Seasonal Changes in Growth Pattern of Tropical Rice

I. Environmental factors affecting plant height, tillering, weight and leaf area*

Akio OSADA**, Hitoshi TAKAHASHI***, Sommart DHAMMANUVONG,
Vichian SASIPRAPA and Sumet GUNTARAROM

(*Department of Agriculture, Bangkok, Thailand*)

INTRODUCTION

In order to improve rice yield in the tropical countries, many promising non- or weakly-photosensitive varieties have developed recently and they permit a wider range of planting dates than heretofore possible because of their insensibility to day length, provided that irrigation facilities are developed. Even under present circumstances, the time of planting rice has been widened to some extent by using these varieties. However, it is not known sufficiently that how the growth of plants is affected and how much yield can be expected when planted at different times.

In Japan, differences in growth habit of rice plant due to planting season has been recognized. For example, plants grown in the earlier period of the rice cultivating season are considerably different from those planted at a later period with respect to shorter height and a larger number of tillers⁹⁾. In Thailand, some difference in growth between rainy and dry season can be observed, but no exact study has been done so far and the reason for such a difference dependent on planting season is still remained unknown.

Therefore, date-of-planting experiments were undertaken in Thailand to reveal the influence of planting season on growth habit of rice plant, its response to environmental factors, by planting at one month intervals throughout the year. Two cycles of experiment were carried out; in the first one mainly changes in growth itself was investigated and in the second, results of which will be presented in the following paper, attention was paid to the seasonal effect on yield.

MATERIALS AND METHODS

Experiments were conducted from 1969 to 1970 at Bangkhen Rice Experiment Station belonged to Ministry of Agriculture, Thailand. It is located about 15 km north of Bangkok.

(1) *Field experiment*

Varieties tested were RD 1, BKN 17-3, C4-63 and IR 8. The former two have been obtained from a cross between the Thai variety Lueang Tawng and IR 8 released from the International Rice Research Institute. C4-63 is a new hybrid derived from the Philippines. All varieties are regarded as semi-dwarf, non- or weakly-photosensitive types and their growth duration is about 130 days.

Seeds were sown at the beginning of every month during from May, '69 to May, '70. (Because growth of the first planting sown in May, '69 was abnormal after transplanting, it was repeated in the next May. Only the seedling heights were obtained from the first planting.) Seedlings were transplanted 20 days after sowing. Spacing was 25 × 25 cm and three seedlings were planted in one hill. N, P₂O₅ and

* Received for publication on February 15, 1973. Outline of this report was presented at the 154th meeting of the Crop Science Society of Japan, October, 1972.

** Present address: Faculty of Agriculture, Utsunomiya University, Utsunomiya, Japan.

*** Present address: Central Agricultural Experiment Station, Konosu, Saitama, Japan.

K₂O were applied at the rate of 75 kg/ha, respectively. Nitrogen was split equally at two times, transplanting time and young panicle formation stage. Plant height, tiller and panicle number and growth duration were observed. Solar radiation energy, rainfall and temperature were collected from the Meteorological Department, Office of Prime Minister, Thailand.

(2) Pot experiment

Twenty-day old seedlings of RD 1 prepared for the field trials were also transplanted every month into pots with inside diameter about 30 cm. Fresh and dry weight, leaf area were determined at 80 days after sowing.

(3) Effect of day length on growth

Seedlings of RD 1 and C4-63 sown at 1st of November were transplanted into plastic pots at about fifth-leaf stage. Long day treatment (16 hours) was given for 3 weeks and plant height and tiller number were measured comparing to those of plants grown under the natural conditions, day length of which was shortest during the year.

RESULTS

(1) Changes in climatic factors

Air temperature, rainfall, solar radiation energy and day length (fig. 1) were observed at Bangkok by the Meteorological Department and are considered to represent approximately the climatic conditions at the experimental site, Bangkhen Rice Experiment Station, because it locates very near to the capital as already mentioned.

The climate of Bangkok which lies at 13°44' north latitude is tropical being under the influence of monsoon winds of seasonal character. Ordinarily, the southwest monsoon brings regular rain between June and October with a peak in September. The rainy season is followed by a cool and dry period caused by the northeast monsoon in November through January, the air temperature in December or January being lowest throughout a year. Then

Fig. 1. Temperature, solar radiation energy, day length and precipitation during the experimental period.

