PROCEEDINGS OF THE WORKSHOP ON

deep-water rice

THE INTERNATIONAL RICE RESEARCH INSTITUTE

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THE INTERNATIONAL RICE RESEARCH INSTITUTE
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Foreword

These proceedings of the Deep-Water Rice Workshop mark a milestone in the international cooperation to improve the grain yield of deep-water rice. Scientific progress has been made since the first International Seminar on Deep-Water Rice was held in Bangladesh in 1974.

Deep-water rice areas are estimated at 25 to 30% of the world's rice land. Bangladesh, India, Thailand, Vietnam, and Burma have extensive deep-water rice areas. In Africa, several countries grow floating varieties; about 70% of Mali's total rice-growing area is in deep-water rice. But the new rice technology has not benefited the extensive regions where water depths range from 50 to more than 600 cm and cannot be controlled.

The importance of those areas is further enhanced because they are the most heavily populated on earth. Man has lived for centuries along river deltas where there is always sufficient water to grow rice even during drought. However, floating rice often is the only crop that can be grown. But in years when floods come early, the floating rice is destroyed because the plants can not withstand submergence; nor can they elongate rapidly at an early growth stage.

The Green Revolution has not helped deep-water rice farmers whose yields have remained at 1 to 2 t/ha. Low yields of traditional floating rice varieties result from poor plant type, i.e. few tillers, long, droopy leaves, very tall stature even in shallow water, low tolerance for submergence, and inability to elongate rapidly in early growth stages. Modern short-statured varieties, on the other hand, are poorly adapted to deep-water conditions; they do not have the ability to elongate, and they mature too early.

The scientists who participated in the Deep-Water Rice Workshop are dedicated to the improvement of rice production in deep-water areas. The International Rice Research Institute (IRRI) was honored to be able to sponsor the workshop, in cooperation with the Thailand Ministry of Agriculture and Cooperatives.

IRRI's research in deep-water rice has been accelerated in the past 2 years with the initiation of the Thai-IRRI Cooperative Deep-Water Rice Research Project. Dr. Ben Jackson of The Rockefeller Foundation serves as IRRI's program leader for deep-water rice research. He is assisted by Dr. Derk HilleRisLambers, a plant breeder, in Thailand, and by Drs. B.S. Vergara, S.K. De Datta, W.R. Coffman, and a number of supporting scientists at IRRI's headquarters in Los Baños.

The growing interest of national programs in research to improve deep-water rice production technology is also noteworthy. Evidence of this increased interest and of initial accomplishments are given in these workshop proceedings. IRRI scientists are pleased to have the opportunity to participate in the activities of the growing network of researchers working on deep-water rice.

The proceedings of this Deep-Water Rice Workshop are an important reference for scientists, administrators, and planners who work on deep-water rice. My congratulations and gratitude to the people who made the workshop a success, including Mr. Don Esslinger, Visiting IRRI Associate Editor from the University of Missouri, who helped edit and prepare these papers for publication.

NYLE C. BRADY
Director General
IRRI, Philippines

Welcome address

Allow me the privilege to welcome you to my country and to make a few remarks concerning your meeting here.

It is a pleasure and privilege to see so many scientists come to my country and exchange ideas on research work on deep-water rice. For one thing, it shows that we are not alone in facing the problem of helping farmers who cannot control water in their rice fields. For these farmers, the so-called "Green Revolution" and "High Yielding Varieties" are only slogans they hear on the radio, read in the newspapers, or learn from their more fortunate neighbors who have good irrigation systems.

It seems appropriate that scientists begin to face problems in areas prone to intermediate or deep flooding because there is no easy or quick alternative. The costs of constructing dams, leveling land, and building drainage facilities in such regions as the Central Plain of Thailand, the Mekong Delta of Vietnam, or the Ganges-Bhramaputra river basins of Bangladesh and India are prohibitive, considering the overall needs of the rapidly expanding population. Rather, we must be realistic and seek a better way of growing rice under existing conditions. I am confident that with the proper outlook and dedication we can produce significant benefits. The soils of deep-water areas tend to be fertile and seldom suffer from drought when the rice is in the final growth stages.

I also thank the International Rice Research Institute for its financial support of this meeting and cooperation in our mutual efforts to perform research on this important crop. We are pleased to acknowledge IRRI's close cooperation through the years; we have been honored to have three directors general of the Ministry serve on the Institute's board of trustees.

We hope that your meeting will yield a fruitful basis for your future work, that your visits to our government experiment stations and your personal contacts will provide greater incentive, and that the information exchanged will serve the intended purpose.

Several Thai scientists are attending this meeting and some will be presenting papers. I hope you will feel free to call on them for help, and I personally request them to help make your visit as comfortable and productive as possible.

We believe the way to progress is through cooperation, not only among our own people but within the international community. This meeting is a good example of such activity and I trust good results will be forthcoming.

We have made some improvement in floating rice, and I'm glad it will be brought to the attention of this meeting. I'm sorry I will not be able to attend. However, bear in mind that my interest and our Ministry's interest are in the development of rice, not only for lowlands where modern varieties are used but also for deep-water areas where floating varieties are grown. The total areas of floating rice in Thailand and in other nations are enormous, and floating varieties are the ones that we should boost.

Thank you and I declare this meeting open.

INSEE CHANTARASATIT
Minister of Agriculture and Cooperatives
Royal Thai Government
Bangkok, Thailand

Summary and recommendations of the deep-water rice workshop

D.G. Kanter, D.H. HilleRisLambers, and B.H. Siwi

Forty scientists from nine countries participated in the Deep-Water Rice Workshop, 8-10 November 1976, at Bangkok, Thailand. More than 40 other scientists observed the proceedings. The participants are listed in the Appendix.

The participants presented papers on research activities on the first and third days of the workshop. The following topics were covered:

1. Basic studies on deep-water rice
2. Screening methods for deep-water rice
3. Country reports on progress in deep-water rice research, and
4. Recent research results

On the second day, the group observed experiments at the Huntra Deep-Water Rice Experiment Station and toured areas growing deep-water rice. The tour also included stops to see on-farm testing of promising lines by the Rice Division of the Thailand Ministry of Agriculture and Cooperatives.

This report summarizes recent research findings and activities of the workshop. In addition, new areas for research and previous recommendations not acted upon are pointed out.

The Honorable Dr. Insee Chantarasatit, Minister of Agriculture and Cooperatives, gave the welcome address. He said that scientists must be realistic in their approaches to research aimed at increasing produc-

D.G. Kanter. Plant Breeder, International Rice Research Institute (IRRI), G.P.O. Box 64, Ramna, Dacca-2, Bangladesh. *D.H. HilleRisLambers.* Associate Plant Breeder, The International Rice Research Institute (IRRI), G.P.O. Box 2453, Bangkok, Thailand. *B.H. Siwi.* Plant Breeder, Jalan Merdeka 99, Bogor, Indonesia.

tivity under local deep-water conditions. He pointed out the benefit of international cooperation on problems of common concern and the need for more rapid progress in improving deep-water rice yields.

Dr. Amirul Islam, Director of the Bangladesh Rice Research Institute (BRRI), reviewed events and activities from the 1974 seminar at BRRI up to the 1975 annual conference at the International Rice Research Institute (IRRI), which led to the present cooperative involvement of scientists and organizations in deep-water rice research on an international basis. He said that instead of making recommendations, scientists should now start research on the priority areas outlined in the 1975 session. He said that this Workshop should make known the results of new research developments since 1974. Physical facilities for deep-water rice research in Bangladesh are nearing completion, and a new project on pest management of deep-water rice is being implemented, he reported.

The "Report of the Deep-Water Rice Group" from the 1975 International Rice Conference at IRRI designated 11 problem areas for investigation to accelerate progress on deep-water rice. Five were given high priority to receive immediate attention. Several objectives were listed for the two areas of varietal improvement and cultural practices. Research responsibilities of highest priority among the affected countries were also outlined.

VARIETAL IMPROVEMENT

Fifteen floating and two nonfloating rices from five countries were grown at five northern and one southern latitude sites to study their flowering responses. The floating rices were divided into seven groups according to their flowering reactions. Among the northern latitude sites, grouping of the varieties in general did not change much but the spread between the earliest and latest groups increased. Although the theory of photoperiod sensitivity is recognizable in the results, the variation observed in estimated day lengths for floral initiation is too high to predict flowering dates based on critical day lengths and length-of-daylight curves. Until more research on photoperiod sensitivity in rice is conducted under natural conditions, actual growing of varieties will be the only reliable guide to flowering behavior and local adaptability.

West Bengal reported on differences in morphological, physiological, and anatomical characteristics among varieties adapted to different deep-water regimes. With simple techniques, differences were found in submergence tolerance among the test varieties. Large air cavities in the stems were associated with these differences. Different types of nodal tillering, stem elongation ability, and total stem length were mentioned as important criteria in selecting varieties suited to different water regimes.

Five lines from Thailand showed promising varietal possibilities. Their satisfactory performance provided evidence of the type of improvement that may be expected in deep-water rice. Other national program participants should be encouraged to know that fruitful progress can be made.

Eleven areas of research lacked information to make breakthroughs in deep-water rice technology.

BREEDING TECHNIQUES

Heritability estimates from two populations, each involving a Thai floating variety and a semidwarf high yielding variety, suggested that only partial success may be expected when selecting for good elongation among F_3 lines in just one season. That could be corrected by postponing selection until breeding lines are nearly homozygous. Apparently, genes for elongation ability may be either recessive or incompletely dominant.

Data from screening of F_3 progeny lines for elongation ability suggested that lines which elongate well in 90 or 100 cm water should also elongate well at depths of 140 or 150 cm. Preliminary screening for deep-water tolerance could be done at stations with only shallow-water (90 to 110 cm) facilities.

Some success in selecting for elongation ability could be expected if selections were based on seedling and plant height, provided that one parent is a floating rice variety. However, selecting for other characteristics may best be done after the lines have been fixed for elongation ability; otherwise lines with good elongation ability may be discarded. Further studies on developing more efficient breeding methods for deep-water rice are required.

A new procedure for handling photoperiod-sensitive hybrid populations of deep-water rice was proposed. Through the use of a combination of controlled conditions of short days, dense spacing, and reduced nutrition, up to three generations may be grown in a year. The use of several hybrid populations having a deep-water rice parent demonstrated the feasibility of rapid generation advance. Practical ways to carry out this procedure without sophisticated facilities were discussed. Only one generation of photoperiod-sensitive rices is obtained per year with conventional procedures. Selection of desirable plants is less efficient in early generations. Rapid generation advance can be accomplished if selection is postponed to later generations when lines are more fixed. The materials could be screened for selected characteristics during the course of generation advance to facilitate studies on the relationships of elongation ability with other traits.

SCREENING OF GERM PLASM AND BREEDING MATERIALS

Scientists must increase their knowledge in all aspects of the deep-water rice plant to improve it. Screening tests are the primary bases for classifying trait expressions of genetic materials under prescribed conditions.

A Bangladesh study compared seven local strains of deep-water rice for elongation of internode, leaf sheath, and leaf blade under controlled water and flooded conditions. Their anatomical differences may be useful in screening rices with different flood tolerance traits. The wild strain Jhora emerged out of the water ahead of the other varieties even though it relied more on leaf sheath and leaf blade elongation. Combining internode and leaf elongation features was suggested as a means to enhance flood tolerance of improved deep-water rices.

Elongating, floating rices were distinguished from nonfloating types by applying special techniques to force differences in morphological characteristics in the early seedling stage. The information is rapidly obtained with simple facilities. Preliminary results suggest that a combination of gibberellic acid and abscisic acid may be responsible for internode elongation. These studies should be continued to include more diverse materials (wild rices, new hybrid lines with different parentages). Correlations between traits of lines from new crosses should be obtained. Historical associations must be distinguished from physiological and pleiotropic associations.

The procedures employed in Thailand to screen breeding materials for elongation ability were described. The physical facilities, including details of 16 deep-water ponds, were described, along with some associated problems and suggestions. The methods of testing were outlined and the scoring system was elaborated. Maximum obtainable water depths in the ponds vary from 200 to 300 cm.

Deep-water tank facilities to screen breeding materials for elongation in 200 to 300 cm water may be beyond the resources available to the Thailand station. A test was described that screens materials for rapid internode elongation by rapidly raising the water level in a 100-cm-deep water tank. Of 770 varieties from Thailand, India, Cambodia, Vietnam, and Bangladesh, about 63 exhibited rapid internode elongation.

During the monsoon season, Southeast Asia's rice crop may be inundated for 1 to 30 days at various growth stages. A technique to screen a large number of lines in the field for submergence tolerance was reported. The screening test is sufficiently flexible so that test parameters may be altered to conform to varying types of flooding submergence prevailing in specific areas where improved varieties may be utilized. Tests in Thailand have helped to identify 16 BKN and KLG lines that showed consistent tolerance for flood submergence. BKN 6986-108 showed good submergence tolerance and good elongation capacity. The findings further revealed that submergence tolerance is independent of elongation ability in floating rice.

Techniques for phytotron, greenhouse, and field screening of large numbers of rices for drought tolerance were presented. Several traditional Bangladesh and Thailand deep-water rices and some deep-water semidwarfs were identified as good genetic sources for seedling-stage drought tolerance. Leb Mue Nahng 111, Nam Sagui 19, BKN 6986-108, BKN 6986-147-2, and IR442-2-59-2-3-3 performed well. There was no suggestion of pleiotropic association between drought tolerance and elongation ability. Therefore, screening for seedling drought tolerance should be a part of any deep-water rice improvement program following hybridization.

A procedure for screening breeding materials for kneeing ability was described. Kneeing ability, the ability of the upper internodes to rise toward the vertical position after the plants have lodged following the receding of floodwaters. is essential for high performance of deep-water rices. Five of the 50 entries in the first International Rice Deep Water Observational Nursery (IRDWON) exhibited good kneeing ability.

CULTURAL PRACTICES

The agronomic performance of four advanced, improved-plant type lines with elongation ability was investigated at three water depths and two levels of soil fertility. The almost zero yield of the nonelongating entry at 100-cm water depth suggests the advantage of these new semidwarf lines with elongation ability in areas where flooding for long periods of time is a problem. Except for T442-57, entries with elongation ability showed no significant yield increases with added nitrogen. The results obtained with T442-57, however, suggest that nitrogen fertilizer can increase grain yields even under medium deep-water conditions.

A yield trial of 25 new semidwarf hybrid lines with genes for elongation ability was conducted at six locations to assess their yield potential in shallow water in comparison with that of RD7, a recently released

Thai high yielding variety. Yields of several lines were comparable with those of RD7 in the 4 t/ha range. The performance indicates that high yielding varieties with elongation ability can be developed.

PEST MANAGEMENT

A new research project on pest management of deep-water rice in Bangladesh was outlined. The United Kingdom Ministry of Overseas Development agreed in principle to fund the project for 3 years in a bilateral grant to the Government of Bangladesh. The objectives are to survey the pests and diseases reducing deep-water rice yields, and to develop reliable, economic control measures without seriously disturbing the faunal balance in the agroecosystem. After the second year, the project will be extended to deep-water rice areas in other countries.

From a provisional check, the ear-cutting caterpillar, stem borers, and ufra nematode may be among the main deep-water rice pests.

INTERNATIONAL NURSERIES

Preliminary observations on the first International Rice Deep Water Observational Nursery (IRDWON) were presented. Ten countries and West Africa Rice Development Association (WARDA) participated in the IRDWON. Among the 50 entries were many improved types from Thailand. To adapt to most deep-water areas, varieties must have a long growth duration or photoperiod sensitivity or both, exhibit good nodal tillering, and show good kneeing ability. Several good lines for each trait were identified.

COUNTRY REPORTS : PROGRESS IN DEEP-WATER RICE RESEARCH

Progress in deep-water rice research in six countries and organizations was reported.

India. The State of Bihar in India reported the first details of rice research activities there. About 2 M ha require varieties adapted to a range of shallow-water and deep-water conditions, stagnant water, and poorly drained areas.

Research on deep-water rice began in 1914. In 1975 the Ford Foundation supported a project at the Pusa Centre to supplement the research on poorly drained lands including deep-water areas.

A promising line (64–117) from germ plasm collected in local deep-water rice areas has been identified. It consistently yielded 10 to 15%

more than did recommended varieties. Several lines derived from the hybridization program show promise.

Bangladesh. Since 1917, activities in Bangladesh have consisted of establishment of institutional deep-water rice research and work with varietal improvement, agronomic aspects, and control of diseases and insects.

Accessions of deep-water rice germ plasm number about 775. The completion of deep-water ponds will accelerate the breeding program and increase the prospects of identifying improved varieties. Preliminary research on relay cropping of deep-water rice with boro rice shows potential in increasing land productivity in deep-water areas.

West Africa. In West Africa, WARDA has launched a regional research project at Mopti in Mali for flooded and deep-water rice. The project allows for expansion of physical facilities and support of research in priority areas.

Deep-water rice is grown on about 320,000 ha but the estimated potential area for growing it is about 635,000 ha. Background on the nature of the area and cultivation practices was presented. Constraints to higher yields were listed.

