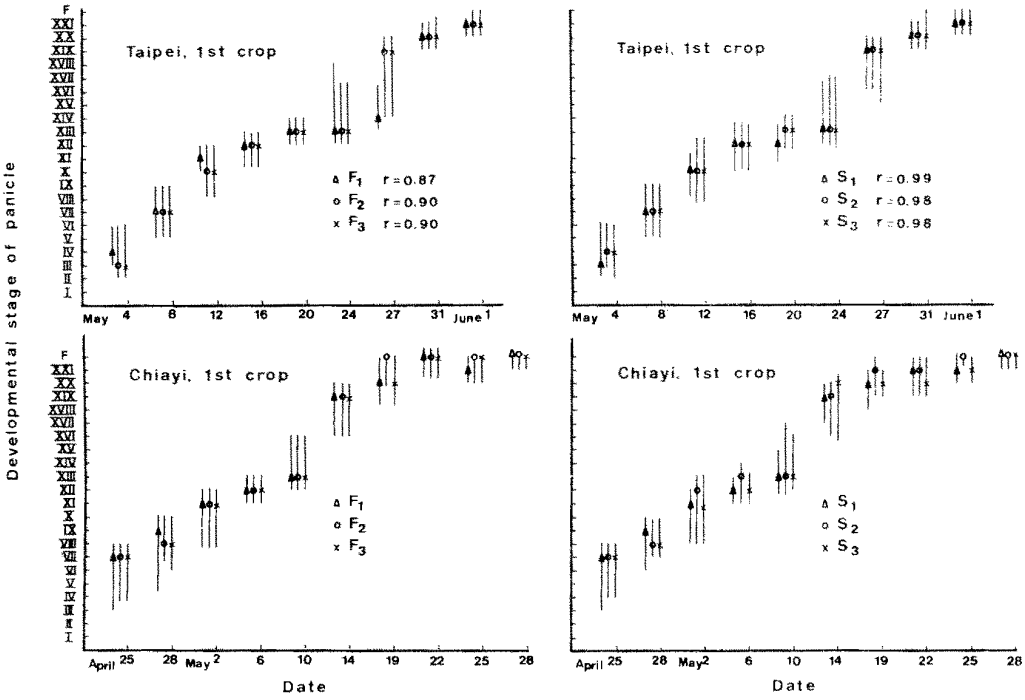


Fig. 14. Relation between developmental stage of young panicle and growing dates (1st crop).

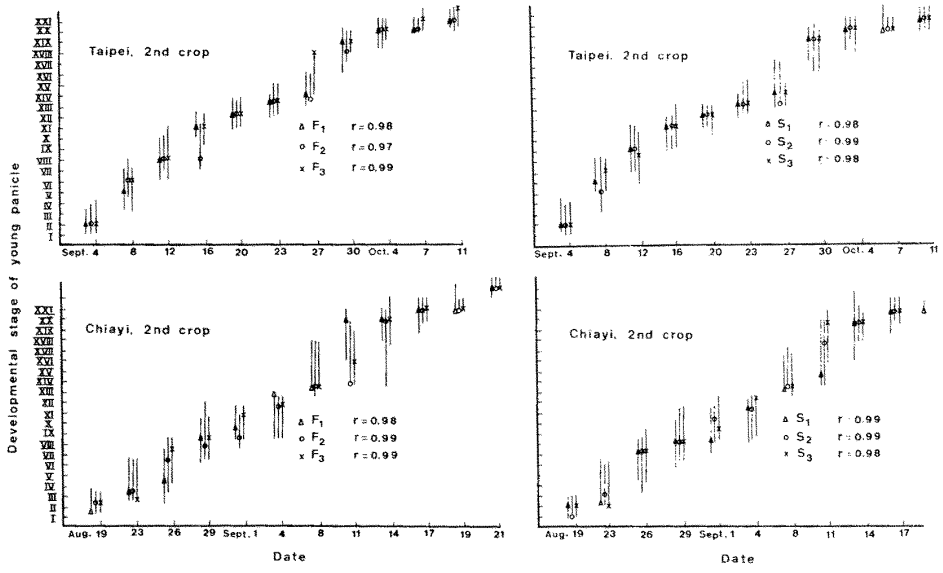


Fig. 15. Relation between developmental stages of young panicle and growing dates (2nd crop).