Source: Meteorological Department, Thailand. Solar radiation values of May, June and July of 1970 were not available. Most of rainfall in February and March of 1970 were concentrated in one day.

comes summer. Toward the end of the dry season temperature increases gradually and April or May becomes the hottest season.

Changes of climatic factors during this experiment, from May, '69 to August, '70, were on the whole same as the ordinary patterns.

(2) Changes in growth duration

Days from sowing to maturity of RD 1, BKN 17-3 and IR 8 fluctuated planting to planting during the year (fig. 2). The mean value of 12 plantings of RD 1 was 131 and both of BKN 17-3 and IR 8, 125 days. Changes in the days to maturity of these varieties did not show any definite correlation to the day length, suggesting that these are almost completely non-

Fig. 2. Changes in the days from sowing to harvesting according to the sowing month.

Dotted line denotes mean value of 12 plantings.

Fig. 3. Temperature and height of 20-day old seedlings sown at the beginning of every month.

Temperature is the mean of daily mean temperature during nursery period.

Fig. 4. Changes in plant height according to the planting season (Variety: RD 1).

Heights at 35, 50, 65, and 80 days after sowing of 12 plantings were plotted against the corresponding calendar date. Temperature is monthly mean of daily mean temperature.

Table 1. Mean plant height of 4 varieties at 35, 50, 65 and 80 days after sowing. (cm)

Sowing month	Days after sowing							
	35 days		50 days		65 days		85 days	
	Date	Height	Date	Height	Date	Height	Date	Height
Jun/'69	6/Jul	42	21/Jul	63	5/Aug	79	20/Aug	95
Jul	5/Aug	46	20/Aug	64	4/Sept	86	19/Sept	103
Aug	5/Sept	43	20/Sept	61	5/Oct	74	20/Oct	94
Sept	6/Oct	45	21/Oct	63	5/Nov	83	20/Nov	94
Oct	5/Nov	53	20/Nov	68	5/Dec	82	20/Dec	85
Nov	6/Dec	36	21/Dec	54	5/Jan	67	20/Jan	88
Dec	5/Jan	43	20/Jan	60	4/Feb	71	19/Feb	91
Jan/'70	5/Feb	48	20/Feb	69	6/Mar	87	21/Mar	108
Feb	7/Mar	48	22/Mar	66	6/Apr	85	21/Apr	105
Mar	5/Apr	43	20/Apr	64	5/May	83	20/May	103
Apr	6/May	44	21/May	64	5/Jun	83	20/Jun	98
May	5/Jun	47	20/Jun	65	5/Jul	87	20/Jul	106

Plant heights of each planting were measured at about 10 days intervals and values in the table were obtained from the height curve of each planting by interpolation. All plants were transplanted 20 days after sowing.

Table 2. Effect of long day treatment on the plant growth in the short day season.

Variety	Treat-ment	Height (cm)	Tiller (per pl.)
2 Weeks after treatment			
C4-63	Natural	44.4±5.4	8.3±3.2
	Long day	45.3±1.9	8.4±3.4
RD 1	Natural	43.2±3.2	9.7±1.2
	Long day	45.1±3.3	10.2±2.8
3 Weeks after treatment			
C4-63	Natural	53.9±4.3	13.1±3.6
	Long day	53.8±3.8	13.7±3.1
RD 1	Natural	51.1±4.6	14.3±2.8
	Long day	51.6±5.1	13.9±3.1

Long day (16 hours) treatment was given to plants from about 5th-leaf stage in December. Natural day length was less than 11.5 hours. Determinations were done 2 and 3 weeks after the beginning of treatment.

photosensitive. C4-63 showed a slight photosensitivity; the difference between the shortest and the longest growth duration was about 2 weeks.

(3) Changes in plant height

Plant heights of 20-day old seedlings sown at the beginning of every month were shorter in low temperature seasons, November, December or January than those in warmer ones (fig.

Fig. 5. Correlation between plant height at 80 days after sowing and mean of daily mean temperature during one month prior to that time.

Plant height is the mean of 4 varieties tested. Numerals in the figure denote sowing month. cf. Table 1.

** Significant at 1% level.

3). Particularly, seedlings grown in December that monthly mean of daily mean temperature was lowest, the height being less than 20 cm.