Research in the associated countries began only recently. Among some 300 *O. sativa* varieties that had been introduced in Mali from Indochina since 1961, five were released for commercial production. The Nigerian Government initiated research on deep-water rice in 1954. In 1971 an improved strain was released from the hybridization program.

Indonesia. About 650,000 ha of tidal swampland is expected to be in rice cultivation in Indonesia by the end of 1979. An estimated 5 M ha is considered suitable for rice cultivation. The development of replacement varieties for these areas has intensified in recent years. Plant characteristics required for varieties well adapted to cultivation in the tidal swamp areas were described. Developing varieties with acceptable flowering dates is a major breeding objective. Both long-season, photoperiod-sensitive and short-season, photoperiod-insensitive indica varieties are required. Several Thai and Bogor lines appear promising.

Date-of-seeding experiments to study the nature of the photoperiod response among selected tidal swamp rice breeding materials were started.

Burma. Rice in Burma is grown on some 5 M ha over a wide range of conditions, including upland, lowland, and deep water. Deep-water varieties are grown in uncontrolled water depths that range from 50 to more than 200 cm. Varietal characteristics and cultural practices vary, and are adapted to local water regimes. Yields of the traditional varieties range from 0.6 to 1.0 t/ha.

An active breeding program is under way. Hybridizations involving local deep-water varieties and improved high yielding varieties were started in 1971. Several promising pure-line selections and new hybrid lines will be placed in preliminary deep-water tests in 1977. Several entries from the IRDWON also show promise.

Vietnam. The performance of 34 Thai BKN lines and nine traditional floating rice varieties at two Vietnam locations in the 1974 rainy season was reported. Elongation ability was not fully expressed because water depths were lower than normal. Some differences among varietal responses between test sites in Vietnam and Thailand may be attributed to local environmental interactions.

TOUR OF DEEP-WATER RICE AREAS

A field tour on the second day of the workshop acquainted participants with research activities and farmers' broadcast rice fields in the Central Flood Plains. At the Huntra Rice Experiment Station the group visited the IRDWON, and observed research on the effect of water depth and fertilizer on performance of new lines and established varieties, a demonstration of kneeing ability, and screening tests for elongation ability and submergence tolerance. The experiments clearly demonstrated that new technology for improved deep-water rice is on the way. Other experiments aimed toward increasing production in farmers' fields are in progress.

The participants visited the deep-water areas of Lopburi, Singburi, Angthong, and Wangnoi. Three stops were made to observe yield trials of promising deep-water lines.

NEW RECOMMENDATIONS

Deep-water rice terminology. Scientists from different countries or regions use different terms for describing the same plant characteristic or behavior. A committee of Workshop participants proposed a terminology for use by all researchers (see Appendix B).

Standard scoring of elongation ability of deep-water rice. A standard scoring system for measuring elongation ability of deep-water rice was submitted by a Workshop committee and approved by the participants. The system was further recommended to replace that described in the Standard Evaluation System for Rice (see Appendix C).

Future deep-water rice meetings. The Workshop agreed that subsequent annual meetings should be held in different countries on a rotating basis as previously scheduled. Meetings are scheduled in India in 1977 and in Indonesia in 1978.

The Workshop requests IRRI's assistance in arranging the 1977 meeting in India.

Travel fund. The Workshop agreed that, as in the past, IRRI is the appropriate institution to seek travel funds for scientists in deep-water rice research who will attend the meetings in 1977 and 1978.

Description of deep-water areas. Descriptions of the main zones of deep-water rice and their flooding characteristics should be developed to aid in the design of programs for varietal improvement, cropping systems, and pest management. The descriptions should include internationally accepted terms. Necessary information could be generated from locally available maps and other data. The Workshop requests IRRI's help in providing support for ways and means and the guiding principles for such a study.

GEU training. The Genetic Evaluation and Utilization (GEU) program includes training in screening for elongation ability, submergence tolerance, and drought tolerance. National programs that need to train scientists in these aspects should send them to a GEU training session.

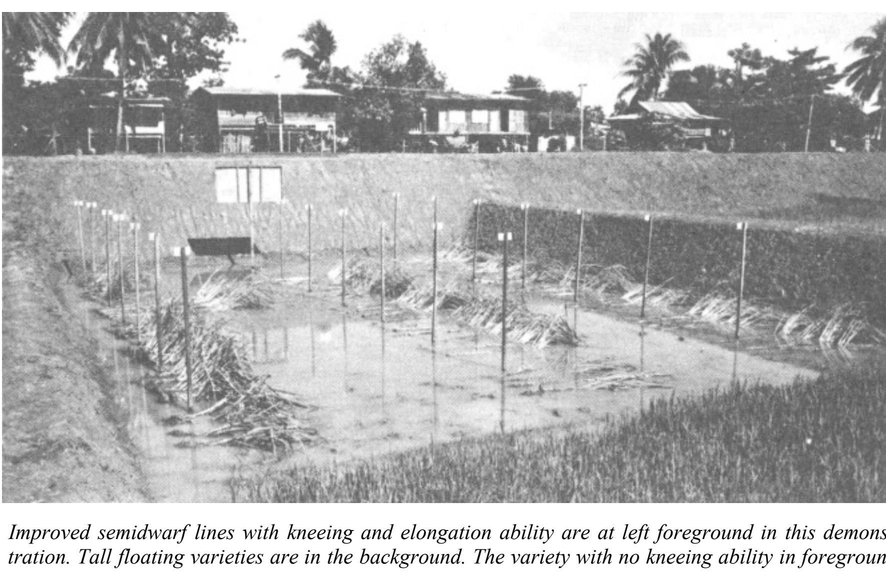
CLOSING REMARKS

The closing remarks were delivered by Mr. Praderm Titatarn, Deputy Director General of the Department of Agriculture. He predicted that the growth of human populations will place greater demand on the deep-water rice areas to increase their productivity. Although the scientists participating in the Workshop were few, they could serve as catalysts to stimulate greater interest among their colleagues to implement research aimed at increasing production of the deep-water areas.

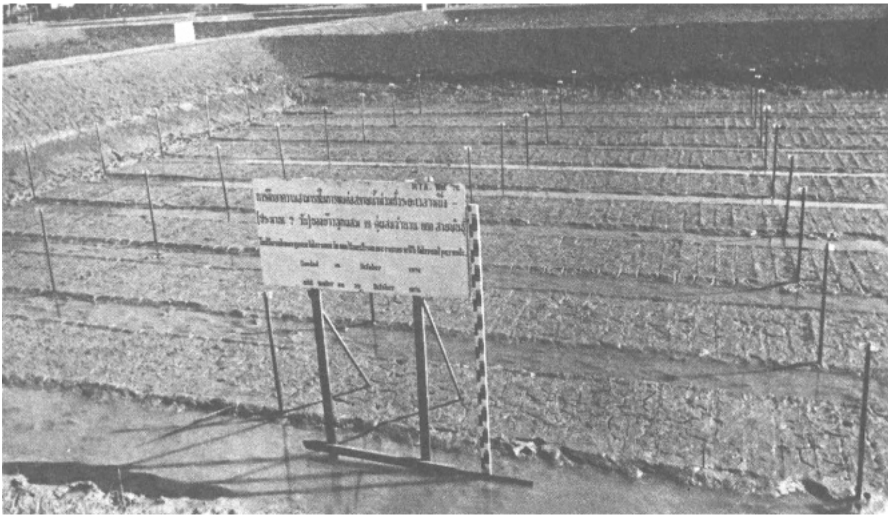
The Huntra Rice Experiment Station, one of 22 stations operated by the Rice Division, is the main site of deepwater rice research in Thailand. It covers more than 24 hectares of deep-water ponds and natural flooding fields.

Outstanding floating rice varieties from different parts of the world are planted at the Huntra Station for observation and physiological studies. Sixteen deep-water ponds are used for trials with water depths of up to 200 cm.

Screening for varietal differences in earliness of elongation.

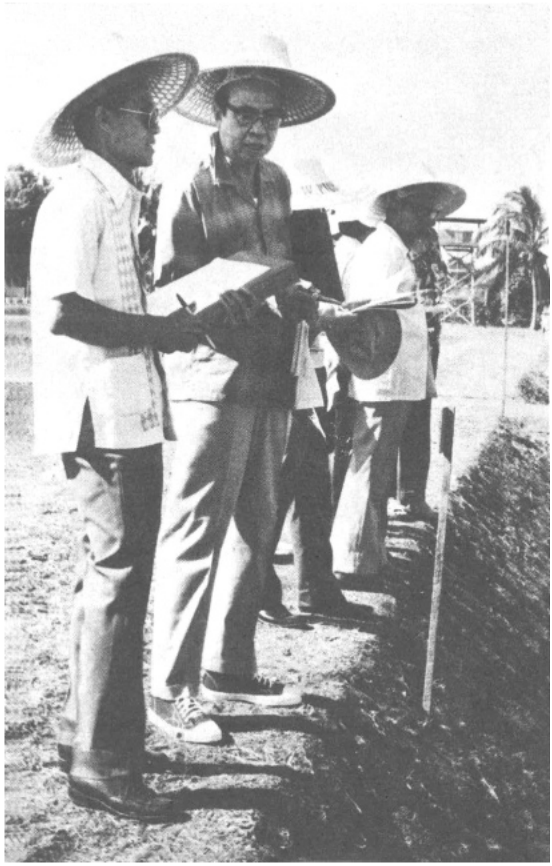


Improved semidwarf lines with kneeing and elongation ability are at left foreground in this demonstration. Tall floating varieties are in the background. The variety with no kneeing ability in foreground of middle row is T442-57.



Seven hundred lines at the seedling stage were submerged for 10 days to test them for submergence tolerance.

Advanced lines are tested at Huntra Station and at six other stations for yielding ability. Here the water depth was gradually increased, at 40 days after transplanting, to a maximum of 130 cm.



Drs. P.B. Escuro and K. Zan discuss a deep-wafer trial at the Huntra Station. Dr. M.S. Ahmed is in the background.

Dr. B.R. Jackson, third from left, explains to Workshop participants and observers how the many breeding lines with improved plant type and elongation ability are being tested in deep water.

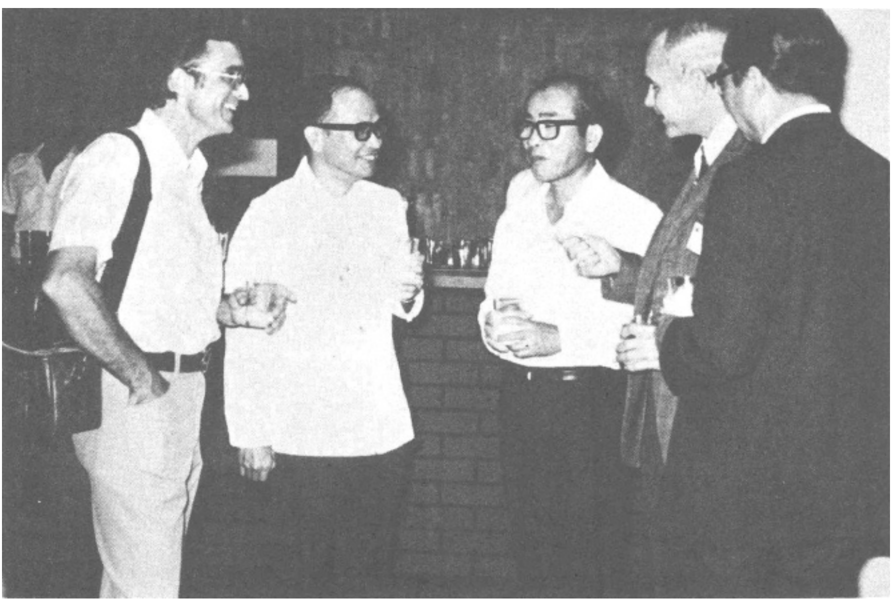
Rice breeders inspect entries in the International Rice Deep-Water Observational Nursery (IRDWON) that was started in 1976 with 10 countries participating. In the background is the Huntra Station's screenhouse.

Drs. D. HilleRisLambers and D. Kanter examine specimens in the demonstration of a suggested method for screening nodal rooting ability of deepwater rice lines.

More than 80 participants and observers attended the three-day Workshop that included a tour of deep-water rice areas and the Huntra Rice Experiment Station in the central plains.

Thailand Minister of Agriculture, Dr. Insee Chantarasatit, second from left, welcomes participants to the Workshop. Others are (L–R) Drs. B.R. Jackson, Ohn Kyaw, and H.D. Catling.

Workshop participants at a reception given by the Thailand Department of Agriculture are (L–R) Wiengpet Sirikant, Dr. B.R. Jackson, Dr. S.K. De Datta, Nopporn Supapoj, Siriporn Karin, and Asanee Sarigabutr.



Dr. Prakob Kanjanasoon (center), Director- General, Department of Agriculture, Thailand Ministry of agriculture and Cooperatives, hosts a reception for participants at the Workshop. Others (L–R) are D. Esslinger, Dr. B.S. Vergara, Dr. B.R. Jackson, and Dr. K. Zan.

Importance of deep-water rice research

M.A. Islam

Bangladesh represents a major deep-water rice growing area in the world. Nearly half of the 10 M ha of rice land in the country is affected by monsoon floods. In approximately 2 M ha planted to deep-water rice, the water rises 1 to 6 m during the monsoon season. The area represents about 20% of the total rice area and about 16% of the total production. Yields average about 0.8 t/ha.

About 13.2 M Bangladeshi (18.5% of 71.3 M) are wholly or mostly dependent on deep-water rice. The farmers in deep-water areas are among the poorest. They are small, subsistence farmers whose existence is extremely precarious. They have not benefited from modern rice production technology. With her limited land resources and increasing population, Bangladesh cannot remain indifferent to the suffering of millions of farmers whose survival and security depend on deep-water rice.

Many other countries in South and Southeast Asia have similar deep-water rice areas (but maybe not as extensive nor as poor as in Bangladesh). About 2 M ha is estimated to be in deep-water rice. Yields are poor because the areas lack water control, and the success or failure of the crop depends on the vagaries of monsoon weather.

Research in deep-water rice is relatively undeveloped in most countries where that rice is grown; moreover, there are very few research workers in deep-water rice. For these reasons, an international seminar was

M.A. Islam. Director, Bangladesh Rice Research Institute (BRRI), P.O. Box 911, Dacca, Bangladesh.

called in Bangladesh in August 1974. It aimed to draw the attention of scientists, administrators, and politicians to the immense scientific, technological, administrative, and economic problems of deep-water rice ; and to find ways and means to improve its cultivation for higher and stable yields.

For the first time, an international team of rice scientists seriously deliberated the problems of deep-water rice cultivation, reviewed existing knowledge, and identified the areas where information was lacking.

The seminar had recommendations on-

1. flood characteristics
2. genetics and breeding
3. plant type and morphology
4. agronomy and physiology
5. plant protection
6. screening of existing varieties
7. international cooperation

Unlike many other seminars where scholarly papers are presented, valuable recommendations are made, but no follow-up action is taken, the international seminar recommended the establishment of a Task Force—composed of active research workers in deep-water rice from national and international institutions-to develop

1. a program for basic studies which would be conducted in designated institutions, and
2. national programs in consultation with national teams to set priorities based on available knowledge.

The Task Force met for the first time in 1975 at the International Rice Research Institute (IRRI), at the time of the annual International Rice Research Conference. Two special sessions of the Conference were devoted to deep-water rice problems. In the Task Force meeting, the problem areas of deep-water rice research were clearly identified, research programs prepared, priorities fixed, and research programs distributed among the participating countries in the spirit of international cooperation. The Task Force also proposed the following actions:

1. Change the name Deep-Water Rice Task Force to Deep-Water Rice Technical Working Group. The chairman submitted for IRRI's consideration the names of the following persons who would serve in an advisory capacity and would channel to IRRI deep-water rice research information and suggestions from their respective countries and organizations.

Mr. H.M. Beachell	Indonesia
Dr. M.A. Choudhury	Bangladesh

Dr. B.R. Jackson	Thailand
Dr. D.K. Mukherji	India
Dr. H.I. Oka	Japan
Dr. B.S. Vergara	IRRI
Dr. Harry Will	WARDA (West Africa Rice Development Association)
Dr. Amirul Islam	Bangladesh

2. Because of the uniqueness and small size of the deep-water research group, annual meetings should be held in different countries on a rotating basis as indicated below.

Bangladesh	1974
IRRI (Philippines)	1975
Thailand	1976
India	1977
Indonesia	1978

3. Realizing that IRRI was the appropriate institution to seek support for international cooperation on deep-water rice, the Deep-Water Rice Technical Working Group should request IRRI's help in providing the following:

a. Travel funds for deep-water research personnel to attend annual meetings for 1976, 1977, and 1978;

b. Funds for conducting a systematic survey of pest and disease problems of deep-water rice in affected areas of Asia (The survey would include assessment studies of crop loss from injurious organisms. Where possible, plant resistance to significant pests would be identified for incorporation into promising varieties);

c. Funds for studies to generate from maps and hydrologic data the information on flood characteristics required for a deep-water rice variety improvement program;

d. Dr. B.S. Vergara's continuing service in screening germ plasm material for deep-water adaptability.

