高品質および耐塩性のバングラデッシュ稲品種を日本で栽培した場合の成長様式および収量構成形質の評価

誌名	東京農業大学農学集報
ISSN	03759202
著者	平井, 八十一 Prodhan, S.H.
巻/号	47巻2号
掲載ページ	p. 130-136
発行年月	2002年9月

Jour. Agri. Sci., Tokyo Univ. of Agric., 47 (2), 130-136 (2002)
東京農大農学集報，47 (2)，130-136 (2002)

Growth Pattern and Yield Component Traits of Bangladesh Rice Varieties with Good Grain Quality and Salinity Tolerance tested in Japan

By

Shamsul H. PRODHAN* and Yasokazu HIRAI**

(Received February 28, 2002/Accepted June 12, 2002)

Summary : Bangladesh rice varieties are diversified into eco-physiological groups corresponding to different cropping seasons. Moreover, various unique landraces, such as deepwater rice, fine-grained aromatic rice and salt tolerant rice are known. Those varieties are important genetic resources for rice breeding not only in Bangladesh but also in other rice growing countries. Two varieties with good grain quality and two with salt tolerance were taken from Bangladesh landraces, and tested under natural conditions in Japan together with two check varieties. Analysis of growth curve and yield component traits showed distinct varietal differences. One of the salt tolerant varieties, Pokkali, showed high yielding potential endowed with sustained growth rate. Salt tolerance and yielding potential of this variety will be appreciated in temperate countries too.

Key Words : Bangladesh rice varieties, growth curve, yield components, internode length

Introduction

Bangladesh and its neighboring Bengal areas are rich in genetic diversity of rice cultivars including eco-physiological variety groups cultivated in different cropping seasons like Aus, Aman and Boro[1] and deep-water rice adapted to flood prone areas. Moreover, some indigenous varieties are known to harbor unique characteristics such as aromatic fine grains and salt tolerance. Improvement of those unique rice varieties has been an important breeding objective in Bangladesh. To evaluate their potential as genetic resources in temperate regions, it is necessary to understand botanical and agronomic characteristics of those rice groups. Four Bangladesh indigenous varieties, two with aromatic fine grains and two with salinity tolerance, were grown under the condition of Japan together with two improved check varieties. Growth pattern of plant height and tiller number and yield component traits were examined in each variety. The results are presented here as a case study, though our experiment is preliminary one.

Materials and Methods

Plant materials

Four indigenous rice varieties cultivated in Bangladesh, Kalijira, Basmati-370, Nonabokra and Pokkali, were selected for the present study. The former two are aromatic fine grained varieties and the latter two are salt tolerant varieties[2]. It is generally considered that Bangladesh rice varieties are Indica type. But isozyme studies showed that aromatic fine grain varieties distributed in Bengal areas were not typical Indica type[3,4]. For comparison, two improved varieties, Nipponbare (Japonica) and IR-36 (Indica) were examined together with Bangladesh varieties. Seeds of the varieties used in the present study were provided from Bangladesh Rice Research Institute, Bangladesh, except for Nipponbare which was supplied from National Institute of Agrobiological Sciences, Japan.

* Department of Agricultural Science, Graduate School of Agriculture, Tokyo University of Agriculture
** Department of Agriculture, Faculty of Agriculture, Tokyo University of Agriculture (Honorary Professor)