In fig. 4, in order to compare plant heights of different plantings at the same growing stage, distributions of plant height of RD 1

Fig. 6. Changes in maximum number of tillers, percentage of productive tiller and number of panicles according to the planting season.

Temperature is the mean of daily mean temperature during one month centering the maximum tiller number stage, 2 months after sowing.

transplanted in the field are shown for 35, 50, 65 and 80 days after sowing and are based on 12 different planting dates. Similarly, changes of mean heights by planting dates of all varieties tested including RD 1 are shown in table 1. As seen in the figure, the lowest height at 35, 50 and 65 days after sowing was seen in the November planting and that at 80 days in the October one. These growing stages which showed the lowest value coincided with the low temperature season, December or early January. This was observed in all varieties without any exception.

Since the day length in December is shortest throughout the year (less than 11.5 hours), the effect upon plant growth was investigated by

Table 3. Fresh and dry weight of shoot and leaf area of RD 1 grown in different seasons. (Pot culture)

	Fresh wt. (g)	Dry wt. (g)	Leaf area (m ²)
I	733	158	1.14
II	309	67	0.47
III	681	156	1.02

Mean of two values obtained from plants sown in July and August (I), November and December (II), February and March (III). Plants were transplanted into pots 20 days after sowing and determinations were done at 80 days after sowing.

giving plants long day (16 hours) treatment using RD 1 and C4-63 sown in November. However, the height and the number of tillers were not influenced by long day, although flowering was delayed slightly (table 2).

For the most part, there was no close relationship between changes in monthly mean temperature throughout the year and plant height up to 65 days after sowing. However, there was a close, positive correlation between plant height at 80 days after sowing and mean of daily mean temperature during one month prior to that time (fig. 5). The plant heights at this growth stage may be regarded approximately as "full length" or "mature length" of the variety, since the plants extracted panicles at about 3 months after sowing.

There was no noticeable correlation between rainfall and hence solar radiation and plant height during the year.

(4) Changes in tiller and panicle number

Seasonal changes in these numbers were not so distinct as in the case of plant height (fig. 6). However, plants tended to produce more tillers when active growing stage was in dry season than in wet season, although there were some fluctuations. On the other hand, no marked difference in panicle number was observed among plantings except October one. Tillering of the October planting was at a high level and its percentage of productive tiller was

highest, resulting in the production of the most panicles among 12 plantings. The October planting was exposed to the lowest temperature at around its maximum tillering and internode elongation stages. The percentage of the August planting was also high but its maximum number of tillers was least.

(5) *Changes in plant weight and leaf area*

The twelve pot plantings made throughout the year were not acceptable because of diseases and other problems. Therefore, some of the data were not conclusive. However, the following points can be mentioned.

Table 3 shows the values of fresh and dry weight, leaf area of the plants grown in rainy (I), low-temperature (II) and high-temperature dry season (III). Each of I, II and III is the mean value obtained from two plantings sown in July and August (I), November and December (II), February and March (III), respectively. Between I and III no marked difference in weight and leaf area occurred. But in low-temperature season (II), growth in weight and development of leaf area were depressed remarkably.

DISCUSSION

Upon the changes in growth habits according to the date of planting during the year, air temperature often had close relations to the growth pattern of plants grown at different seasons; whereas rainfall, solar radiation energy or day length did not show definite influence.

Because in the tropics temperature is generally high and is more or less constant, experiment dealing with the temperature effects on indica rice was rather scarce, except for particular problems such as introduction of new varieties to high-altitude areas³⁾. On the contrary, in the temperate zone like Japan, temperature range during the rice cultivating season is far wider than that in the tropics and there are many reports with temperature and rice growth. Sasaki¹⁰⁾ reported that opti-

mum temperature for longitudinal growth of rice leaves is 31°C. Results of various experiments done by Matsushima and his co-workers^{2,5,6,7,8)} are summarized as that low temperature always affects plants to increase the number of tillers and to reduce plant height. Samoto *et al.*⁹⁾ also deemed that the changes in growth pattern due to the planting seasons (stated in the introduction) may be attributable to the difference in temperature, the early season being cooler than the late one. In the experiments done by Tanaka *et al.*¹¹⁾ in the Philippines, on plant height and tillering of the indica varieties grown at different seasons, independent influence of temperature was obscure. However, it was observed in India that plant height of MTU-15, an Indian variety, was shorter and its tillering was more when planted in the cool season, January than in the hot season, June⁴⁾. It is commonly said that rice plant in northern areas has shorter stature and more panicles than that in southern areas not only in Japan¹⁾ but also through Asian rice-growing countries⁴⁾.