Dr. N.C. Brady, Director General of IRRI, was kind enough to respond promptly to the proposals. And so, we are having here today at Bangkok the Deep-water Rice Workshop sponsored by IRRI. Expenses are paid from IRRI's core budget.

It is a matter of great satisfaction to us that rice scientists around the world, and national and international organizations attach great importance to research on deep-water rice. IRRI collaborates with Thailand—Dr. D. HilleRisLambers and Dr. B.R. Jackson from The Rockefeller Foundation work in cooperation with the Thai Government. IRRI plans to station a second scientist—an agronomist—in

Thailand. This person would be concerned with stand establishment, weed control, and nutrient supply in deep-water rices.

The Bangladesh Rice Research Institute (BRRI) has prepared an elaborate research program on deep-water rice. Physical facilities such as a set of tanks and a water reservoir are nearing completion. The Habiganj Deep-Water Rice Research Station is getting additional facilities for irrigation, drainage, embankments, and housing for office, staff, and guests. The position of scientific personnel has been strengthened by the recruitment of local scientists and an expatriate scientist from IRRI. We also have a collaborative program with the Thailand group of deep-water rice scientists and with the scientists of WARDA.

Considering agroecological conditions, we realize that rice varieties for deep-water conditions in Bangladesh should have—

1. drought tolerance at the early vegetative stage
2. internode elongation and tolerance for submergence
3. high basal tillering and nodal rootings
4. a plant type with high yielding potential

Local varieties have some or most of these desired characters, but they are poor yielders. Emphasis is thus on increased yield potential through the breeding of new varieties for deep-water conditions. Separate papers from BRRI will be presented on the above subjects.

Because little work has been done on deep-water rice, it is difficult to properly evaluate the effects of insects and diseases on its yield. The BRRI is giving special attention to pest management on deep-water rice. A proposal for such a study has been prepared. We have been assured of financial support from the British Overseas Development Ministry through a bilateral agreement with the government of Bangladesh. The IRRI has also assured us the services of a competent entomologist under the Memorandum of Understanding between BRRI and IRRI for scientific and technical cooperation in research on rice and cropping systems involving rice.

I believe that the scientists from other countries who participated in the 1974 Deep-Water Seminar at BRRI and the 1975 International Rice Research Conference at IRRI have started their own research program on deep-water rice. They are guided by the priority areas and research responsibilities voluntarily accepted by the participating scientists of the affected countries in the 1975 session at IRRI. We are past the stage of writing recommendations and programs. We are now to assess and evaluate programs undertaken and the results of research activities.

You will note that deep-water rice scientists are implementing most recommendations and proposals of the 1974 seminar and the 1975 working group meeting, except that on the hydrology of deep-water rice. The 1974 Deep-Water Seminar recommended that efforts be made in each country to initiate interdisciplinary studies designed to generate from existing maps and hydrological data the information on flood characteristics that might be required for the design of deep-water rice improvement and development programs.

Rice areas that are affected by deep water and floods during the monsoon season have been estimated at 30 to 40 percent of the total rice land in Asia. On one-fourth of this area, where water depths range from 1 to 6 m, farmers grow deep-water rice or special floating rice varieties.

Modern rice production technology has not reached either the deep-water areas nor the medium-deep areas where water depths may vary from 50 cm to 200 cm. The latter group represents more than half of the total rice area in Asia. Varietal characteristics and agronomic practices differ between medium-deep and deep-water areas. Flood characteristics differ from area to area and from time to time. For the success of deep-water rice research, the study of flood characteristics of each country cannot be overemphasized.

Flood studies require the services of a group of engineers and hydrologists in addition to those of plant breeders, agronomists, and plant protection specialists. During the 1975 session, we requested study funds from IRRI to generate from existing maps and hydrological data the information on flood characteristics required for designing a deep-water rice varietal improvement program. We realize the large financial requirements of such studies. Considering their importance, however, I hope that this group will find ways and means of initiating them.

The sowing and harvesting seasons, the advent of and the receding of monsoons, the duration and peak of flood periods vary from country to country. We therefore need strong national programs to develop deep-water rice, to build local physical facilities, and to upgrade local scientific competence.

Farmers in Bangladesh, wherever irrigation can be provided, are diverting some marginal lands from deep-water rice to dwarf rice in the dry season. Though high rice yields can thus be obtained, the disadvantages of the system are that it will—

1. have difficulty in providing capital-intensive irrigation facilities to such areas;
2. eliminate crops such as wheat, oilseeds, and pulses, which can be cultivated during the dry season with residual moisture and without irrigation; and

3. reduce cropping intensity because the land will remain completely fallow during the monsoon season.

Thus, the challenge to scientists is to provide better nutrition for the people of deep-water areas by encouraging them to practice multiple cropping — rice during the flooded monsoon season, and crops other than rice during the dry season. The scientists' task will be to evolve high-yielding rice varieties for deep-water areas.

DISCUSSION

SUBIYANTO: According to your paper, 30 to 40% of the total rice land in Asia is affected by deep water and floods. What would be the more specific classification of these deep-water areas concerning the range of water depth? What is the relative importance of the various classes in your country?

Islam: Classification of flood-affected rice areas on the basis of water depth needs more study. The 1974 Deep-Water Rice Seminar in Bangladesh and the 1975 International Rice Research Conference at IRRI recommended initiation of studies on flood characteristics. Bangladesh does not have such classification. We feel this should be done.

VERGARA: As we get to know more about deep-water rice areas, we find that soil is an important problem in them, e.g., salinity in West Bengal, acid sulfate soils in Vietnam and Thailand, iron toxicity in African countries, peat soils in Indonesia, etc. What recommendations can you suggest regarding this problem? To develop varieties for these areas, problem soils and elongation ability of rice should be considered at the same time.

Islam: Studies of deep-water rice will not cover all the problems of saline soils, acid sulfate soils, iron toxicity, and peat soils. These problems require as much serious study as the deep-water rice research. Deep-water rice research involves mostly flood tolerance and elongation capacity and submergence.

SARAN: Can a crop of wheat be grown after the harvest of deep-water rice in Bangladesh if some irrigation facilities are provided? In West Bengal (India), a very large area is now in wheat which is cultivated after the harvest of the rice crop.

Islam: I think it should be possible to grow wheat or other nonrice crops after harvesting deep-water rice, with residual moisture or with minor irrigation facilities. But to grow rice after the deep-water rice crop will require costly irrigation facilities, and no deep-water rice crop in the following monsoon season. Essentially a reduced cropping intensity and an unbalanced cropping system will result.

HASANUZZAMAN: The Bangladeshi farmers from time immemorial have been growing legumes, potatoes, wheat, chilies, and other nonrice crops after the harvest of deep-water rice in early November. Because additional mechanical irrigation facilities are available. boro rice is grown in those areas, particularly in those with light-textured soil. Dr. Islam and other BRRI scientists are trying to impress upon the government that boro rice must not be grown; instead wheat and other nonrice crops should be grown so that when these crops are harvested in March-April, another crop of deep-water rice can follow.

JACKSON: Do we have a proposal to submit to IRRI for approval in the next deep-water meeting planned for India?

Islam: There was a proposal in the 1975 IRRI Conference. This has not yet been confirmed by IRRI. A fresh proposal may be sent by this Workshop to IRRI. If IRRI approves the proposal it will be IRRI's responsibility to take up the matter with the government of India so that the 1977 Workshop can be held in India with their cooperation.

BASIC STUDIES

Segregation for elongating ability in two crosses of floating rice with ordinary lowland rice.

1. Estimates of heritability and implications for selection efficiency

N. Supapoj, C. Setabutara, K. Kupkanchanakul, and E. Shuwisitkul

Crosses between high yielding semidwarf, nonfloating, and floating varieties were first made at the International Rice Research Institute (IRRI) in 1964 to produce a high yielding, deep-water, dwarf rice. From such crosses, a series of lines and varieties with the common designation 442, T442 or IR442 have evolved.

In Thailand, results of initial investigations on the IR442 material were published in 1970 (Yantasast et al., 1970) and formed the basis for an expanded breeding program for deep-water tolerance. From this beginning, many semidwarf × deep-water crosses have been made and the segregates have been evaluated for elongation ability through a series of experiments aimed at determining optimum conditions—the most appropriate age, water depth, and rate of water increase—for evaluating elongation ability. However, no study has been done to obtain estimates of the effect of genes and environment on the expression of this character.

Knowledge of the degree of environmental and genetic influence could help breeders in Thailand and in other countries who are selecting for elongation. This paper reports the results of heritability estimates obtained from F_3 and F_4 of two hybrid populations involving the Thai floating varieties Pin Gaew 56 and Nakorn Gan when crossed with the semidwarf experimental line IR648 ($Sigadis^5$ /TN1) which is not deep water tolerant.

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This study presents the relationships between elongation ability and varying water depths, and the frequency distribution of elongation of F_3 and F_4.

MATERIALS AND METHODS

Elongation ability at different water depths and the heritability of the character were studied in the F_3 and F_4 of two crosses, Nakorn Gan/IR648 (SPR 7292) and Pin Gaew 56/IR648 (SPR 7297). Nakorn Gan and Pin Gaew 56 are traditional Thai floating rice varieties, while IR648 is a short-statured breeding line selected at IRRI from the cross $Sigadis^5$/TN1. The F_2, F_3, and F_4 populations of the two crosses were grown at the Huntra Rice Experiment Station, Ayutthaya province.

The F_2 bulk seeds of each cross were space-planted in 1974, at one seedling per hill and 25 × 25-cm spacing. To reduce the number of plants in F_3 and to assure randomness in selection, every other plant in F_2 was harvested. About 400 F_2 plants from each cross were saved to represent the F_3 populations. Seeds from each selected F_2 plant were divided into two parts; one part was designated for an F_3 elongation ability test and the other was grown under shallow-water conditions for F_4 study of heritability.

The F_3 test was made under field conditions in a deep-water pond. Pregerminated seeds from each F_2 plant were direct seeded in 1.5-m rows, 25 cm apart. Three check varieties, namely RD1, T442-57, and Pin Gaew 56, were alternately planted every 20 rows to serve as reference for elongation ability. The semidwarf RD1 had previously shown very little tolerance for deep water and usually died at the 80-cm depth. The T442-57 check is an experimental line resulting from a cross between the Thai floating variety Leb Mue Nahng 111 and the semidwarf selection IR95 made at IRRI several years ago. It had shown good tolerance for deep-water conditions (up to 150 cm depth) when compared with ordinary semidwarf varieties. Pin Gaew 56 is a recommended floating variety that has exhibited good elongation ability in natural water depths of nearly 400 cm. The Nakorn Gan parent is a native floating variety obtained in a collection from farmers' fields made by the Suphanburi Rice Experiment Station. Elongation tests conducted at the Huntra Station showed its similarity to Pin Gaew 56.

At 25 days after seeding, water in the experimental pond was increased at the rate of 10 cm every other day until a maximum of 150 cm was reached. Scoring at the various water levels was based on a 1-to-5 scale. Lines that exhibited elongation similar to that of RD1, T442-57, and Pin Gaew 56 were scored 1, 3, and 5, respectively. Lines that performed better than RDl but poorer than T442-57 were scored 2. Lines that showed better elongation than T442-57 but poorer elongation than Pin Gaew 56 were scored 4.

The F_4 bulk seeds harvested from each F_3 row were tested for elongation ability in 1976 by the same procedures as those used for F_3.

Seven unexpected floods occurred at the Huntra Station when the F_3 lines were growing to advance the generation. Water depths increased to more than 100 cm when the early segregates were flowering and completely destroyed some lines. Nevertheless, seeds from surviving lines were bulk harvested for the F_4 elongation test. From each bulk line, a 5-g sample was obtained to represent the respective F_3 progeny.

Heritability in the narrow sense was estimated from the regression of F_4 progeny on F_3 parent lines at two water depths—110 and 130 cm.

Correlation coefficients were obtained for elongation scores of the F_3 lines at five water depths ranging from 90 to 150 cm. In addition, correlations between elongation of F_4 progeny and F_3 parent means were computed to compare with the regression values.

RESULTS AND DISCUSSION

Elongation ability was scored at water depths of 90, 110, 130, 140, and 150 cm. Correlation coefficients based on 400 entries of each cross and 800 entries of both crosses combined showed strong positive associations for all combinations (Table 1, 2, 3). The findings suggest that lines that performed well due to good elongation ability (score 4 or 5) at 90- or 110-cm water depths should also perform well at greater water depths (140 or 150 cm). On the other hand, lines that showed poor elongation

Table 1. Correlation coefficients for elongation ability of 400 F_3 lines of the cross Nakorn Gan/Sigadis[5]/TN1 (SPR 7292) obtained from scoring at different water depths. Huntra Rice Experiment Station, 1975.

Variable	Elongation 1 (90-cm depth)	Elongation 2 (110-cm depth)	Elongation 3 (140-cm depth)	Elongation 4 (150-cm depth)	Elongation 5 (130-cm depth)
Elongation 1 (90-cm depth)	–	0.8484	0.7323	0.7007	0.7073
Elongation 2 (110-cm depth)		–	0.8143	0.7634	0.7681
Elongation 3 (140-cm depth)			–	0.7867	0.8193
Elongation 4 (150-cm depth)				–	0.8184

Table 2. Correlation coefficients for elongation ability of 400 F_3 lines of the cross Pin Gaew 56/Sigadis[5]/TN1 (SPR 7292) obtained from scoring at different water depths. Huntra Rice Experiment Station, 1975.

Variable	Elongation 1 (90-cm depth)	Elongation 2 (110-cm depth)	Elongation 3 (140-cm depth)	Elongation 4 (150-cm depth)	Elongation 5 (130-cm depth)
Elongation 1 (90-cm depth)	—	0.8823	0.8327	0.8041	0.7784
Elongation 2 (110-cm depth)			0.8735	0.8469	0.7794
Elongation 3 (140-cm depth)				0.8326	0.8041
Elongation 4 (150-cm depth)					0.7895

Table 3. Combined correlation coefficients for elongation ability of 800 F_3 lines of two different crosses (SPR 7292 and SPR 7297) obtained from scoring at different water depths. Huntra Rice Experiment Station, 1975.

Variable	Elongation 1 (90-cm depth)	Elongation 2 (110-cm depth)	Elongation 3 (140-cm depth)	Elongation 4 (150-cm depth)	Elongation 5 (130-cm depth)
Elongation 1 (90-cm depth)		0.8649	0.7842	0.7536	0.7368
Elongation 2 (110-cm depth)			0.8427	0.8026	0.7695
Elongation 3 (130-cm depth)				0.8104	0.8115
Elongation 4 (140-cm depth)					0.8046

at 90- or 110-cm water depths would be expected to also exhibit poor elongation at water depths of 130, 140, or 150 cm.

The results suggest that tests for elongation ability can be considered at water depths that exceed 90 cm. Such tests would be especially suitable for stations that have no facilities for extreme water depths but are capable of testing water depths up to 1 m. Even though using a 90-cm maximum depth could lead to more chances for misclassification, preliminary screening of lines could be done.

In Table 4, the correlation between F_4 progenies and their F_3 parents, and the regression estimates of F_4 progeny lines on F_3 parental lines are presented to estimate heritability of elongation. For SPR 7292 (Nakorn Gan/IR648) and SPR 7297 (Pin Gaew 56/IR648), the correlation of elongation abilities between F_4 and F_3 was determined at 110-cm

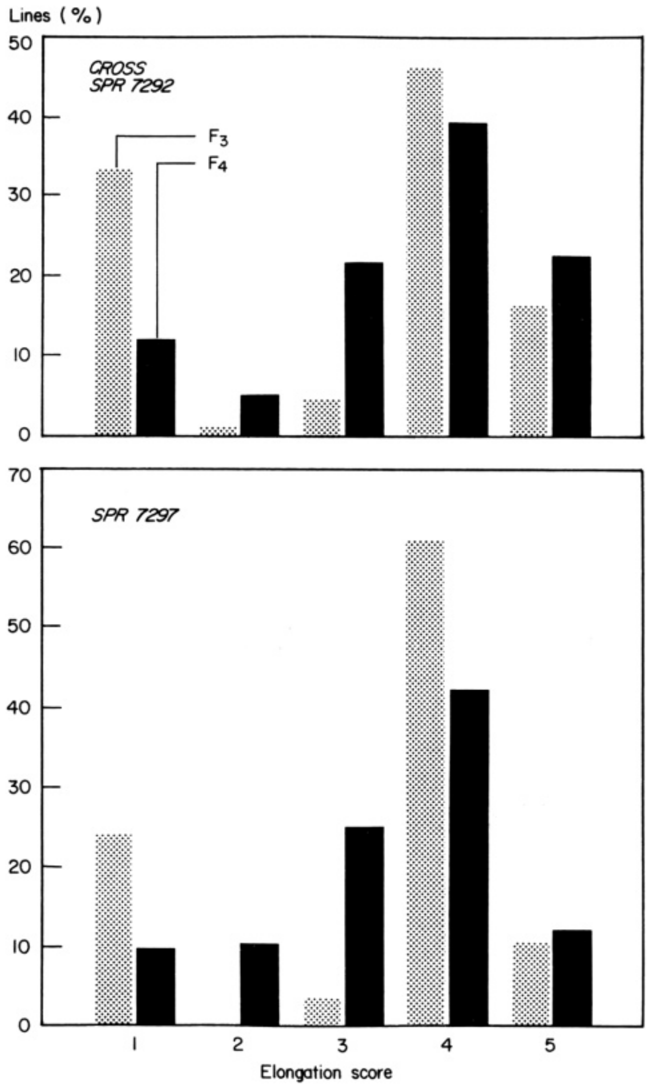
Table 4. Correlation coefficient and regression values for elongation of F_4 progeny on F_3 parent lines of two crosses of floating rice with the semidwarf experimental line IR648 when tested at two water depths. Huntra Rice Experiment Station, 1975 and 1976.