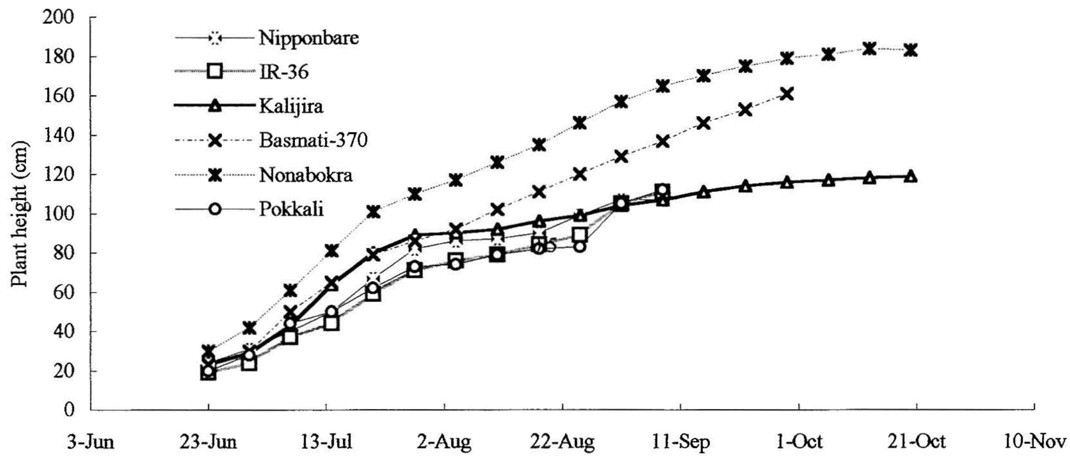

Fig. 1 a Plant height increase

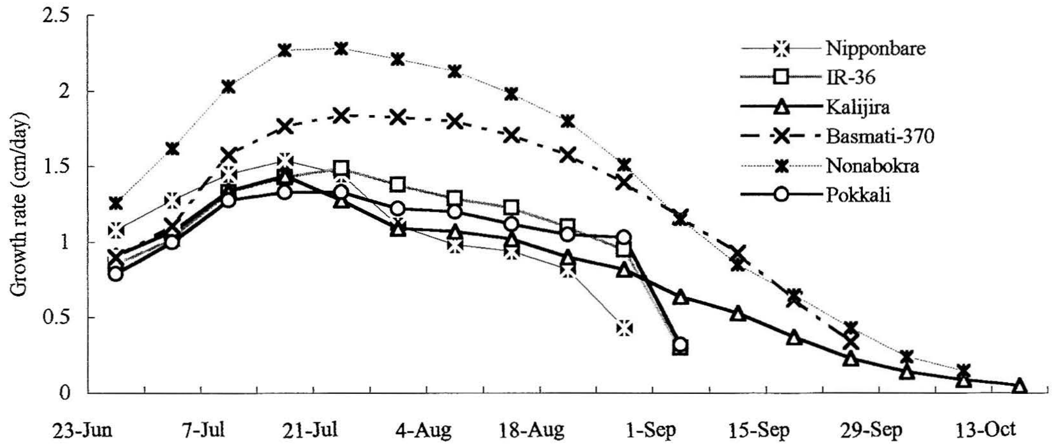

Fig. 1 b Changing pattern of growth rate in plant height

Cultivation method

About 6 kg of friable granular soil was taken in the pot (1/2000 a) after sieving and compacted with hand pressure. Then 4.2 kg granular sieved soil was mixed with 8 g fertilizer (10%, 18% and 16% of NPK) and placed on the compacted soil. Fifty seeds for each variety were sterilized using Sumithion and Tekolith C and sown in pots kept in the greenhouse of Atsugi Farm, Tokyo University of Agriculture on May 29th 2000. Sterilized seeds were spread on top of the soil and then covered by a thin layer of soil and watered for seedlings. Twenty-day old seedlings were transplanted in five pots for each variety, each pot containing two hills. Since germinability of Pokkali was quite low, only one hill was grown in a pot.

Trait measurement

From the next day after transplanting, plant height, tiller number and leaf age were observed once a week. The date at which 50% and 80% of the reproductive tillers exerted panicles were recorded as two measures of flowering time of the plant. At the time of seed maturity, panicle number per hill, panicle length, panicle weight per hill, highest stem length, and dry weight of stem and leaf were measured. Further, spikelet number per panicle, number of filled and unfilled spikelets, weight of 1000 good seeds were recorded. Percentage of filled spikelets was calculated on the basis of number and weight, respectively. Length of respective internodes were measured for all culms of two hills for each variety. Measurements were averaged for each variety.

Fitting of growth curve equation

Growth curve was estimated by fitting the weekly recorded data of plant height and tiller number in each variety to the Robertson's equation[5],

$$\log_e y/(A-y)=b(t-t_{1/2}),$$

Table 1 Final measurement and growth parameters for plant height and tiller number

		Variety					
		Nipponbare	IR-36	Kalijira	Basmati-370	Nonabokra	Pokkali
a)	**Plant height**						
	Mean (cm)	107	111	114	161	184	112
	$t_{1/2}$ *1 (days)	44.2	51.6	46.9	58.0	53.4	50.6
	b *2	0.058	0.054	0.049	0.045	0.050	0.048
	dy/dt *3 (cm/day)	1.55	1.50	1.45	1.85	2.29	1.34
b)	**Tiller number**						
	Mean (max)	41	40	41	43	18	44
	(final)	32	30	17	18	10	42
	$t_{1/2}$ *1 (days)	37.3	40.3	40.7	38.2	36.2	44.6
	b *2	0.215	0.161	0.158	0.192	0.232	0.187
	dy/dt *3 (no./day)	2.21	1.61	1.62	2.07	1.13	2.06