Experimental site, Bangkhen is in the Central Plain of Thailand, a low elevation zone in the tropics. During the year, temperature was very high and the difference between maximum and minimum monthly mean of daily mean temperature did not exceed only 5°C. Even under such conditions, low temperature around December depressed evidently plant growth such as elongation, weight increase and leaf expansion. In addition to such a low temperature effect, throughout the year temperature seemed to affect plant growth. Changes in temperature during one month from 50 to 80 days after sowing, which was almost one month before flowering, influenced "full length" of plant. The higher the temperature, the taller the final plant height. Heights of seedlings in nursery and of plants younger than 80-day old in field did not correlated significantly with the changes in temperature throughout the year. Heights of those plants would be more variable

than those of older ones not only by temperature but also by various other factors such as irrigation conditions, rooting after transplanting etc. Therefore, it may be thought that the influence of temperature observed in 80-day old plants was masked in those younger plants.

Temperature effect on tillering and panicle formation was not so evident compared to that on plant height. As already cited, number of tillers or panicles has generally a negative correlation with temperature. Tillering and panicle formation of the October planting might be regarded to follow to such general tendency, because its maximum tillering to internode elongation stage coincided with the lowest temperature season. However, plants often produced many tillers in the hotter seasons also. This discrepancy is remained unexplained. With tillering or panicle formation in tropical rice different factors would be concerned complicatedly.

SUMMARY

By planting non- or weakly-photosensitive varieties of indica rice in every month throughout the year, seasonal changes in growth were investigated at Bangkhen Rice Experiment Station located near Bangkok in the Central Plain of Thailand. Varieties tested were RD 1, BKN 17-3, C4-63 and IR 8. N, P_2O_5 and K_2O were applied at the rate of 75 kg/ha, respectively. Results are:

Among various climatic factors, temperature seemed to have strong influence on the seasonal changes in plant growth, although it was considerably high throughout the year and its annual range was only within 5°C. Low temperature (about 25°C as monthly mean of daily mean temperature) in December or January depressed plant height, plant weight and leaf expansion apparently. Moreover, throughout the year temperature showed limiting influence on plant growth with regard to its mature height.

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〔和 文 摘 要〕

熱帯稲の生育の季節的变化

第1報 草丈、分けつ、植物体重および葉面積に対する環境条件の影響

長田 明夫・高橋 均*・S. ダマスボン**・V. サンブラパー**

S. ガンタラロム**

(宇都宮大学農学部, *農事試験場, **タイ国農務局)

年間を通じて稲の栽培が可能な熱帯において、栽植季節によつて、生育がちがうかどうか、気象要因の変化にどう反応するかを研究した。すなわち、タイ国バンコク近郊のバンケン稲作試験場において、感光性のない、あるいはごく僅かな品種、RD 1, BKN 17-3, C4-63 および IR 8 を供試し、1969 年5月より1年間、毎月1日に播種し、移植栽培によつて生育相をしらべた。N・P₂O₅・K₂O を各 75 kg/ha 施用した。

その結果、季節によつて、生育にかなりのちがいが認められ、気象要因のうち、温度が大きな影響をもつようにみられた。まず、12月、1月頃の低温期には、苗代、本田において、草丈の伸長が顕著に低下することが明らかに認められた。このような場合には、植物体重の増加や葉面の展開も抑制される。また、品種の成熟時の草丈とみられる、出穂期近くの草丈と、その時期までの1ヵ月間の平均気温との間には、年間を通じて高い正の相関があつた。一方茎数・穂数に対する温度の影響は、やや不明瞭であつた。しかし、分けつ盛期から節間伸長期にかけて低温にあうと、分けつが多く、かつ有効茎歩合が高く、穂数が多いという特徴がみられた。試験地点は熱帯低地で、気温は年間を通じて高い。実験期間中の日平均気温の月平均値は25.1~29.8°Cであり、その差はわずか5°Cにすぎなかつた。このような条件下で、熱帯稲の生育が温度の影響を強くうけていることは注目される。