	SPR 7292 (Nakorn Gan/IR648)		SPR 7297 (Pin Gaew 56/IR648)	
	Correlation coefficient	Regression coefficient	Correlation coefficient	Regression coefficient
F_4, F_3 (110 cm)	0.4114	0.3489	0.4826	0.3402
F_4, F_3 (1 30 cm)	0.2314	0.2212	0.5322	0.4395

and 130-cm water depths. The correlation coefficients for SPR 7292 were 0.4114 at 110 cm and 0.2314 at 130 cm. Those for SPR 7297 were 0.4826 at 110 cm and 0.5322 at 130 cm. All values were relatively low; however, they were significantly different from zero. The result suggests that selection for good elongation ability based on individual lines in F_3 would have resulted in limited success. To offset this problem, breeders might postpone selection for elongation until the lines approach homozygosity, since the character appears either recessive or incompletely dominant.

Only two floating varieties were used as parents in this study. If other genetic material had been involved, the results might have been different. There is a strong indication that misclassification could occur if selection were based on only one generation and year. In the study, the regression coefficients represent performance in two different years; thus, some genotype × environmental effects were taken into account. All estimates were obtained from means rather than from individuals, and should be realistic. It is hoped that other breeders and geneticists will pursue the subject further to clarify the results obtained here.

Elongation scores for the F_3 and F_4 of two crosses tested at 130-cm water depth are in Fig. 1. SPR 7292 (Nakorn Gan/IR648) contained a relatively large group of F_3 segregates that were in Class I for elongation; SPR 7297 (Pin Gaew 56/IR648) had 10% fewer F_3 segregates in that class. The largest class for both crosses and generations was formed by lines scored 4 for elongation. The largest difference in elongation scores between F_3 and F_4 occurred in elongation classes 2 and 3, which showed a large increase in the F_4 progeny lines. This may have resulted from destruction of class 1 lines in F_3 as a result of unexpected flooding. In both generations and crosses, the proportion of lines that were scored 5 for elongation tended to be relatively small. Thus, few segregates were similar to the floating rice parents, which were rated 5 for elongation.



1. Elongation scores of experimental lines from two crosses exposed to a maximum water depth of 130 cm at the Huntra Rice Experiment Station.

SUMMARY

Two populations were studied for heritability of elongation at the Huntra Station in 1975 and 1976. Heritability estimates using a parent-progeny regression indicate that selection for elongation based on a single generation and season would not be highly successful. The regression coefficients, which presumably measure heritability in the

narrow sense, ranged from 22% for one cross to 44% for the second population when F_3 and F_4 parent-progeny lines were exposed to a 130-cm water depth over a 2-year period.

F_3 lines gave relatively high positive correlations between elongation and different water depths. Elongation ability was expressed in water depths as low as 90 cm; however, the chances for misclassification were increased. Frequency distributions for the F_3 and F_4 lines indicated a strong shift from poor to fair elongation between F_3 parent lines and F_4 progenies, but this may have been due to segregation and natural selection for deep-water tolerance as a result of unexpected flooding in 1975.

REFERENCE

YANTASAST, A., C. PRECHACHART, and B.R. JACKSON. 1970. Breeding dwarf varieties of rice for tolerance to deep water. Thai J. Agric. Sci. 3:119–133.

DISCUSSION

DE DATTA: Are you continuing your scoring using the 1 to 5 scale? Or have you changed to the SES system of 1 to 9 scale where 1 = best and 9 = poorest, to conform with others?

Supapoj: Yes, we are still using the 1 to 5 scale. We find it satisfactory for Thailand since it uses biological comparison. For the 1 to 9 scale, we don't have enough details for operation, and I think we have to use more facilities to use that scale.

PARK: Is it appropriate to use scores for (quantitative) genetic analysis? It may be all right for practical work. You may want to measure actual plant height at different water depths?

Supapoj: The problem with plant height is that we are using biological standards for scoring, i.e. RD1, T442-57 and Pin Gaew 56, which we think are more realistic for breeding purposes.

OHTA AND NASIRUDDIN: What is your estimate of the number of genes involved in elongation ability?

Supapoj: The primary objective of this study is to determine the heritability of elongation ability. I cannot answer how many genes are involved. Some earlier studies suggested three to four genes.

HAMAMURA: I would like to know the value of heritability for other characters, such as plant height, flowering date, etc. Were these data collected and the values calculated for the same materials?

Supapoj: Only heritability of elongation ability was calculated in this study. For the others I don't have information. I would expect that heritabilities for height and maturity would be similar to those found and reported for ordinary lowland rice.

IKEHASHI: The estimate of regression can be affected by the different growing conditions. To what extent are the growing conditions of F_3 and F_4 similar?

Supapoj: Growing conditions were similar, i.e. the rate of water increase, age of plants, size of plot, etc. were the same, but different ponds were used for the F_3 and F_4 generations. The large variable undoubtedly was years. Parent-progeny regression has the advantage of considering genotype × environment interactions.

KANTER: In your research, you began to increase the water depth when the seedlings were 25 days old. I do know your reasons for selecting 25 days after sowing. However, Dr. Vergara has found differences among local deep-water rices at the age when they have internode elongation—from 3 to 6 weeks. I would like to know if any such differences have been observed among your hybrid progenies, and if so, is 25 days after sowing the optimum time to subject seedlings to greater water depths for efficient screening?

Supapoj: I don't have the information on internode elongation. We believe that 25 days after sowing is a suitable age for screening. Also there has been research on the appropriate age in increasing the water; 25 or 30 days after seeding was recommended. The varieties we used in crosses do not exhibit early internode elongation. Some elongation would be expected in the leaf sheath.

CATLING: The basic work discussed in both Supapoj's and HilleRisLambers' papers is based on Thai deep-water rice varieties. Would these facts necessarily apply to mateials from Bangladesh which are adapted to much deeper water?

Supupoj: Not necessarily. I would suspect the direction and sign of the correlations to be similar, but the actual graphed relation could be at a different level. In view of some differences between Thai, Indian, and Bangladesh varieties (Mazaredo and Vergara, 1974) in ability to elongate at tillering stage, the relationships discussed in my paper could be different for Bangladesh materials.

VERGARA: If we select at an early generation, and select only those with a score of 4 and 5 for elongation, then there is less chance of losing the elongation ability. Why not select for elongation ability at an early generation so that one will have less lines to work on? Why select first for yield, insect resistance, drought tolerance, submergence tolerance, and other characters when we are not sure if the line will elongate when subjected to deep water?

Supapoj: According to our findings, the selection for elongation ability should be made when homozygosity is approaching. However, we selected for elongation ability in early generations and at the same time also selected for other traits, for example, insect resistance, drought tolerance and so on. The method will depend on the land and money resources available.

Segregation for elongating ability in two crosses of floating rice with ordinary lowland rice.

2. The effect of correlated traits on elongation performance

D.H. HilleRisLambers, C. Setabutara, N. Supapoj,
K. Kupkanchanakul, and E. Shuwisitkul

This is the second and concluding paper on segregation for elongation ability in the two crosses Nakorn Gan/IR648 and Pin Gaew 56/IR648. The first paper (Supapoj et al., 1977), also presented in this workshop, dealt with several estimates of heritability of elongation ability between F_3 and F_4 and implications of the findings for future success in obtaining lines with good elongation ability from segregating populations.

Additional data are presented on measurements and observations of seedling height and seedling appearance in the deep-water ponds, and on plant height and flowering date in the 1975 seed multiplication in shallow water.

The objective was to find answers to three questions:

1. What are the component traits that collectively make up the complex "elongation ability" in deep-water rice breeding in Thailand?
2. Which component traits can a plant breeder use in an ordinary shallow-water nursery to increase the proportion of elongating types in his materials? Or, conversely, what otherwise relevant traits should the plant breeder not consider in his ordinary lowland nursery, so as not to prejudice his chances for good elongation in subsequent deep-water tests?
3. What are the implications for selection methods and selection schedules in breeding deep-water tolerant varieties?

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MATERIALS AND METHODS

The crosses, planting methods and schedules, and the elongation scoring method were adequately covered in the first paper. The following is additional information.

1. SPR 7292 is the cross Nakorn Gan/IR648; Nakorn Gan is a Thai floating rice variety, and IR648 is a dwarf (Sigadis^5 / TN1).
2. SPR 7297 is the cross Pin Gaew 56/IR648; Pin Gaew 56 is a Thai floating rice.
3. Seedling height was measured in the pond in 1975 (F_3) and in 1976 (F_4), at 23 and 30 days of age. The average of two height observations in each row was used.
4. Seedling appearance was estimated at 30 days of age, before the water was increased (only in the 1975 pond). The appearance was expressed in leaf angle from the vertical. High leaf angle values were given for a wide divergence of leaves that were often floppy. Low values were given for erect leaves. Recorded values ranged from 30 to 65°.
5. Plant height was scored in the 1975 F_3 seed increase in shallow water. From each row, five plants chosen at random were measured from the base to the tip of the panicles, and the average was taken.
6. Flowering date was the date on which 50% of the plants in a given row flowered. Dates were recorded at 1- to 2-week intervals, beginning in late August when the first rows flowered and ending in late October.
7. Coefficient of correlation data are given in the form of linear correlation coefficients of the product-moment type, with elongation ability as one variable.
8. For discussion purposes, a trait having a high correlation with elongation ability can be considered a better predictor of elongation ability than a trait having a low such correlation.

RESULTS

Seedling height and elongation. Table 1 presents the correlations between elongation at successive water depths and seedling height measured in the same experiment. Correlations ranged from 0.4999 to a maximum of 0.6412 in the F_3 experiment. These coefficients may be compared with those given in the companion paper (Supapoj et al., 1977; Table 1, 2, 3) between sequential elongation scores in the same 1975 experiments. Correlation coefficients among elongation scores in F_3 ranged between 0.7007 and 0.8823. Table 2 lists correlation coefficients of seedling height and elongation across generations. Correlations of F_3

Table 1. Correlation between elongation and seedling height within F_3 in 1975 and F_4 in 1976. Huntra Rice Experiment Station, Thailand.

Year	Water depth (cm)	SPR 7292	SPR 7297	Two crosses combined
1975	90	0.7112	0.7175	0.6139
1975	110	0.7263	0.7320	0.6412
1975	140	0.6617	0.7075	0.5730
1975	150	0.6033	0.6317	0.4999
1976	110	0.8209	0.7950	0.7933
1976	130	0.7631	0.7868	0.7595

Table 2. Correlation between elongation and seedling height across F_3 in 1975 and F_4 in 1976. Huntra Rice Experiment Station, Thailand.

Year measured					
Elongation	Seedling ht	Water depth (cm)	SPR 7292	SPR 7297	Two croses combined
1975	1976	90	0.2498	0.5128	0.4422
1975	1976	110	0.3844	0.4295	0.4135
1975	1976	140	0.2887	0.3858	0.3387
1975	1976	150	0.2461	0.4154	0.3590
1976	1975	110	0.3988	0.3944	0.4033
1976	1975	130	0.2882	0.4108	0.3669

Table 3. Correlation between elongation in 1975 (F_3) and in 1976 (F_4) and leaf angle in 1975 (F_3). Huntra Rice Experiment Station, Thailand.

Year	Water depth (cm)	SPR 7292	SPR 7297	Two crosses combined
1975	90	0.3560	0.4915	0.4202
1975	110	0.3523	0.5176	0.4295
1975	140	0.3278	0.4749	0.3951
1975	150	0.2404	0.4153	0.3204
1976	110	0.1293	0.2280	0.1899
1976	130	0.0454	0.2373	0.1742

seedling height with F_4 elongation and of F_3 elongation with F_4 seedling height exhibited a common genotype x year effect, which lowered the correlations. The correlations for SPR 7292 were greatly reduced compared to the data in Table 1. Results from the companion paper (Supapoj et al., 1977; Table 4) suggest little difference in efficiency between predicting F_4 elongation from F_3 elongation and predicting from F_3 seedling heights. Correlation coefficients ranged between 0.2314 to 0.5322.

Table 4. Correlation between elongation[a] and flowering date.[b] Huntra Rice Experiment Station, Thailand.

Year	Water depth (cm)	SPR 7292	SPR 7297	Two crosses combined
1975	90	–0.0731	–0.1744	–0.1230
1975	110	–0.1208	–0.1482	–0.1313
1975	140	–0.1390	–0.1965	–0.1498
1975	150	–0.2152	–0.1018	–0.1182
1976	110	0.0383	0.0219	0.0301
1976	130	0.0039	–0.0132	0.0335

[a] Observed in the pond in F_3 in 1975 and in F_4 in 1976. [b] Observed in a duplicate F_3 planting in 1975.

Conclusions from Tables 1 and 2 are that:

1. A substantial part of the variation in elongation ability in the crosses could be explained by variation in seedling height.

2. Predictions on F_4 elongation in 1976 could have been made in 1975 on the basis of F_3 seedling heights alone. Extrapolations from these results must be made with considerable caution. Correlation coefficients were lowest when the two crosses were pooled because SPR 7292 combined a longer average seedling height with a lower average elongation score (Table 1).

Leaf angle and elongation ability. Leaf angle correlations with elongation ability in the F_3 experiment, and between F_3 and F_4 experiments are in Table 3. Predictive ability across experiments was negligible for SPR 7292, but SPR 7297 showed some correlation between F_3 leaf angle measurements in 1975 and F_4 elongation in 1976. Leaf angle is an important ingredient of plant type. These data should instill caution against selecting erect types without previously testing elongation ability.

Flowering date and elongation ability. Table 4 presents correlations between flowering date and elongation ability within the 1975 F_3 and between 1975 F_3 shallow-water plantings and 1976 F_4 elongation tests. The magnitude of the correlations is not enough for firm conclusions. The following observations are made of the results:

1. The low correlation scores between 1975 elongation and 1975 flowering dates must be partly due to measuring the two parameters in different plantings of the same lines in the same year.

2. Flowering dates were recorded at intervals of 1 to 2 weeks.

3. The absence of correlation between 1975 F_3 flowering dates and 1976 F_4 elongation may be explained by the sampling bias in the 1975 shallow-water planting.

Correlations of flowering date and seedling height were negative and

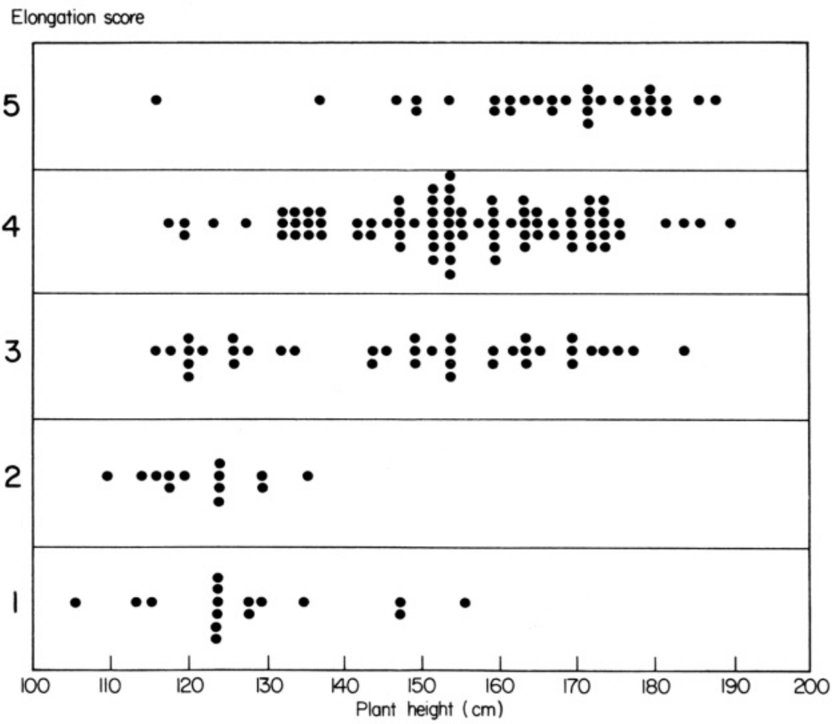
Table 5. Correlation among traits other than elongation ability in the F_3 in 1975.

Correlated traits	SPR 7292	SPR 7297	Two crosses combined
Seedling height Plant height	0.3473	0.5145	0.3934
Seedling height Flowering duration	–0.1309	–0.2961	–0.3234
Seedling height Leaf angle	0.3823	0.5493	0.4060
Plant height Flowering duration	0.0414	0.0284	0.0288
Plant height Leaf angle	0.1139	0.3676	0.1869
Flowering duration Leaf angle	0.0031	–0.1915	–0.1036

significant. The data in Table 5 suggest that early flowering lines may have relatively vigorous elongation in the seedling stage, before the water starts to rise. This elongation vigor is maintained with rising water, partly because of the increased growth seen in most rice varieties shortly before flowering. The number of remaining internodes capable of elongating becomes finite with floral initiation, but does not become limiting with the maximum water depth of 150 cm.