*1 Time at which one half of the final measurement is attained

*2 Growth rate parameter b in $y = A\,(1+ae^{-bt})^{-1}$

*3 Growth rate at $t_{1/2}$

in which A is the final (maximum) measurement, $t_{1/2}$ is the time at which the measurement y reaches $1/2A$, and b is the growth rate parameter. This is a modification of the logistic equation,

$$y=A(1+ae^{-bt})^{-1},\ or\ \log_e(A/y-1)=\log_e a-bt,$$

in which $t_{1/2}$ is given by $(\log_e a)/b$. Then, actual growth rate at $t_{1/2}$ is, since $y=1/2A$, given by

$$dy/dt=b\cdot y(1-y/A)=1/4\,b\cdot A$$

Growth parameter b was estimated for each variety by least square method.

Results

Vegetative growth pattern

All varieties showed normal vegetative growth under the test condition. Increase in plant height for six varieties are shown in Fig. 1 a. Basmati-370 and Nonabokra showed quite tall stature. In contrast, Kalijira and Pokkali were short, similar to the two semi-dwarf control varieties, Nipponbare and IR-36. Growth curve of plant height was estimated for each variety, and the values of $t_{1/2}$ (the time at which plant height reaches a half of the final value), b (growth rate parameter), and actual growth rate represented by dy/dt at $t_{1/2}$ were obtained (Table 1). Changing pattern of actual growth rates computed for weekly data is shown in Fig. 1 b.

As shown in Fig. 1 b, two tall varieties, Basmati-370 and Nonabokra, kept high growth rate until late (maximum growth rate was attained at 5 to 6 weeks after transplanting). The other two short varieties, Kalijira and Pokkali, attained maximum growth rate at 3 to 4 weeks after transplanting with relatively low growth rate, similar to the check varieties, Nipponbare and IR 36.

Changing pattern in tiller number per hill was shown in Fig. 2 a. Number of tillers reached maximum values (40–44 except for Nonabokra) at 5 to 6 weeks after transplanting in all varieties. Nonabokra stopped tillering at 3 weeks after transplanting, producing only 18 tillers.

After reaching the maximum tiller number, two salt tolerant varieties, Nonabokra and Pokkali, did not show significant decrease in tiller number. But in other varieties tiller number significantly decreased as shown in Fig. 2 a. Growth curve equation until reaching the maximum tiller number was fitted for each variety. Parameters $t_{1/2}$, b and dy/dt at $t_{1/2}$ were obtained as shown in Table 1. Changing pattern of actual growth rate estimated for weekly data is shown in Fig. 2 b. Nonabokra had a short growth period with the lowest growth rate. In contrast, another salt tolerant variety, Pokkali, had a sustained growth pattern (large $t_{1/2}$) with a relatively high growth rate.

Leaf development was evaluated by counting leaf age every week. As shown in Fig. 3, development rate of leaves for six varieties seemed similar. Total