There was no marked differece in mean developmental stages due to different spacing, in both the 1st and 2nd crops in Taipei, though variations due to spacings were noticed in both crops at Chiayi. Varietal differences at mean developmental stage is noted in Figure 16. It is indicated in Figure 16, that the early development of young panicle of Tsai-yuan-chung (V4), which is a panicle-weight-type variety, always proceeded other 3 varieties.

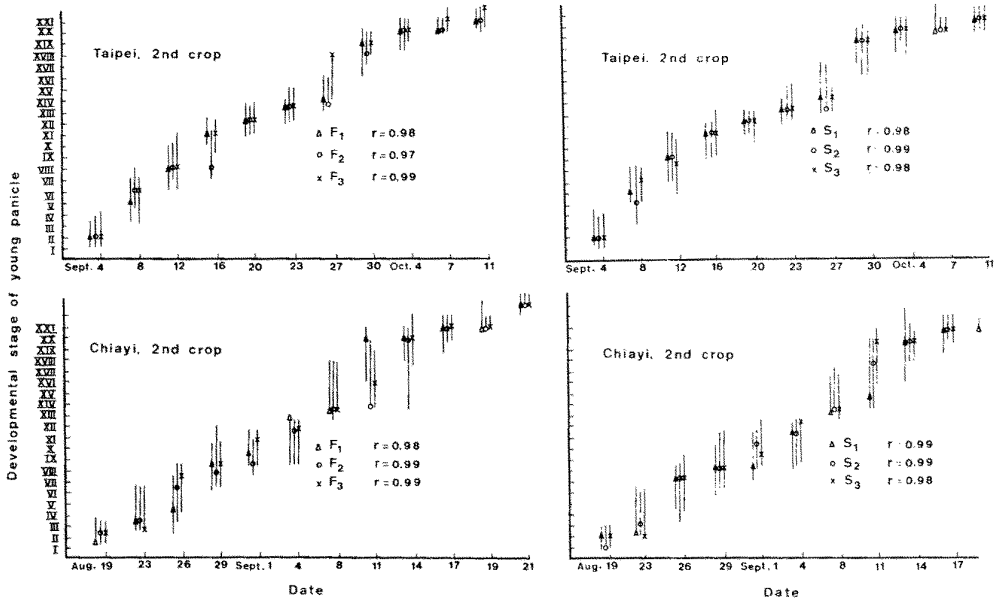


Fig. 16. Relation between developmental stages of young panicle and growing dates in different varieties and crop seasons.

3. Variations in young panicle length at the different developmental stages due to different locations, crop seasons, and fertilization methods

The variations in young panicle length at each developmental stage are shown in figures 17~19. As shown in figures 17~19, the young panicles gradually increases its length from stage I (panicle neck differentiation) to stage VIII (branch differentiation stage), 0.52~2 mm. After stage IX (spiklet differentiation stage), the young panicle continued to increase its length at the late stage (XIII) of spikelet differentiation, and the young panicle reached to 2~8 mm long. The second method of fertilizer application (F2) in which a top dressing at the young panicle initiation stage was applied, appeared to show a slight promotion in the young panicle length in both the first and second crops at Taipei and Chiayi, though the increase of young panicles length under different methods of fertilization is not statistically significant (Table 4).

Form Figure 18, it should be noted that spacing 2 (S_2) which has 86 plants per $2m^2$ resulted in a slight increase of young panicle length in the first crop at both Taipei and Chiayi. The

situation remained the same until the panicles were fully developed in the first crop at Chiayi. The difference in young panicle length due to different spacing is also not statistically significant (Table 4).

Table 4. F values from analysis of variance for length of young panicles at different stages, due to different methods of fertilizer application, planting densities and varieties

(Taipei, 1st crop)

Source of variation	Degree of freedom		Observed F values				Theoretical F values	
	1	2	May 4 III,IV,VII	May 8 V,VII,IX	May 12 VIII,X,XI	May 16 XI,XIII	5%	1%
F	2	2	0.063	1.288	4.170	0.362	19.00	99.00
S	2	6	0.566	0.352	7.354*	0.223	5.12	10.92
V	3	27	148.520**	55.950**	1.173	7.308**	2.98	4.64
F×S	4	6	1.587	0.146	27.657**	1.475	4.53	9.15
F×V	6	27	6.975**	7.157**	6.791**	0.537	2.46	3.56
S×V	6	27	2.006	1.043	2.094	0.352	2.46	3.56
F×S×V	12	27	58.407**	2.068	6.068**	0.207	2.13	2.93

Note: Roman letters III,IV, indicate developmental stages of young panicle in respective day.