Plant height and elongation. Table 6 gives the correlations between plant height measured in F_3 seed multiplication in shallow water and the elongation scores obtained in the ponds in 1975 and 1976. The heritability correlation coefficients of plant height and elongation ranged from 0.2907 to 0.7632. The conclusion is that the F_3 shallow-water plant height should be a better predictor of elongation ability in F_4 than the F_3 elongation data. That is theoretically possible, assuming that the measurement of plant height is accompanied by less error variation than the measurement of elongation ability. The correlations involving plant height were done on fewer lines than those among elongation scores only because of flood in the shallow-water field.

The correlations of plant height and elongation ability were the most important ones, not only because they were quite high, but also because plant height is one of the most familiar phenotypic measures of the rice plant. Plant breeders usually have an optimal plant height as standard for each varietal type for which they are selecting. As a result, they regularly cull their nurseries, throwing away plants having heights too different from the standard they seek. In view of the observed correlations between plant height and elongation, perhaps some plant breeders are discarding materials with plant heights conducive to good elonga-



1. Relation between F_4 elongation score at 130 cm (1976) and F_3 shallow-water plant height (1975).

tion, while keeping materials having little of such potential. Figure 1 illustrates the relation between the 1975 F_3 plant height and the 1976 F_4 elongation scores at 130-cm water depth (Table 6: $r = 0.5874$) for the two crosses combined. Allowing for some variation, the following conclusions are apparent:

Table 6. Correlation between elongation[a] and plant height.[b] Huntra Rice Experiment Station, Thailand.

Year	Water depth (cm)	SPR 7292	SPR 7297	Two crosses combined
1975	90	0.3615	0.6758	0.4610
1975	110	0.3578	0.7632	0.4877
1975	140	0.3171	0.6392	0.4123
1975	150	0.2907	0.7138	0.4256
1976	110	0.6481	0.4927	0.5881
1976	130	0.6612	0.4748	0.5874

[a]Observed in the pond in F_3 in 1975 and in F_4 in 1976. [b]Observed in a duplicate F_3 planting in 1975.

1. Few lines taller than 140 cm failed to elongate completely.

2. Breeders looking for lines with elongation score of 5 (presumably good for 2 m of water) can discard plants shorter than 140 cm, and give special emphasis to those around 170 cm.

3. Lines better than T442-57 (reference variety for score 3) may be found at plant heights under 140 cm.

4. Some lines equivalent to T442-57 may have plant heights of 120 cm, but not much less. One problem in interpreting Figure 1 is the rather discrete segregation for plant height apparent in that graph, with a gap in the frequency of lines around 140 cm tall.

Other correlations. Table 5 gives the correlations between selected traits. Some correlations (flowering duration with leaf angle, flowering duration with plant height) are insignificant. The data suggest that elongation ability as measured in these tests is influenced by a cohesive group of mutually correlated traits that include seedling height, leaf angle, and plant height.

CONCLUSIONS AND RECOMMENDATIONS

The results imply that elongation ability in water up to 150 cm is strongly determined by such factors as plant height, seedling growth, leaf angle and, to a lesser extent, flowering duration. The high correlation coefficients observed for plant height and seedling height indicate that elongation ability across generations could be successfully predicted.

The data in Figure 1 suggest that there is a minimum plant height at which a certain degree of elongation is feasible. Elongation better than that of T442-57 should not be expected in lines shorter than 130 cm, at least not in the two crosses studied. Breakthroughs in this relationship could only be expected if new genetic variability and additional recombinations were created by crosses among deep-water rice varieties with different survival strategies.

Plant breeders should defer rigorous selection for short plant heights and for plant type until they have tested materials for elongation ability. Breeding strategies which allow for relaxation of selection should be studied; for example, the Single Seed Descent Method.

Experimentation on genetic or pleiotropic correlations influencing elongation ability should be done after judicious selection and stratification of populations that vary in the traits of interest, but are grouped to achieve homogeneity within groups for traits such as plant height and flowering duration.

The flowering dates are preliminary and should be seen merely as a stimulus to reconfirm the data in other experiments using a more stratified sample of early and medium flowering deep-water lines.

The relation of flowering duration with elongation ability should be studied more closely and flowering dates obtained with greater precision, preferably with lines of uniform plant heights and early or medium duration.

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DISCUSSION

DATTA: Have you observed any relationship between leaf angle and yield potential of rice varieties under low-lying, waterlogged conditions?

HilleRisLambers: No, not from my data, nor from anybody else's. I should mention that our thinking on the potential of high yielding varieties with some elongation ability is not necessarily restricted to varieties in low-lying waterlogged conditions: a quite limited part of the selection objectives would call for a high yielding variety, and everything that goes with it, plus some elongation ability. When selecting for such a genotype, it should be kept in mind that elongation ability is not something completely independent of other important traits: the pleiotropic relations that are suspected to exist make it important to monitor both elongation ability and HYV plant type traits during selection.

HAMAMURA: Did you mention that low correlations between elongation ability and flowering date were partly due to the advantage of early flowering lines in showing internode elongation?

HilleRisLambers: No, I did not. What I said was that I suspect correlations between elongation ability from one generation to the other to be low partly because of the simultaneous segregation for flowering duration, on top of the genetic segregation for elongation ability.

ESCURO: Do you have information on whether or not reaction to photoperiod is related to elongation ability?

HilleRisLambers: Photoperiod-sensitive varieties planted during the monsoon season have longer periods for elongation.

JACKSON: We find no relation between elongation ability and reaction to photoperiod.

New procedure for breeding photoperiod-sensitive deep-water rice with rapid generation advance

H. Ikehashi

A number of modifications to the standard pedigree method have been proposed in the breeding of self-pollinating plants. Along with the bulk method or evolutionary breeding, a breeding procedure characterized by initial plant selection after a certain degree of fixation has attracted many plant breeders. Several reports on the breeding of soybeans (Boerma and Cooper, 1973; Brim, 1966), oats (Kauffman, 1971), and wheat (Knott and Kumar, 1975) recently demonstrated the relative advantages of the procedure referred to variously as modified pedigree method, random method, or single seed descent (SSD).

Most rice breeders in Japan, through extensive collaborative studies since the late 1950's have adopted the proposed procedure under the name "bulk method" (Sakai et al., 1958). They have developed special facilities to accommodate this method (Okabe, 1967).

Through trials, such genetic properties of SSD populations as advanced fixation and recovery of recessive types have been identified. Besides its genetic advantages, SSD requires only a small field space, allows shortcuts in record keeping, and facilitates rapid generation advance of the breeding material. For instance, five to six generations in a year seemed possible in a wheat breeding program (Mukade, 1974).

Rapid generation advance is extremely important to rice breeding in the tropics. Dwarf varieties with short growth duration have been successfully introduced. However, dwarfism is of no use in deep-water areas, estimated to be at least one-fourth of the world's rice land. An

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important constraint to breeding for rice with intermediate stature and longer duration—requirements in deep-water areas—is the plant's sensitivity to photoperiod, which limits the breeder to one generation a year. Consequently, 5 to 6 years are needed to obtain relatively fixed lines after hybridization.

If we can advance the generation of hybrid populations two or three times a year through the SSD method, nearly fixed lines would be available for selections within a few years after hybridization. Screening with nearly fixed lines may relieve plant breeders of repeated, painstaking tests and selections with segregate materials. The present method of rapid generation advance was tested for feasibility.

MATERIALS AND METHODS

The first experiment involved

1. four F_2 populations from crosses of IR varieties (IR28, IR34) with a deep-water rice (Saran Kraham or Tarao Bao),
2. one cross of the same generation between salinity-tolerant materials (Nona Bokra and IR2071-88-8), and
3. parent varieties IR28, IR34, Saran Kraham, and Tarao Bao.

A second experiment was conducted to detect the degree of reduction in growth period of 12 varieties differing in growth duration and in reaction to photoperiod.

All plants were seeded on 12 April 1976 in the IRRI phytotron. Throughout the experiment the temperature was kept at 32°C during the day (0800–2000) and at 24°C during the night (2000–0800). On 4 May when most plants had reached the five-leaf stage, a short-day treatment of 8 hours (0800–1600) was initiated by transferring the plants to the dark room. The treatment lasted until 4 July when most plants were in the booting stage or were mature.

Two nutritive conditions were adopted.

In the first experiment, the five hybrid populations were grown in flat, iron boxes 38 × 85 cm, filled with Maahas clay to a 6-cm depth. The seeds were spaced 3 × 3 cm, and each of 28 rows in a flat box accommodated 13 hills. For each hybrid population 1,456 seeds were raised in four flat boxes. The four parent varieties were grown with the same spacing in one box. Two grams of ammonium sulfate was applied every 10 days from 27 April to 27 May.

All plants were subjected to short day length. The mature plants were harvested individually at 1-week intervals from 21 June 10 weeks after seeding. The number of grains and plant height of 20 randomly sampled plants were measured at three times of harvest.

In the second experiment, single plants were grown in small plastic cups filled with 290 g of Maahas clay to determine the effect of nutritive conditions different from those of the first. Each cup was 10 cm high with a diameter of 6.5 cm at the upper end and 4.5 cm at the bottom. Under these conditions, 15 plants of each of the 12 varieties were subjected to short day length, while another 15 were kept at natural day length. In addition, plants of the hybrid IR9274, grown in the same conditions under short day, were tested under three nitrogen regimes: no fertilizer, 0.2 g of ammonium sulfate per cup at the stage of 3–4 leaves, and 0.1 g of the same fertilizer every 10 days until the end of May. Each of the three nitrogen levels had 120 plants. Flowering time of each plant was recorded.

EXPERIMENTAL RESULTS

The cumulated distribution of maturing time in the five hybrid populations is in Table 1. Only a few plants (1.6–2.5%) were immature when the test was discontinued 126 days after seeding. More than half of the plants in each of the crosses, except IR9288, reached maturity 100 days after seeding. IR9288 had delayed maturity and 13% sterility.

The plants that matured earlier than 100 days after seeding, judged from the reaction of the check varieties, could be either photoperiod sensitive or early maturing varieties like IR28.

The high ratio of missing plants in Table 1 could be explained partly by poor germination or retarded growth due to poor seed quality. A part of the decrease in harvested plants was attributed to damage while transferring the plants to a narrow space in the dark room. Elongating stems were occasionally folded and prevented from normal flowering, and some plants easily fell over. Thus, the growth of the main stem terminated, and the upper nodes showed vigorous branching and tangling of auxiliary stems, which is characteristic of floating rices.

The number of sterile plants differed among the crosses. Further investigation seems necessary to determine whether or not high temperatures caused sterility. Sterility would be a major handicap with IR9288 in which the backcrossing of IR34 with Tarao Bao seems to cause relatively high sterility.

Measures of some agronomic characters are presented in Table 2. Data were taken from 20 randomly sampled plants at three times of harvest. With dense spacing under substarving nutritive conditions, height was reduced to 40–60 cm in most plants, while the average number of fertile grains in each cross ranged from 7 to 13. Reduced plant height was also accompanied by a relatively high degree of sterility in each

Table 1. Distribution of maturing time of F_2 population under short day conditions. IRRI phytotron, 1976.

Cross [a]	Harvested plant									Unharvested plants (%)	Sterile plants (%)	Missing plants (%)
	Weeks after seeding											
	10	11	12	13	14	15	16	17	18			
IR7706	5.3	19.6	31.8	45.8	55.6	59.8	65.1	69.7	72.5	2.6	0.6	24.3
IR7732	0	8.1	20.0	40.9	58.8	65.3	67.1	67.9	68.7	2.8	5.0	23.4
IR8711	0	12.5	33.5	53.8	61.3	69.1	72.8	75.8	77.4	1.6	3.4	17.6
IR9274	17.1	30.5	41.8	59.8	71.9	77.0	78.6	79.4	80.5	5.2	3.3	11.0
IR9288	0	0.6	2.9	18.7	37.3	50.8	60.6	65.8	68.5	3.0	13.0	15.2

[a] IR7706: Saran Kraham/IR28; IR7732: Tarao Bao/IR2061-2-13-216; IR8711: IR2071-88-8-10/Nona Bokra; IR9274: Saran Kraham/IR28//IR34; IR9288: Tarao Bao/IR34//IR34. Maturing time of parent varieties: IR28, Saran Kraham, Tarao Bao: 14 weeks; IR34: 15 weeks.

Table 2. Agronomic characteristics of harvested plants in flat, iron boxes under short day length.[a] IRRI phytotron, 1976.

Cross	Date of harvest	Culm length (cm)	Panicle length (cm)	Florets (no.)	Fertile grains (no.)
IR7706	28 June	58.8 ± 16.9	15.4 ± 6.5	22.0 ± 20.4	13.2 ± 14.4
	5 July	54.6 ± 23.9	13.2 ± 4.3	14.8 ± 15.6	8.7 ± 7.4
	12 July	68.0 ± 35.4	12.9 ± 8.2	26.7 ± 14.0	10.9 ± 7.8
IR7732	28 June	59.2 ± 23.5	13.9 ± 3.4	28.5 ± 15.2	10.4 ± 11.3
	5 July	54.4 ± 22.2	13.7 ± 3.4	27.1 ± 15.2	9.0 ± 5.6
	12 July	55.7 ± 27.9	12.4 ± 6.1	23.8 ± 62.9	7.2 ± 3.9
IR8711	28 June	47.5 ± 23.1	13.3 ± 0.4	23.4 ± 14.8	9.9 ± 7.8
	5 July	59.5 ± 15.2	11.1 ± 3.4	16.6 ± 11.3	8.6 ± 6.1
	12 July	58.6 ± 25.3	10.2 ± 3.9	15.7 ± 13.9	7.0 ± 7.8
IR9274	28 June	43.9 ± 14.8	17.4 ± 5.2	25.5 ± 23.5	9.8 ± 4.3
	5 July	52.3 ± 24.4	15.4 ± 5.6	29.6 ± 23.1	11.3 ± 6.1
	12 July	54.5 ± 15.7	14.1 ± 3.0	34.9 ± 15.2	11.6 ± 9.1
IR9288	28 June	44.9 ± 19.2	12.9 ± 3.9	24.1 ± 16.2	7.8 ± 6.9
	5 July	41.9 ± 13.0	12.3 ± 5.2	22.7 ± 13.9	7.4 ± 3.9
	12 July	44.1 ± 14.4	13.3 ± 3.4	24.5 ± 18.3	11.1 ± 11.7

[a] A single productive tiller was obtained from each plant.

Table 3. Growth duration of selected varieties seeded in plastic cups, April 12, 1976. IRRI phytotron.

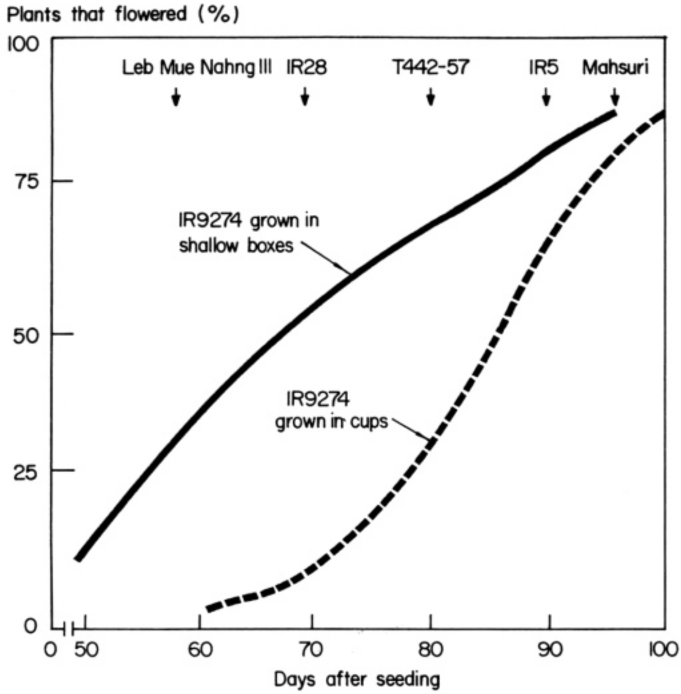
Variety	Days after seeding			
	Short day length		Natural day length[a]	
	Flowering	Maturity	Flowering	Maturity
Speed 70	66	88	66	88
IR28	69	91	66	88
IR1632-93	73	92	73	93
IR26	90	113	88	111
IR5	90	111	94	118
Mahsuri	96	117	103	128
T442-57	80	106	94	120
Nam Sagui	55	76	114	NF
IR1060-90	68	86	NF	NF
BPI 76	58	80	NF	NF
Leb Mue Nahng 111	58	81	NF	NF
Habiganj DW8	68	87	NF	NF

[a] NF = no flower until the end of August.

panicle. Nevertheless, most plants produced four or five fertile grains, enough to produce the next generation.

In the second experiment, plant spacing was greater. Flowering and maturity data from the check varieties are given in Table 3.