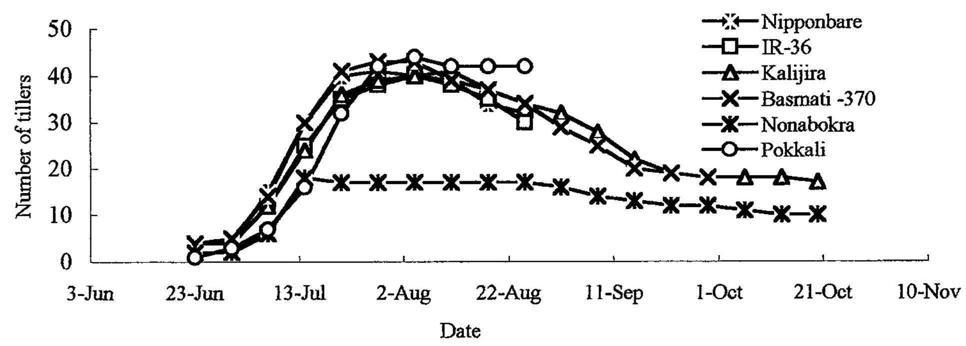

Fig. 2 a Flux of tiller number

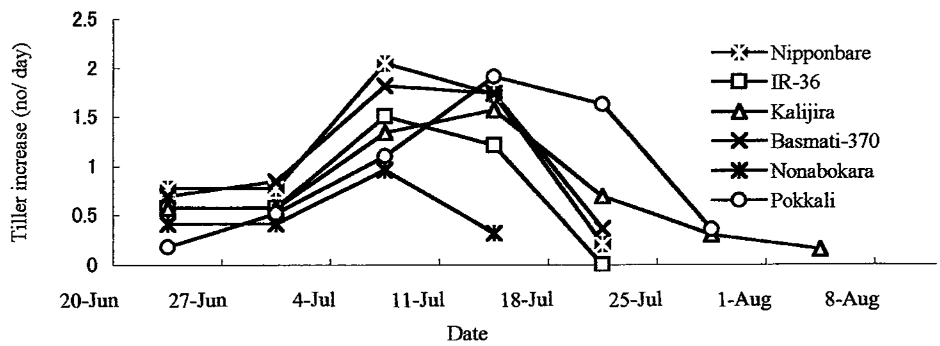

Fig. 2 b Growth rate of tiller number

number of leaves were 20 in Pokkali as well as in Basmati-370 (Nipponbare and IR36 developed 19 and 18 leaves, respectively). Kalijira and Nonabokra continued leaf growth without heading and 21 and 22 leaves were formed, respectively.

Lengths of each internode for four varieties are shown in Fig. 4. In Kalijira and Nonabokra, data were not taken because they did not reach heading and internode elongation was incomplete. Gradual decrease in length from the top to lower internodes shown in Fig. 4 is a general pattern observed in rice plants. A tall variety, Basmati-370, showed the length of the third internode as long as the second internode, and it's lower internodes were longer than other varieties. A short variety, Pokkali, had essentially the same internode elongation pattern as the check varieties.

Yield component traits

Pokkali and Basmati-370 flowered in early September and early October, respectively. Kalijira and Nonabokra did not reach heading until the end of October in outdoor conditions in Atsugi, Japan, though differentiation of young inflorescence was observed in both varieties. Two check varieties, Nipponbare and IR 36, flowered in late August to early September. Consequently, yield component traits, such as panicle number, spikelet number per panicle, seed fertility, number of filled spikelets per hill, panicle weight per hill, 1000 grain weight and dry weight of leaf and stem, were measured for four varieties which flowered and reached maturity (Table 2). Pokkali had the largest number of panicles (22), and Basmati-370 had the lightest single grain weight (0.019 g).

In addition to the direct estimates of grain yield (F ; panicle weight per hill), the product of four yield components (E ; panicle number x spikelet number per panicle x seed fertility x single grain weight) was calculated for each variety as an indirect estimate. In both estimates, Pokkali showed highest value and Basmati-370 showed the lowest. High grain yield observed in Pokkali is most probably because only one hill was grown in a pot owing to a shortage of seedlings, though two hills were grown in other varieties. If we roughly estimate the probable grain yield of Pokkali by dividing the presently observed grain yield by two, the values 30 (E)-36 (F) g are obtained. Those values are still high enough as compared with two check varieties.