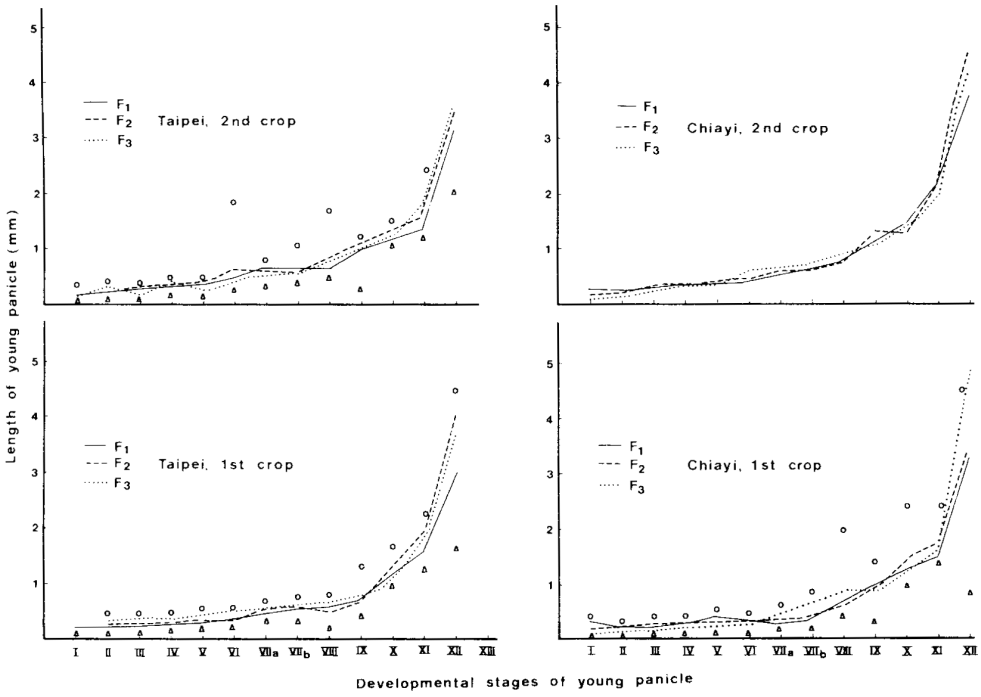


Fig. 17. Variations of young panicle length at the different developmental stages due to different fertilizer levels, crop seasons and locations (○△ mark shows the range of young panicle length at each stage).