Under short-day conditions, four early maturing varieties and four photoperiod-sensitive varieties reached maturity within 100 days after



1. Cumulated distribution of flowering date of hybrid population of IR9274 as contrasted with that of check varieties in the cup culture.

seeding. However, IR26, IR5, Mahsuri, and T442-57 needed from 106 to 117 days to mature.

Under natural day lengths only three early varieties reached maturity within 100 days. The mentioned four varieties matured within 110-128 days, showing little difference in duration from those under short-day conditions. Four photoperiod-sensitive varieties remained in the vegetative stage until the end of August.

Records on IR9274 in cups at three nitrogen levels were pooled because nitrogen level showed no effect on growth duration. Only one panicle was obtained from plants without fertilizer; the increased nitrogen level was reflected in two or three productive tillers.

The flowering behavior of IR9274 in shallow boxes and that in plastic cups are compared in Figure 1. Poor nutritive conditions seemed to accelerate flowering by about 20 days in the earlier components of the population. However, acceleration did not seem remarkable in plants with longer duration. Continued exposure of the longer duration plants to reduced nitrogen levels may have led to deterioration of general growth and to retarded flowering.

Table 4. Agronomic characteristics of plants in cups at short day length. IRRI phytotron, 1976.

Variety	Culm length (cm)	Panicle length (cm)	Florets (no.)	Grains (no.)	Tillers (no.)
Speed 70	104.7	18.9	61.9	31.0	3.0
IR28	61.5	23.0	73.5	43.0	4.0
Leb Mue Nahng 111	110.3	18.8	60.8	23.8	1.3
BPI 76	72.9	19.5	90.9	52.9	1.0
Nam Sagui	79.9	16.5	51.8	21.6	2.1

Some measures of agronomic traits of the earlier harvested varieties in cups are in Table 4. At least 20 fertile grains were harvested from most plants.

DISCUSSION

Even the slightest modification of existing breeding procedures often needs the integration of diversified disciplines, ranging from genetic and developmental physiology to details of cultivation practices.

In the early years of breeding work at the International Rice Research Institute (IRRI), generation advance with bulk population was tested, but it proved impractical for breeding dwarf types, which are less vigorous in competition with traditional tall rices (IRRI, 1966, 1967). Since the common sources of dwarfism are genetically recessive, short-statured plants in early generations have been selected to achieve quick fixation. However, if emphasis is to be placed on intermediate-height types, which genetically are more complex than dwarf types, the quick fixation of such a plant type should not be expected within one or two generations. Hence, the genetic advantages of single seed descent may help meet more diversified breeding objectives.

Extensive work on growth durations of tropical rices has been continued; detailed figures of the dynamics of growth pattern are available together with genetic explanations (Chang et al., 1969; IRRI, 1972). But all the previous works on the effect of temperature and day length on growth duration were conducted under normal nutritive conditions. The present study showed that restricted nutritive space is a significant factor in remarkably reducing the growth period.

The proposed method can be appropriate for hybrid populations consisting mainly of photoperiod-sensitive materials with relatively shorter basic vegetative growth, common to waterlogged areas. The drastic reduction of the growth period is possible under conditions of short days and dense spacing.

However, the experimental results indicated that varieties such as Mahsuri and IR5, commonly grown in deep-water areas and least affected by short day length, needed 100 to 120 days to mature under short day length. The reduced nutritive space in the flat, iron boxes seemed less effective than the cup culture in accelerating flowering of those varieties. Thus, consideration of the growth period in this group of rices with longer basic vegetative growth is critical in the proposed cultivation procedure. Many of those types should be eliminated in the course of SSD. More trials are needed to reduce their growth period before they can be safely included under the scope of the proposed method.

Along with the investigation to reduce growth period, such operational practices as getting fast, uniform germination, and careful management of nutrition should be improved.

Furthermore, if we introduce some selection pressure in those operations, for example, controlled infestation by brown planthopper or saline water to screen for tolerant seedlings, the efficiency of the proposed method could be enhanced.

The most important point is to organize the single seed descent population into an entire scheme of a breeding system. Additional testing is needed, and the growing of materials harvested from the greenhouse or in the field in a suitable season will be a key point. Fortunately, under natural day length at Los Baños, Laguna, photoperiod-sensitive rices can be harvested in the field from November to April, although some reduction of nitrogen should be taken into account. If this point is confirmed, then two successive generations of single seed descent can be grown from March to October, and the population seeded in the field in November.

Additional testings should be done to verify the following scheme:

1. growing F_2 and F_3 from March to October in the greenhouse short-day conditions,
2. growing F_4 population in the field to harvest sufficient seed, and
3. growing F_5 pedigree lines from April or May under specific conditions such as deep-water, rainfed area, saline soil, and so on.

SUMMARY

Hybrid populations advanced to later generations without substantial selection have at least three major genetic properties: advanced fixation, recovery of phenotypes governed by recessive genes, and enhanced genetic recombinations. To make full use of these properties, a number of modified pedigree methods have been proposed. The methods are

characterized by initial selection at later generations after reproducing each generation from nearly all plants from the preceding generation. The term single seed descent (SSD), which reflects a specific mode of reproducing subsequent generations, can be used to represent breeding procedures that are based on initial selection at a later generation.

The feasibility test of SSD showed that harvesting photoperiod-sensitive hybrid populations within 100-110 days is possible if the plants are grown under short-day conditions with reduced nutrition and close spacing (1,000 plants/sq m).

A new procedure for breeding photoperiod-sensitive materials is proposed:1) growing F_2 and F_3 from March to October under short-day conditions and dense spacing, 2) growing F_4 in the field to harvest sufficient seeds per plant from November to April when natural short day can reduce the growth duration, and 3) testing F_5 lines during the monsoon season under specific problem conditions from May or June. The proposed breeding procedure will greatly facilitate the work of rice breeders who handle photoperiod-sensitive materials, which can be tested only once a year in practice.

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DISCUSSION

PARK: How will you advance the generation if the number of grains per plant is different? Most likely you may push the population toward one direction if you harvest all the seeds and use them for the next generation.

Ikehashi: To prevent any undesirable deviations of the traits of hybrid populations, we should harvest a definite number of seeds of each plant.

CHOUDHURY: By using the SSD method, how do you propose to select for basal and nodal tillering and panicle length, which are required characters for deep-water rice?

Ikehashi: The major objective of SSD is to keep variability, while allowing fixation of progeny line until materials are subjected to intensive selection under actual growing conditions. The selection of agronomic traits can be done by ordinary methods. Although some selection can be done during the growing of the hybrid population in the specific condition with short-day treatment, selection should be done under actual field conditions.

ZAMAN: Under artificial growth conditions, the number of grains produced per panicle is greatly reduced. If bulking is done under such conditions, a lower percentage of crossing over may result, reducing the probability of getting a desirable genetic combination. Along with this, the probability of retaining undesirable linkage of characters will be higher in the subsequent generation. That may adversely affect the selection efficiency. Please comment.

Ikehashi: The number of grains per panicle to be seeded for producing the next generation may not be related to the frequency of crossing over. The repeated recombination from F_2 to F_4 or F_5 may provide a good chance for recombination, which may also lead to breaking of undesirable linkages. If the selection of a trait is very effective from F_2, SSD may not be necessary.

VERGARA: Your paper has shown great promise for a rapid generation advance. You stated that the restricted nutritive space is a significant factor in remarkably reducing the growth period. I think it is the short days and high temperatures that are the significant factors. Our test with Leb Mue Nahng III actually showed a delay of flowering with lower nitrogen level in the soil. Low N level of the soil may accelerate flowering, but very low N level actually delays flowering.

Ikehashi: You are right, high temperature and short days are major factors in reducing the growth period, and limited spacing apparently can also reduce it (Fig. 2). But extremely reduced nitrogen prolongs the growth period according to our experience.

DE DATTA: Why is the salt-tolerant variety Nona Bokra included in the deep-water rice crossing program?

Ikehashi: We also have a project for salt-tolerant varieties where deep water is a problem. Earlier fixation is also convenient to screen the materials for salinity.

Genotypic adaptability of rice (*Oryza sativa* L.) and a suggested formula for measuring adaptation to water depths above 30 cm

D.K. Mukherji and S.K.B. Roy

West Bengal has 5.2 M ha under rice, of which 4 M ha is planted in kharif (wet season). The average yield in kharif is 1.1 to 1.2 t/ha, in boro (dry season) it is 3.0 t/ha. The contraints to yield increase in kharif are cloudy days, high temperature, high humidity, prevalence of diseases and pests, and poor drainage that causes difficulty in water control. More than 75% of the kharif rice area suffers from stagnant water. The heavy soil type and poor drainage conditions allow accumulation in the fields of water from monsoon rains and, in some cases, from overflowing irrigation channels. The water depth sometimes reaches up to 90 cm, but is generally from 10 cm to 60 cm.

So far, very few semidwarf, high yielding varieties have shown promise in low-lying areas when water depth reaches above 40 cm. Pankaj, a selection from the cross Peta/Tongkai Rotan (IR5-114-3-1), has performed well in areas with water depths of 30 to 40 cm. It is weakly photoperiod sensitive and takes 150 days to mature. Two other entries from IRRI-IR442-2-50-1-3-2 and IR442-2-58-2-1-2, sister selections from the cross Peta^2/TN1/Leb Mue Nahng—have given good results in some places where water depth reaches up to 50 cm. However, they are not widely accepted in low-lying areas in the State because they are photoperiod insensitive, rather early maturing (about 120 days), and susceptible to blast disease.

A few germ plasm materials at the Rice Research Station, Chinsurah (West Bengal), show promise for the low-lying areas. OC 1393, a selec-

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tion from such germ plasm, had been recommended in the State. It gives moderate yield, has excellent yield stability, is photoperiod sensitive, and has field resistance to major diseases and pests. However, it matures late, taking nearly 180 days, and the yield is not high enough.

There is, therefore, need for proper screening of genotypes for their floating abilities. Morishima (1974) standardized a method and gave the following formula for this purpose:

$$X_F = 1.00A + 0.47B + 0.50C + 0.24D$$

where X_F = the measure for floating ability, A = number of elongated internodes longer than 3 cm, B = the total length of elongated internodes, C = number of nodes with adventitious roots per stem, and D = number of branches per stem. This formula, however, did not take into account the rate of increase in height. Moreover, a more practical method for measuring elongating ability in a huge population is perhaps needed by the plant breeder.

To identify varieties that may be suitable for such low-lying, water-stagnant areas in the State, a comprehensive screening and breeding program has been in progress since 1971. A large number of crosses have been made and the cultures are being rigorously tested under various stress conditions. In addition, mutation work through X-irradiation has been initiated. A number of cultures from IRRI and Thailand have been obtained.

This paper presents partial results of comparative evaluation of mutants of Pankaj and of OC 1393 and one set of IRRI and Thailand cultures.

MATERIALS AND METHODS

Fifteen genotypes were used: Pankaj, OC 1393, three mutants of Pankaj, two mutants of OC 1393, one culture of IRRI (IR442-2-58), and seven HTA cultures of Thailand. The HTA cultures were among promising selections from bulk lines received from Thailand in 1974. They carry the designation "CNB," which stands for selections made at Chinsurah (CN) from bulk (B) materials.

The plants were grown in two water levels under natural field conditions at the Rice Research Station at Chinsurah in 1975 kharif. The water levels were normal—never exceeding 10 cm—and above normal —varying from 30 cm to 90 cm at different periods of plant growth. The seeds were sown on 19 May and the seedlings transplanted on 20 June 1975 in duplicate rows, each 3 m long, spaced 25 cm both ways with one plant per hill. Water level was measured every fourth day and data on height, number of tillers, branches, nodes with adventitious roots, etc. were noted at 15-day intervals. Dates of first flowering, 50% flowering, and maturity were noted. At maturity, the internodes were measured and the grain yield was recorded.

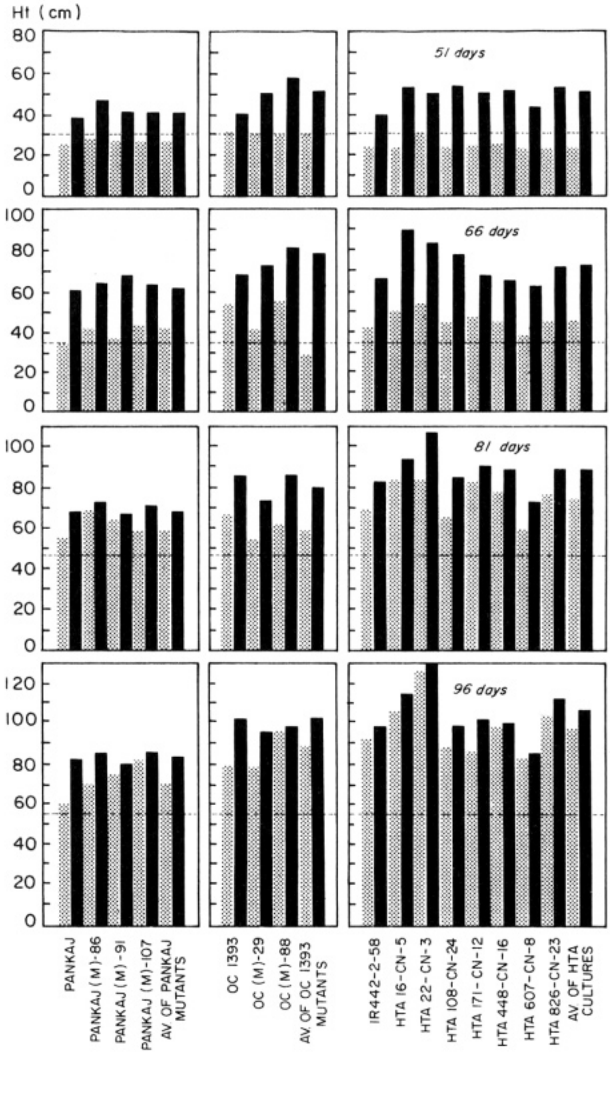
RESULTS AND DISCUSSION

Figure 1 shows that under normal water depth, the maximum height of the tall variety OC 1393 was recorded at maturity, as was the average of its two mutants. However, under above-normal water depth, the average height of the HTA cultures exceeded that of OC 1393 and the average of its two mutants. IR442-2-58 was shortest under both water depths. The average height of the HTA culture was greater than that of Pankaj and OC 1393 under both water depths from 81 to 111 days. That was probably because the HTA cultures were selected from deep-water tanks and involved semidwarf Thai floating rice. At 51 and 66 days the average height of OC 1393 mutants was higher than that of HTA cultures, although OC 1393 itself was taller under normal water depths but shorter under above-normal water depth.

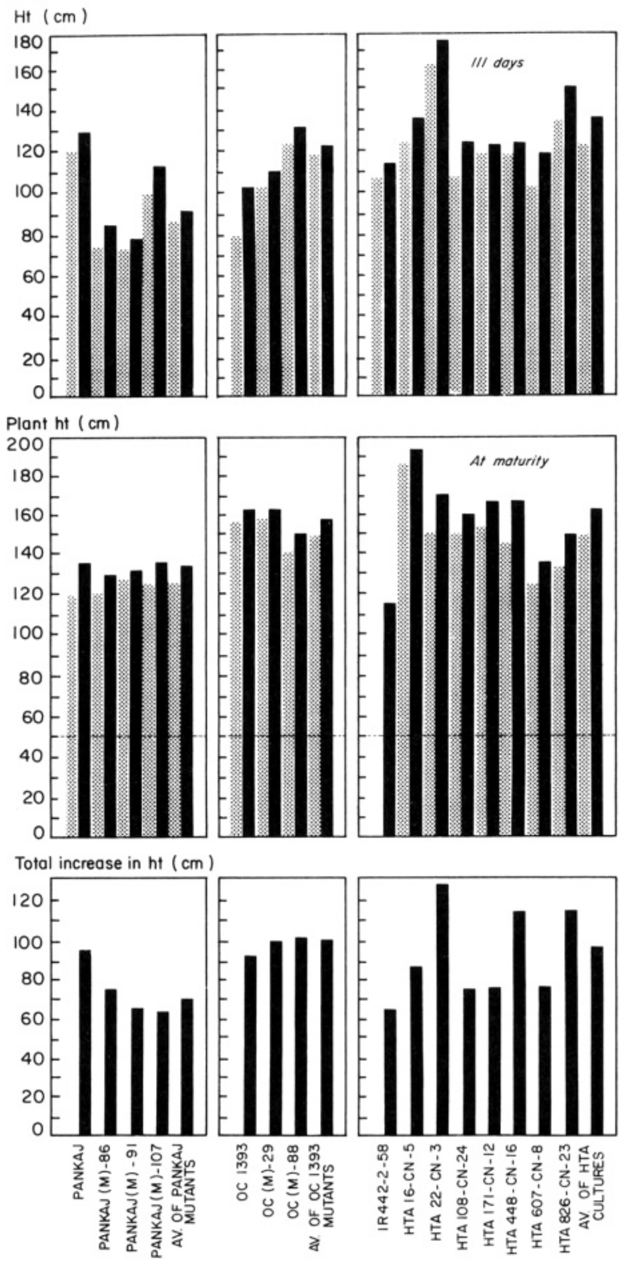
The rate of increase in plant height was not linear with either plant age or increase in water depth. The rate of increase in Pankaj was fastest between 96 and 111 days when the water level rose from 55 cm to 73 cm. Only one mutant, Pankaj (M)-107, increased during this period. From 111 days till maturity, the mutants had maximum increase in height when the water level went down from 73 cm to 50 cm. OC 1393 showed a response similar to that of the Pankaj mutants (M)-91 and (M)-107. The mutants of OC 1393 and the HTA cultures increased in height more or less gradually throughout their growth period. IR442-2-58 behaved like the HTA cultures but ceased to elongate after 111 days.