Harvest index was estimated as the ratio of direct or

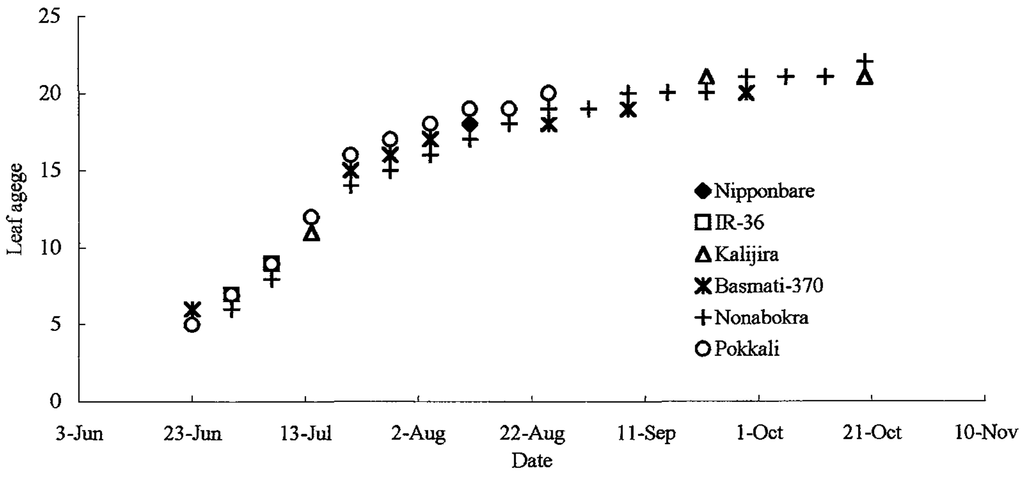

Fig. 3 Leaf development shown by leaf age

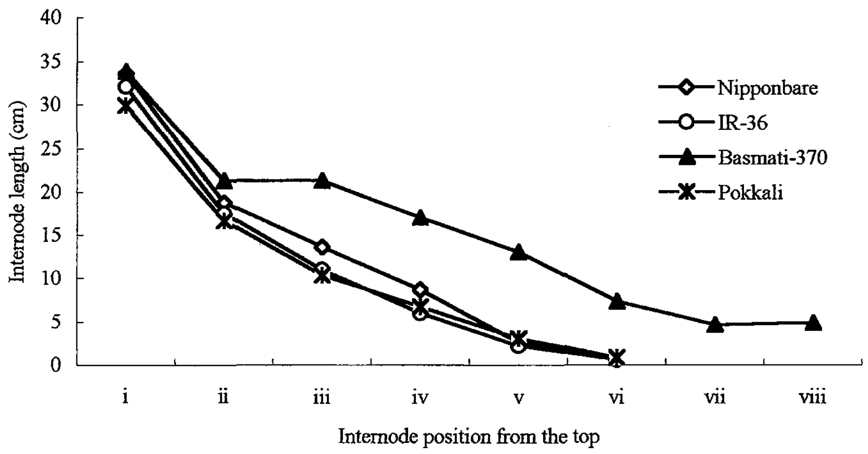

Fig. 4 Internode length

Table 2 Grain yield component traits

Variety	Panicle number A	Spikelet No. per panicle B	Seed fertility (%) C	Single grain weight (g) D	Grain yield per hill (g) AxBxCxD E	Panicle wt. per hill (g) F	Harvest index (%) E/total wt.	F/total wt.	Source = filled grain no.	Sink = A x B
Nipponbare	17	75	0.88	0.026	29.2	32.6	45	42	1137	1275
IR-36	12	130	0.67	0.026	27.1	34.2	55	48	1124	2717
Basmati-370	17	84	0.60	0.019	16.3	21.8	19	15	916	1428
Pokkali	22	139	0.76	0.026	60.4	71.5	51	46	2337	3058

indirect estimate of grain yield per hill to the total plant weight (sum of total grain weight and dry weight of stem and leaf). Basmati-370 showed quite small harvest index (15-19%), and Pokkali showed intermediate value between two check varieties (46-51%). To evaluate "sink" capacity or potential container capacity to be filled by carbohydrate, the product of panicle number and spikelet number per panicle (including unfilled spikelets) was calculated, and realized "source" capacity to fill the container was evaluated by the total number of filled spikelets per hill[6]. Rate of source to sink measurement showed a similar trend to the harvest index, Basmati-370 being the lowest and Pokkali between the two check varieties.

Discussion

Four Bangladesh varieties used in the present study belong to the transplanted Aman group that is grown in summer to autumn season in Bengal areas. Kalijira, Basmati-370 and Nonabokra are sown in mid July and harvested in mid ovember to early December, similar to other typical Aman varieties in Bangladesh[7] while, Pokkali is sown in the middle of June and harvested in early October in Bangladesh. The reason why Kalijira and Nonabokra did not reach heading in Japan might be due to their long vegetative growth period and/or strong photoperiod sensitivity. MATSUSHIMA and TSUNODA[8] reported the optimum temperature for differentiation and development of glumous flower to be 32℃ and for preventing the degeneration of glumous flower to be 36℃/21℃ (day/night). Therefore temperature conditions at Atsugi do not seem to be inappropriate for flower initiation.

Basmati-370 and Nonabokra showed sustained growth pattern (late $t_{1/2}$) with high growth rate (large dy/dt) in height increase giving tall stature. They elongated their internodes, particularly in the lower parts (under the third internodes). In contrast, Kalijira and Pokkali with short stature showed rapid growth pattern (early $t_{1/2}$) and relatively low growth rate (small dy/dt) and essentially the same internode elongation pattern as two semi-dwarf check varieties.