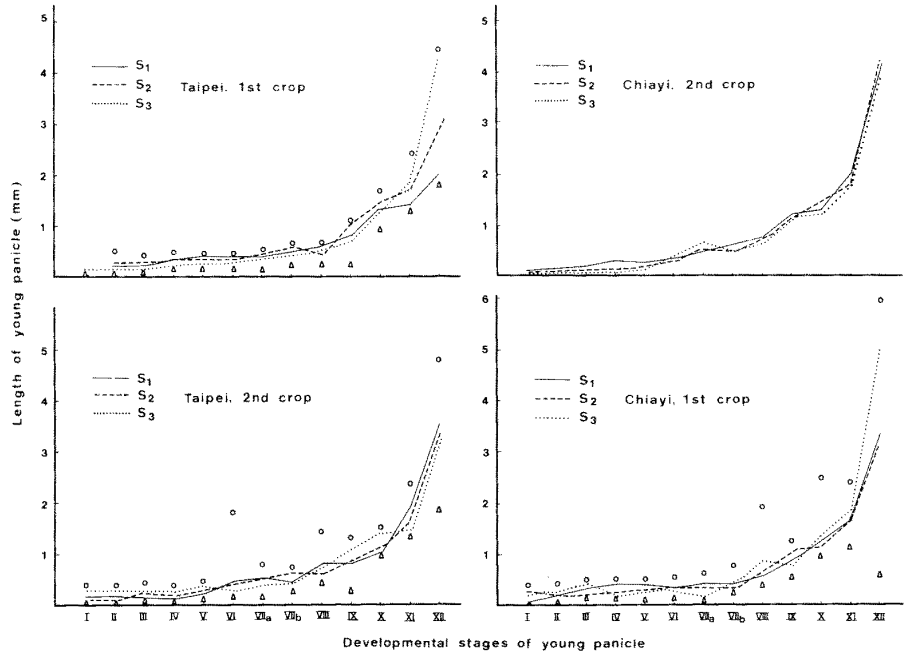


Fig. 18. Variations of young panicle length at the different developmental stages. due to different plant spacing, crop seasons and locations (○△ mark shows the range of young panicle length at each stage).

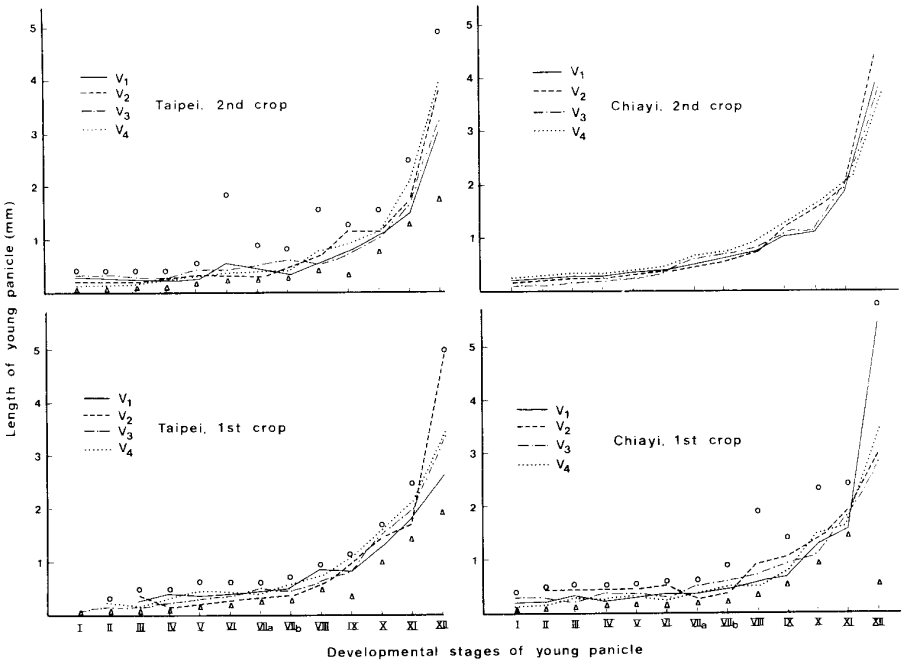


Fig. 19. Varietal variations of young panicle length at the different developmental stages (○△ mark shows the range of young panicle length at each stage).

In Figure 19, varietal variations in young panicle length at different stages are indicated. Data from the analysis of variance show there is a significant difference in young panicle length at each developmental stage, except for stages VIII~XI observed on May 12 (Table 4). Interaction between spacing and varieties and that among fertilizer, spacing, and varieties were noticed in certain developmental stages. IIowever, in the late stage (XI~XII) no such interaction was observed. The change of interaction between variety, spacing, and fertilizer application in different developmental stages may be largely due to environmental conditions during growing periods.

The initiation of young panicles in the second crop tended to be earlier than that of the 1st crop (Figure 20). This is due to high temperatures at the initial stage of young panicle growth in the second crop.