Within the HTA group the total increase in height of a genotype grown under above-normal water depth showed very wide variations (Fig. 1). It appeared to be wholly an inherent characteristic rather than an environmental one. There was no relation between increase in height and the actual height of the plant.

Thus, the final height of the plant under above-normal water depth might be one criterion for its adaptation to above-normal water conditions, but not necessarily the primary one. The steady increase in height during the growth period might be more useful in this respect. Based on these two criteria, the HTA cultures and OC 1393 mutants appeared promising for above-normal water level conditions. Although IR442-2-58 did not increase in height between 111 days and maturity and was the shortest, it steadily increased in height till 111 days. The steady



1. Plant height (cm) at 51, 66, 81, 96, 111 days of age and at maturity of three groups of rice varieties of cultures grown under normal (N) and under above normal (H) water levels and the total increase in plant height over N when grown under H. Chinsurah Rice Research Station, 1975 wet season.



Ht (cm)
180
160
140
120
100
80
60
40
20
0
111 days
Plant ht (cm)
200
At maturity
Total increase in ht (cm)
PANKAJ
PANKAJ (M)-86
PANKAJ (M)-91
PANKAJ (M)-107
AV. OF PANKAJ MUTANTS
OC 1393
OC (M)-29
OC (M)-88
AV. OF OC 1393 MUTANTS
IR442-2-58
HTA 16-CN-5
HTA 22-CN-3
HTA 108-CN-24
HTA 171-CN-12
HTA 448-CN-16
HTA 607-CN-8
HTA 826-CN-23
AV. OF HTA CULTURES

height increase made it suitable for above-normal water conditions in a restricted way.

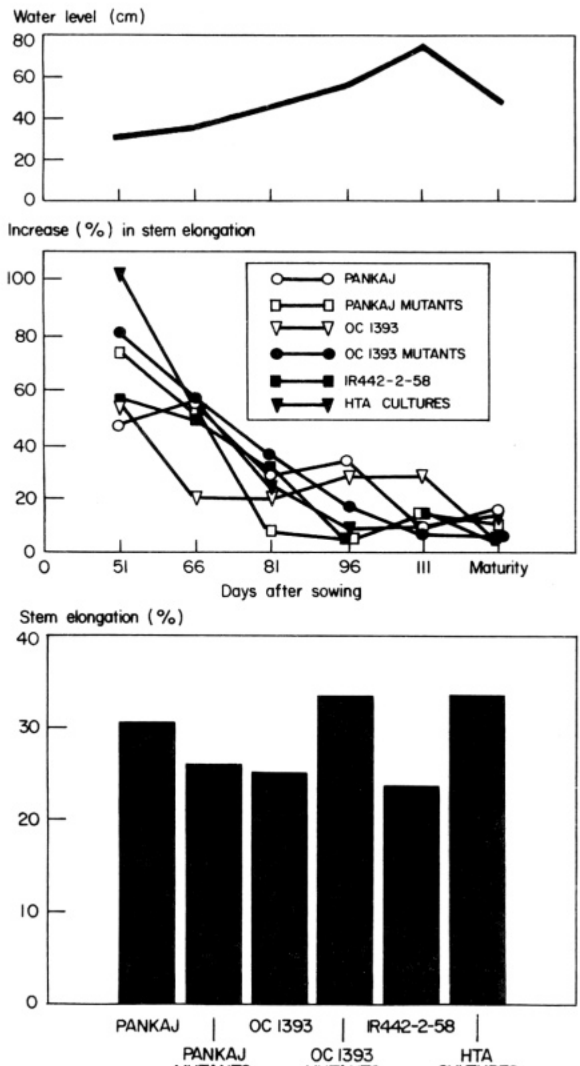
Kihara et al. (1962), who studied the genetics of floating ability in rice under laboratory conditions, concluded that three factors—'a,' 'b,' and 'c'—were responsible for floating ability. OC 1393 might be regarded as being controlled by the factor 'a' which produced tallness. The OC 1393 mutants might have both 'a' and 'b' factors; the latter factor allowed a steady stem elongation rate with increased water depth. The HTA cultures might have only the 'b' factor, but a few might have the 'a' factor as well. IR442-2-58 appeared to have only the 'b' factor. It was not possible to study the 'c' factor that allowed the plant to elongate at the maximum rate. Jackson et al. (1972) found low values for the factor 'a' and high values for 'b' in the T442 lines, which are sister selections from IR442 progenies. They also found high values for factor 'a' and low values for factor 'b' in traditional, tall Thailand varieties as observed in the traditional, tall local variety OC 1393 in the present investigation.

The increase in stem elongation of the plants grown under normal over those grown under above-normal water depth conditions (Table 1) showed a trend rather contradictory to that of height increase with increasing water level or the total height of the plant. That was also pointed out earlier by Mukherji (1974) who reported on 13 genotypes, including 7 from Thailand and 2 from The International Rice Research Institute (IRRI). The stem elongation coefficient (*Se*) values gave rather confusing trends. The HTA cultures and OC 1393 mutants had high initial increase in stem elongation that held till 66 and 81 days, respectively. The gradual decline in the increase till maturity in OC 1393

Table 1. Increase in stem elongation of three groups of rice varieties grown under above-normal water levels over those grown under normal water levels and total stem elongation throughout the life period. Chinsurah Rice Research Station, West Bengal, India, 1975 wet season.

Group	Variety	Increase in stem elongation (cm) at						Total increase in stem elongation (cm)
		51 days	66 days	81 days	96 days	111 days	Maturity	
1	Pankaj	12.70	20.80	15.80	20.20	9.80	14.70	94.00
	Pankaj mutants	19.30	21.50	5.80	4.80	9.47	8.77	69.64
2	OC 1393	16.10	11.10	14.41	21.40	25.40	4.50	92.91
	OC 1393 mutants	24.50	26.45	21.05	13.90	8.80	6.50	101.20
3	IR442-2-58	13.50	21.40	12.60	3.40	8.10	5.20	64.20
	HTA cultures	25.25	25.27	14.79	6.51	12.05	13.52	97.39

mutants, and the almost similar values, except at 96 days, for HTA cultures separate these two groups from the others. Pankaj had low initial value and then moderately high values till 96 days, but its mutants showed high values only up to 66 days. OC 1393 had high values only from 96 to 111 days, while IR442-2-58 had a high value only at 66 days. The total stem elongation was highest in OC 1393 mutants, second highest in the HTA cultures, and lowest in IR442-2-58.



2. Percentage of increase of stem elongation at different stages (A) and average percentage of increase (B) of three groups of rice varieties grown under above normal water level (H) over those under normal water level (N) against water depth at different growth stages. Chinsurah Rice Research Station, 1975 wet season.

Table 2. Variations in some plant characters and floating abilities (X_F and F_D) of three groups of rice varieties grown under above-normal water levels. Chinsurah Rice Research Station, West Bengal, India, 1975 wet season.

	Variety	Internodes above 3 cm (no.)	Nodes (no.) with adventitious roots	Tillers or branch (no./plant)	Floating ability index: Morishima's (1974) formula X_F	Floating ability index: Proposed formula F_D
Group I						
1	Pankaj	6.6	3.00	9.6	73.615	134.45
2	Pankaj (M) - 86	6.8	2.00	7.8	73.357	129.63
3	Pankaj (M) - 91	6.0	3.00	7.0	73.100	120.50
4	Pankaj (M) - 107	5.8	3.00	8.0	69.380	129.72
	Av. of Pankaj mutants	6.2	2.67	7.6	71.945	126.77
Group II						
5	OC 1393	7.0	3.00	7.0	85.380	140.94
6	OC 1393 (M) - 29	8.2	2.00	8.2	86.838	170.21
7	OC 1393 (M) - 88	7.8	3.00	7.8	82.612	170.15
	Av. of OC 1393 mutants	8.0	2.50	8.0	84.725	170.90
Group III						
8	IR442-2-58	5.2	3.00	7.2	62.572	117.97
9	HTA 16 - CNB - 5	6.0	3.00	5.8	88.792	173.95
10	HTA 22 - CNB - 3	7.0	4.00	6.4	102.651	169.15
11	HTA 108 - CNB - 24	8.0	5.00	5.0	75.350	156.19
12	HTA 171 - CNB - 12	8.0	4.00	11.0	87.372	133.74
13	HTA 448 - CNB - 16	7.0	4.00	4.8	88.642	145.06
14	HTA 607 - CNB - 8	7.0	5.00	6.2	81.018	130.18
15	HTA 826 - CNB - 23	6.0	4.00	5.6	87.834	158.34
	Av. of HTA mutants	7.0	4.14	6.3	87.380	165.09

It appeared that initial high increase in stem elongation till 66 days was more significant than either later increase or definitely low increase values at most stages of plant growth. That substantiates the basis of the screening technique evolved by Prechachart et al. (1975) to screen for deep-water conditions after 56 days from seeding. The percentages of increase in stem elongation shown by OC 1393 mutants and HTA cultures (Fig. 2) were similar, i.e., sharp linear fall from a high initial pitch. Pankaj mutants showed a similar trend, but the fall was sharper. IR442-2-58 had much lower initial pitch, and OC 1393 followed a rather horizontal path in this respect. It appeared that the initial high pitch and sharp fall till 81 days were desirable for adaptation to above-normal water depths.

While Morishima's (1974) formula for calculation of floating ability (X_F) in rice genotypes was being applied, three other characters apart from the total length of elongated internodes were scrutinized. The data indicated (Table 2) that except for the number of internodes longer than 3 cm, the other two characters—number of nodes with adventitious roots and number of tillers or branches per plant—had no direct correlation with floating ability. The desirable number of internodes longer than 3 cm appeared to be seven and eight for adaptation to above-normal water level. Among the groups, HTA cultures had the highest X_F value, followed by OC 1393 and its mutants. This finding corroborates that on height, increase in height, and increase in stem elongation as discussed earlier. IR442-2-58 had the lowest X_F value, which might be due to its shortness as compared to the others, its low total increase in height (Fig. 1), and low number of internodes longer than 3 cm. That the total height and total increase in height contributed substantially toward the determination of the X_F value might be proved by scrutinizing the data in Table 2 and in Figure 1. The high X_F value of HTA 22-CNB-3 was due to high total increase in height. Although HTA 16-CNB-5 had maximum height, its rather low value for total height increase, together with low number of internodes longer than 3 cm gave this genotype an X_F value lower than that of HTA 22-CNB-3.

CONCLUSION

It appears that 1) final height, 2) steady increase in height with increase in water depth, 3) high total increase in height, 4) initial high increase in stem elongation, 5) initial high pitch with a sharp fall in percentage of increase in stem elongation, and 6) number of internodes (longer than 3 cm) above 7 were the major criteria for determining the ability to adapt to above-normal water depths in the field. However, since no direct correlation could be found between the ability and the number of nodes with adventitious roots or number of branches or tillers per plant, a new formula for determining adaptation to above-normal water depths is suggested :

$$F_D = 1.00A + 0.50B + 0.20C + 1.00D - 0.25E$$

where F_D = adaptation to above-normal water depth or floating ability factor, A = number of internodes longer than 3 cm, B = final height under above-normal water level, C = total increase in stem elongation, D = total increase in stem elongation from sowing till 81 days, and E = percentage of total stem elongation of plants grown under above-normal water depth over normal water depth conditions.

The F_D values (Table 2) gave more precise information about the adaptation capacity of rice genotypes to above-normal water depths. They indicated that the two OC 1393 mutants responded better to above-normal water depths than all the HTA cultures except HTA-16-CNB-5. Another HTA culture (HTA-22-CNB-3) was similar to the OC 1393 mutants in this respect. IR442-2-58 had the lowest F_D and X_F values. All the HTA cultures, except HTA 108-CNB-24 and HTA 22-CNB-3, had X_F values similar to those of OC 1393 and its mutants. Although OC 1393 and its mutants had similar X_F values, OC 1393 had lower F_D values than its mutants, a finding that was consistent with the field observations on adaptation to increasing water depths. It would be possible to classify the genotypes into four distinct groups according to adaptation to increasing water depths as follows:

1. Very high (F_D value above 160) — HTA 16-CNB-5, OC 1393(M)-29, OC 1393(M)-88, HTA 22-CNB-3.
2. High (F_D value of 140-159) — HTA 826-CNB-23, HTA 108-CNB-24, HTA 448-CNB-16, OC 1393.
3. Moderate (F_D value of 120–139)— Pankaj, HTA 171-CNB-12, HTA 607-CNB-8, Pankaj(M)-107, Pankaj(M)-86, Pankaj(M)-91.
4. Low (F_D value below 120) — IR442-2-58.

Another group might be made for F_D values below 100 to include most semidwarf, high yielding varieties that have very low adaptation ability. However, that needs confirmation. Such a methodology may be satisfactory for screening large numbers of genotypes at a time to evaluate their adaptation to poorly drained, stagnant-water conditions that limit the production of kharif rice in West Bengal.

SUMMARY

Fifteen rice genotypes suitable for water-stagnant fields were grown under normal and above-normal water depths in the field at the Rice Research Station, Chinsurah (West Bengal) in 1975 kharif. Water depth never exceeded 10 cm under normal condition, and varied from 30 cm to 90 cm at different growth phases of the plants under above-normal water depth. Large phenotypic differences in adaptation ability were observed among the genotypes. IR442-2-58 from IRRI had been quite promising in low-lying areas in West Bengal where water depth varied from 30 cm to 50 cm, and also under upland conditions, but it showed low floating ability when water rose above 50 cm. Some HTA cultures from Thailand and two X-ray-induced mutants of OC 1393 developed at Chinsurah had good floating ability. The Pankaj mutants, also developed from X-irradiated seeds at Chinsurah, had lower floating ability than their parents. Morishima's (1974) formula for measuring the floating ability of rice was discussed. Data obtained from the present experiment showed that the number of nodes with adventitious roots

and the number of branches or tillers per plant had no relation to floating ability. The major factors related to floating ability were final height of plant, steady increase in height with increase in water depth, high total increase in height, initial high rate of stem elongation, initial high pitch with a sharp fall in percentage of increase in stem elongation, and number of internodes (longer than 3 cm) above 7. Accordingly, a new formula for measuring the adaptation capacity of the plant to increased water depth was suggested. The new formula gave more precise information than Morishima's formula, at least for situations where water depth rose to 90 cm.

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Effects of flooding on morphological characteristics of floating rice varieties of Bangladesh

M. Nasiruddin, M.S. Ahmed, S.M.H. Zaman, and E. Haq

Floating or deep-water rice, also known as broadcast aman, is usually grown in low-lying areas where water depths range from 1.5 to 5.0 m. The main distinguishing characteristic of this group of rice is that the internode, leaf sheath, and blade can elongate with rising water. The rices also can withstand some submergence, produce nodal branches and roots, form knees, and, when uprooted, float on the water surface. The long culms get entangled during the later stages of growth, and strong currents and winds often uproot the entangled mass. The uprooted plants can grow and produce panicles (Hasanuzzaman et al., 1974). The mechanism by which the internode, leaf sheath, and blade elongate is not clearly understood.

MATERIALS AND METHODS

Two floating rice varieties of Habiganj Aman (V and VIII), one Rayada (R16-02) and one strain of wild rice (Jhora) were used.

Habiganj Aman varieties are recommended for deep-water areas. Rayada is a special type of deep-water rice mixed with boro rice; it is usually sown in November and harvested after about 12 months (Perez and Nasiruddin, 1974). Rayada has photoperiod sensitivity, but unlike other deep-water rice varieties, it lacks seed dormancy. The wild rice is common in deep-water areas and is usually considered a

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weed, but sometimes it is used as green fodder for cattle. The wild rice for the study was collected from the flooded areas of Dacca district.

Seeds of all materials were sown in pots. Plants of each variety or strain received separate treatments of shallow water and flooded conditions.

In the shallow-water treatment, the plants were grown under non-flooded conditions. In the deep-water treatment, the plants were subjected to flooding 6 days after seeding. The pots were suspended so that the upper 15 to 20 cm of the leaves remained above water. Six water-depth adjustments were made at 5-day intervals over 30 days. The plants were then allowed to grow undisturbed for about a week. On the 8th day, the length of the internode, the leaf sheath, and the leaf blade was measured. At 2½ months of age, samples for anatomical studies were collected from n-2 internodes, and fixed in FAA solution. Hand and microtome sections were prepared and studied. Data on thickness of the cellular part of internodes, size of air spaces and cells around air spaces, and diameter of peripheral and inner vascular bundles were collected.