In tiller development, two aromatic fine grain varieties, Kalijira and Basmati-370, differentiated many tillers, but in the later stage more than half of them deteriorated. A salt tolerant Pokkali showed a vigorous tillering ability, as high as the two check varieties, and high efficiency of production of reproductive tillers. Another salt tolerant variety Nonabokra stopped tillering at very early stage differentiating only a few tillers. Attaining maximum tiller number and resulting from the death decreasing the number of tillers after a certain stage (remaining the productive tillers) is the general pattern for rice, which depends partially on the characteristics of varieties[9].

Good quality rice Basmati-370 is a low yielder even in Bangladesh producing 1.5–2 ton/ha, other three varieties yielding 2–2.5 ton/ha[7]. It showed low yielding capacity also in the present study. Low yield of Basmati-370 observed in Japan may be partly due to its late heading time which caused seed sterility under the cool climate in October. Our results indicated high yielding potentiality of Pokkali mainly depends on the large number of panicles per hill. Environmental effect on the yield components[10] is most noticeable in the number of panicles per hill. Even when wider planting density given for Pokkali in the present study is taken into consideration, this variety seem to be a high yielder. It suggests that this tropical variety has a wide regional adaptability possibly because of its weak or non-photosensitivity and can be a valuable genetic resource for the breeding of salt tolerance in temperate areas.

Acknowledgments : We are grateful to Dr. Takeshi TANABE and Dr. Tokihide NAGOSHI for their technical guidance during the experiment and also would like to thank Dr. Hiroko MORISHIMA for valuable and generous discussions.

References

1) YAMADA, N., 1975. Rice Production in South-East Asia and Some Nearby Countries. Rice Production in Bangladesh. *In* Rice in Asia, University of Tokyo Press. Tokyo, 99–106.
2) AKBAR, M. and SENADHIRA, D., 1988. Sensitivity of rice seedling to salinity. *International Rice Research Newsletter.*, **13** (3), 19.
3) GLASZMANN, J.C., 1987. Isozyme and classification of Asian rice varieties. *Theor. Appl. Genet.*, **74**, 21–30.
4) CAI, H.W. and MORISHIMA, H., 2000. Diversity of rice and cropping system in Bangladesh deep-water areas. *JARQ*, **34**, 225–231.
5) ROBERTSON, T.B., 1923. The chemical basis of growth and senescence. Lippincott C., Philadelphia.
6) ISHII, R., 1995. Roles of photosynthesis and respiration in the yield determination process. *In* Science of the Rice Plant. Food and Agriculture Policy Research Center. Tokyo, **2**, 691–696.
7) Bangladesh Rice Research Institute, 1995. *Annual Report.*
8) MATSUSHIMA, S. and TSUNODA, K., 1958. Analyses of developmental factors determining yield and the application to yield prediction and culture improvement of lowland rice. 45. Effects of temperature and its daily range in different growth-stages upon the growth, grain yield and its component factors in rice plants. *Proc. Crop Sci. Soc. Japan*, **26**, 243–244.
9) HANADA, K., 1993. Plant growth and tillering. *In* Science of the Rice Plant. Food and Agriculture Policy Research Center. Tokyo, **1**, 222–258.
10) MATSUSHIMA, S., 1959. "Theories and techniques in rice cultivation—Theory on yield analysis and its application" (Inasaku no riron to gijutsu—Shuryo seiritsu no riron to oyo). Yokendo, Tokyo.

高品質および耐塩性のバングラデッシュ稲品種を日本で栽培した場合の成長様式および収量構成形質の評価

Shamsul H. PRODHAN* ・平井八十一 **

(平成 14 年 2 月 28 日受付/平成 14 年 6 月 12 日受理)

要約：バングラデッシュのイネは異なる作期に対応する品種群が分化しているばかりでなく，在来品種の中には，深水イネ，香りのある高品質米，耐塩性イネなど特異な品種が存在する。それらの品種改良はバングラデッシュのイネ育種において重要であるばかりでなく，広く遺伝資源としての価値が再認識されている。バングラデッシュで栽培されている高品質米 2 品種および耐塩性 2 品種を用いて，我が国で栽培した場合の生育特性を評価した。その結果，成長様式および収量構成形質の品種間差異が見出された。耐塩性品種 Pokkali は生育後期まで高い成長率を持続しそのため高い収量性を示すことがわかった。この品種は温帯地域においても遺伝資源として有用である可能性があり，さらに調査する必要があることを指摘した。

キーワード：バングラデッシュのイネ品種，成長様式，収量構成形質，節間長

* 東京農業大学大学院農学研究科農学専攻
** 東京農業大学農学部農学科（名誉教授）