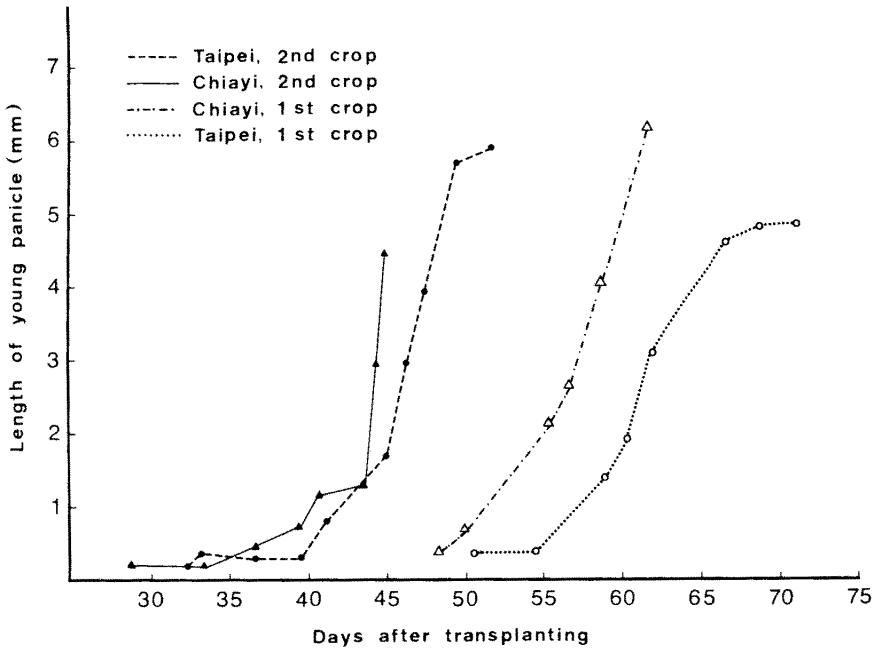


Fig. 20. Relation between length of young panicle and growth duration.

CONCLUSION

Increasing the rice yield has been the focus of attention by the rice growers for many years. Yield measurement is composed of number of plants per unit area, number of panicles, number of grains per panicle and weight per 1,000 grains.

In order to promote these yield components, the following problems should be clarified first: (1) When the number of panicles is determined, (2) How to predict the number of panicles, (3) How to increase the number of panicles, (4) When and how the panicle is determined, (5) How to

determine each growth process, (6) When and how to determine the number of grains, (7) How to increase the number of grains per panicle. These problems were studied using four varieties of rice at Taipei (Northern Taiwan) and Chiayi (Central Taiwan) in this experiment.

In general, the young panicles start differentiation 29~47 days after transplanting. The growth duration of rice panicle was 33~38 days, varying slightly from locations and varieties. These values are in close agreement with those reported by Hsieh[2] and also with the values of 33.6~27.4 days reported by Matyushima[6] in Japan. Twenty one developmental stages of flower bud and young panicle developments were identified following Matsushima's scheme of classification[5,6].

There is a significant difference in young panicle length at each developmental stage. The young panicle length was influenced by the interaction between spacing and varieties, also by the interaction among fertilizer, spacing and varieties.

In order to obtain the maximum grain yield, the fertilizers must be applied at the proper stage of panicle development[2,5]. The technic of how to identify the stage of panicle development withoug causing the damage to plant itself is then needed to be developed. Matsushima correlated the leaf-age index number and tiller number to the length of young panicle[6]. With the writers coraboration, Lin conducted the similar experiment with two of the four varieties used in this study[3]. The positive results reported by Lin[3] had been studied in more detail and the results of the research findigs will be reported in the next paper.

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不同環境下之稻產量及產量構成要素之研究
第一報　在不同環境下稻花芽之形成及幼穗之發育情形[1]

謝順景[2]

摘　要

利用四個稻品種在不同期作，地點及施肥法之情形下，探討其花芽分化之過程及幼穗發育之情形，以供決定肥料分施時期時之參考。

本研究曾根據松島氏(1956)的方法把稻之花芽分化過程分爲21時期，並做顯微鏡的仔細觀察調查，同時將其結果進行秈稻與粳稻之間及台北與嘉義之間及一期作與二期作之間進行比較研究。一期作稻在台北自播種後47天(在嘉義則爲45天)就開始幼穗的分化，而在35天後(在嘉義則爲30天)即完成。二期作稻的幼穗分化較一期作稻提前16天開始。二期作稻之幼穗發育期間在台北爲38天而在溫度較高的嘉義則縮短爲33天。

同一株內之幼穗發育時期，隨植株生育之進形而進展，兩者之間有顯著的正相關(r=0.80~0.90)存在。幼穗發育時期之早晚在不同栽培密度下之差異並不大。

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