RESULTS AND DISCUSSION

The number of tillers per plant and number of leaves on the main culm 42 days after seeding are shown in Table 1. Habiganj Aman V and VIII produced few tillers but had more leaves. Rayada showed poor tillering and six leaves. Jhora had 8 tillers/plant and seven leaves 42 days after seeding. The effect of flooding on the length of the internodes, the leaf sheaths, and the leaf blades of the rice varieties is shown in Tables 2 to 5. The percentages of increase in length of internode, leaf sheath, and leaf blade due to flooding are in Table 6. Habiganj Aman VIII had the highest internode elongation (1073%), followed by Rayada (921%) and Habiganj V (662%). Jhora had the lowest internode elongation (260%). It had the highest combined leaf sheath and leaf blade elongation (107%),

Table 1. Tillers and leaves of three deep-water rice varieties and Jhora, 42 days after seeding. Bangladesh Rice Research Institute, 1976.

Variety	Tillers (no./plant)	Leaves (no.) on the main culm
Habiganj Aman V	2	8
Habiganj Aman VIII	2	8
Rayada 16-02	3	6
Jhora (Dacca 08)	8	7

Table 2. Effect of flooding on the length of internode, leaf sheath and leaf blade of Habiganj Aman V. Bangladesh Rice Research Institute, 1976.

Position of internode	Mean length (cm) of					
	Internode		Leaf sheath		Leaf blade	
	Flooded	Nonflooded	Flooded	Nonflooded	Flooded	Nonflooded
1	1.33	1.00	–	–	–	–
2	6.16	3.33	–	–	–	–
3	12.16	4.33	–	20.50	–	32.00
4	19.50	4.83	–	22.75	–	–
5	12.16	5.66	–	21.33	–	39.50
6	19.33	4.66	–	24.00	–	48.33
7	23.33	4.00	–	25.33	–	50.33
8	33.00	2.50	–	23.50	–	47.50
9	38.33	–	26.50	25.50	57.00	51.00
10	33.33	–	24.33	–	56.00	–
11	25.33	–	24.33	–	59.00	–
12	7.00	–	23.33	–	58.33	–
13	–	–	25.00	–	58.00	–
Total	230.96	30.31				
Mean			24.70	23.27	57.66	44.77

Table 3. Effect of flooding on the length of internode, leaf sheath, and leaf blade of Habiganj Aman VIII. Bangladesh Rice Research Institute, 1976.

Position of internode	Mean length (cm) of					
	Internode		Leaf sheath		Leaf blade	
	Flooded	Nonflooded	Flooded	Nonflooded	Flooded	Nonflooded
1	4.75	4.00	–	–	–	–
2	8.75	4.66	–	20.00	–	30.00
3	7.00	4.33	–	20.00	–	31.00
4	7.75	3.6	–	21.16	–	39.33
5	23.00	0.5	–	19.00	–	42.50
6	23.50	–	23.0–	19.50	–	44.00
7	14.25	–	22.00	–	50.00	–
8	6.75	–	20.00	–	44.00	–
9	4.00	–	–	–	–	–
10	34.50	–	23.00	–	40.00	–
11	36.00	–	22.50	–	–	–
12	19.50	–	24.50	–	51.00	–
13	1.00	–	22.50	–	54.00	–
Total	194.75	16.59				
Mean			22.53	19.33	47.80	37.37

followed by Rayada (32%). During flooding, Jhora emerged out of the water earlier than the other varieties.

Elongation of leaf sheath and leaf blade may be important to floating ability and to survival during flooding with an abrupt rise in water.

Table 4. Effect of flooding on the length of internode, leaf sheath, and leaf blade of Rayada 16–02. Bangladesh Rice Research Institute, 1976.

Position of internode	Mean length (cm) of					
	Internode		Leaf sheath		Leaf blade	
	Flooded	Nonflooded	Flooded	Nonflooded	Flooded	Nonflooded
1	7.13	1.00	–	–	–	–
2	15.33	2.66	–	20.00	–	40.00
3	12.70	3.33	–	23.83	–	37.50
4	7.33	4.00	–	25.33	–	42.75
5	13.00	3.16	–	24.66	–	49.00
6	34.66	0.50	28.00	25.66	–	60.33
7	36.00	–	29.00	–	58.33	–
8	19.16	–	31.16	–	66.50	–
9	3.00	–	27.00	–	66.00	–
Total	148.31	14.65				
Mean			28.79	23.89	63.61	45.91

Table 5. Effect of flooding on the length of internode, leaf sheath, and leaf blade of Jhora (Dacca 08). Bangladesh Rice Research Institute, 1976.

Position of internode	Mean length (cm) of					
	Internode		Leaf sheath		Leaf blade	
	Flooded	Nonflooded	Flooded	Nonflooded	Flooded	Nonflooded
1	9.33	4.16	–	–	–	–
2	14.66	6.33	–	13.00	–	19.50
3	14.33	8.66	–	14.50	–	32.50
4	14.00	8.83	–	15.33	–	34.00
5	29.33	6.00	27.00	15.83	62.00	39.83
6	26.33	2.83	26.83	16.83	66.50	24.83
7	15.50	0.50	26.83	15.00	73.50	34.00
8	18.00	–	30.00	–	64.00	–
Total	141.48	37.31				
Mean			27.66	15.08	66.50	30.78

Anatomical differences exist in the subepidermal layers (sclerenchyma layer), and in the arrangement and distribution of peripheral and inner vascular bundles. In the Habiganj Aman varieties, peripheral vascular bundles lie on the same plane and are usually embedded in the tissue close to the epidermis.

Habiganj Aman V and VIII have two sclerenchyma layers, but Habiganj Aman III has three. Inner vascular bundles lie alternately in an up-and-down position (they are not on the same plane as the peripheral vascular bundles). Rayada 16–02 has three sclerenchyma

Table 6. Height and percentage of increase in length of internode, leaf sheath, and leaf blade of plants subjected to flooding, 42 days after seeding. Bangladesh Rice Research Institute, 1976.

Variety	Plant ht (cm)	Increase (%) in length of			
		Internode	Leaf sheath	Leaf blade	Sheath + leaf blade
Habiganj Aman V	313.0	662	16.5	29	21
Habiganj Aman VIII	280.0	1073	16.0	28	24
Rayada 16–02	240.7	912	20.50	37	32
Jhora (Dacca 08)	236.0	260	83.0	116	107

layers, but the distribution and arrangement of vascular bundles are different from those of the Habiganj Aman varieties. Normally peripheral vascular bundles lie on the same plane and are embedded into the sclerenchyma layers, but a few are found one to two layers below the air spaces, a characteristic that differentiates Rayada from Habiganj Aman and wild rice.

Wild rice has two layers of sclerenchyma. The peripheral and inner vascular bundles are connected by a group of thin-walled elongated cells. Such connections are not found in Habiganj Aman and the Rayadas. In wild rice, the peripheral and inner vascular bundles lie in an up-and-down position. All the materials have air spaces at the center of four vascular bundles. Flooding increases the thickness of the cellular part of internodes, the size of air spaces, the size of cells around air spaces, and the diameter of vascular bundles.

Varietal differences under flooded and nonflooded conditions in the above characteristics are in Table 7. Hasanuzzaman et al. (1974) reported variable changes in thickness of the cellular part of internodes of eight aman varieties under flooded and nonflooded conditions. Marked differences were observed in the size of air spaces and the cells around air spaces, but there was little change in the thickness of the cellular part of internodes and in the diameter of the peripheral and inner vascular bundles (Table 7). Peripheral vascular bundles lie close to the sclerenchyma layers. The inner vascular bundles were scattered in the ground tissue. In Habiganj Aman varieties there is a tendency for a bridge to form between the peripheral and inner vascular bundles. In Jhora, the bridge between peripheral and inner vascular bundles is decreasing. Table 8 shows the difference in length of parenchymatous cells taken

Table 7. Differences in thickness of cellular part of internode, size of air space and cells around air space, and diameter of outer and inner vascular bundles of two floating rice varieties and one wild rice in flooded and nonflooded conditions. Bangladesh Rice Research Institute, 1976.

Variety	Thickness of the cellular part of internode (mm)		Size of air space (sq mm)		Cell size around air spaces (sq mm)		Diameter of outer vascular bundle (mm)		Diameter of inner vascular bundle (mm)	
	Flooded	Nonflooded	Flooded	Nonflooded	Flooded	Nonflooded	Flooded	Nonflooded	Flooded	Nonflooded
Habiganj Aman VIII	0.8036	0.7504	0.065208	0.15202	0.003074	0.002106	0.1075	0.1036	0.1750	0.1725
Rayada 16–02	0.7952	0.7784	0.143262	0.025051	0.002714	0.001696	0.1065	0.1036	0.2049	0.1960
Jhora (Dacca 08)	0.9156	0.8316	0.113832	0.042335	0.003255	0.002106	0.1047	0.0980	0.1960	0.1803

Table 8. Differences in mean length of parenchyma cells between outer and inner vascular bundles of two floating rice varieties and one wild rice. Bangladesh Rice Research Institute, 1976.

Variety	Mean length (mm) of cells	
	Flooded	Nonflooded
Habiganj Aman VIII	0.09604	0.04928
Rayada 16–02	0.12600	0.06776
Jhora (Dacca 08)	0.10192	0.05748

from identical positions in plants subjected to flooded and nonflooded conditions.

CONCLUSIONS AND RECOMMENDATIONS

Jhora (wild rice) had the lowest internode elongation among the varieties and strains tested. It had the highest leaf sheath and leaf blade elongation and showed flood tolerance comparable with that of the best Habiganj Aman varieties.

Plant breeders, in addition to incorporating internode elongation capability, should consider greater elongation capacity of the leaf sheath and the leaf blade to survive flooding during sudden rises of water.

The varieties and strains tested showed little anatomical difference in thickness of cellular part of internodes and in diameter of peripheral and inner vascular bundles. The sizes of air spaces and the cells around them accounted for most of the difference.

The elongation of the internode and other vegetative parts of the plants subjected to flooding was mostly due to the increase in length of cells.

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DISCUSSION

PARK: Are there morphological or anatomical characteristics of practical value as criteria for selecting deep-water rice? If so, they should be easily identified and quite highly heritable.

Nasiruddin: Deep-water varieties should have internodes and other vegetative parts with the capacity for elongation. Tall plant height has some positive correlation with internode elongation ability. It can be used to select deep-water varieties. At present there is no laboratory method to test elongation ability, or any morphological characters except plant height, that can be associated with flood tolerance.

OHTA: Please explain your method of calculating percentage of increase of internode length; you report as much as 1073 % (Table 6).

Nasiruddin: Please refer to Table 3 on mean length of internode of Habiganj Aman VIII under flooded and nonflooded conditions. The simple calculation was made as follows:

$$\frac{194.75 - 16.59 \times 100}{16.59} = 1073\%$$

ZAN: Was there any difference in number of internodes among the varieties tested?

Nasiruddin: Yes, there were varietal differences in the number of internodes of the varieties tested. We studied the varieties for 2½ months, but not up to flowering.

ZAN: Was there any difference in the length of internodes on the same plant? If so, which region of the plant showed the highest elongation?

Nasiruddin: Usually the middle region of the plant showed the highest elongation. That also depends on time and rate of flooding. Earlier internodes and those close to panicle initiation showed poor elongation.

VERGARA: Is it possible to have good internode elongation, as in Habiganj Aman VIII, plus good leaf sheath and leaf blade elongation as in Jhora?

Nasiruddin: This could be an ideal combination for deep-water rice. But at this stage we do not know the relationship between internode elongation and elongation of leaf sheath and leaf blade. Some observations indicated that nondeep-water varieties have more leaf sheath and leaf blade elongation. Jhora (wild rice) has more flood tolerance than ordinary deep-water varieties. The situation needs further study.

DATTA: Was there any difference in lumen between flooding and nonflooding conditions?

Nasiruddin: Yes, there were varietal differences in lumen size under flooded and nonflooded conditions. A Bangladesh wild rice with a minimum lumen size exhibited a higher degree of flood resistance. The lumen size also depends on the stage at which the internode elongates, and when the flood stabilizes. If the plant gets good nutrition, the diameter of the lumen increases.

SARAN: Why are Rayada types grown as mixed crop with boro rices? Can a pure boro rice crop be grown instead?

Nasiruddin: Farmers can grow two crops on natural lands. Rayada is nondormant and is suitable only for that purpose.

Some observations on germination, growth, yield, and anatomy of deep-water rice plants

S.K. Datta and B. Banerji

About 2 M ha in West Bengal are continuously submerged at varying depths and durations, depending on the topography, during the rainy (kharif) season. During that season, most crop growth occurs. Deep submergence causes significant yield loss, and some areas are left uncultivated. Rice, with its many varieties and wide adaptability, is the only crop that can be successfully grown in these areas (Datta and Banerji, 1975, 1976a,b,c). These low-lying rice areas can be broadly classified on the basis of water depth during the period between the vegetative and reproductive phases:

1. Shallow-water, up to 60 cm;
2. Knee-deep water, 70–90 cm;
3. Semideep-water, 120–160 cm; and
4. Deep-water, more than 160 cm.

In these water-logged areas, germination and seedling growth in water are very important characteristics of rice. Rice varieties for those areas should be screened for tolerance to complete submergence at seedling stage, and for high germination capacity in water. Very little information is available on varietal suitability, cultural practices, and application and effect of fertilizers on rice grown under these conditions (Datta and Banerji, 1974a, b, c,). Information on the morphogenetic and anatomical changes associated with varietal adaptability under deep-water conditions is also lacking. No doubt, information on the above

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aspects will contribute considerably towards increasing rice production in West Bengal and will help to bring to fruitful production a large area which has so far been mostly unproductive. With that objective the following aspects of some water-loving rice varieties have been studied:

1. Germination and seedling growth under submerged conditions
2. Growth and yield under deep-water conditions
3. Anatomical changes under deep-water conditions

GERMINATION AND SEEDLING GROWTH UNDER SUBMERGED CONDITIONS

Different rice varieties were allowed to germinate and grow for 55 days in tall glass jars (32 cm × 8 cm) filled with turbid water (Datta and Banerji, 1974b). The varieties were adapted to deep water (Jaladhi 1, a selection from *Kalakhersail;* and Jaladhi 2, a selection from *Baku*), high yielding (Pankaj and Jagannath), and flood resistant (FR 13A and FR 43B).

Seedlings of the deep-water varieties showed a greater resistance to submergence and continued their rapid growth rate in plant height until they emerged from the water (up to 11–12 days), but the flood-resistant and the high yielding varieties did not come above the water surface. The growth of the deep-water varieties in the water was about seven times greater than that in the atmosphere. A daily growth of as much as 5 to 6 cm was frequently observed when seedlings were growing in the water.

There is also some evidence that deep-water varieties possess anatomical adaptations that facilitate the internal aeration of plants. The anatomical structure of the varieties shows large air cavities in which air is stored for the respiration of the plants.

The simple technique of growing plants in tall jars can be profitably used to isolate varieties tolerant to submergence at early growth stages, and to select promising rice varieties for low-lying areas.

GROWTH AND YIELD UNDER DEEP-WATER CONDITIONS

Two deep-water rice varieties—Jaladhi 1 and Jaladhi 2—and the flood-tolerant variety FR 43B were grown under deep-water (10–190 cm and 35–210 cm depth during the vegetative and reproductive phases, respectively) and normal field conditions (Datta and Banerji, 1972). Deep-water varieties showed better growth habit and yield attributes under deep-water than under normal field conditions. The flood-tolerant variety gave higher grain and straw yields and had higher numbers of main tillers and panicles under normal field conditions (Datta and Banerji, 1973a, b).

Nodal tillering is a deep-water variety characteristic that produces a considerable amount of grain and straw and contributes towards the yield. It is the most important character for the selection and breeding of promising deep-water varieties. Generally, most nodal tillers arise from specific nodes of the culm (7th, 8th and 9th nodes from the base). That appears to be the most active region in the formation of nodal tillers, depending on the water level at the vegetative phase. It shows that a relationship exists between extension growth of the culm and water level for the formation of nodal tillers (Datta and Banerji, 1972).

Stem elongation of Jaladhi 1 and Jaladhi 2 was investigated under varying water regimes (Datta and Banerji, 1976a). Four suitably constructed field plots were used for the water regimes: shallow water, knee-deep water, semideep water, and deep water. Under shallow-water conditions, the plants showed low values for growth in stem length and number of internodes, and behaved like normal, tall *indica* rice varieties.

Considerably higher values for total stem production were obtained under knee-deep water and semideep-water conditions. That clearly shows that the stems have a tendency to grow spontaneously on the water surface and that the particular behavior is responsible for their floating habit. Jaladhi 1 showed maximum culm growth under deep-water conditions, attaining a stem length of 342.8 cm per plant at harvest. Jaladhi 1 had 18 internodes in the main shoot under deep-water conditions, and Jaladhi 2 had 17. The results suggest that the total stem length a particular variety is capable of attaining is one important criterion that can be used for selecting varieties for different water depths (Datta and Banerji, 1976c).

ANATOMICAL CHANGES UNDER DEEP-WATER CONDITIONS

The effects of different cultural methods, such as deep-water and normal field conditions, on the anatomical changes in the stems of three rice varieties—the deep-water types Jaladhi 1 and Jaladhi 2 and the flood-resistant type FR 43B—were studied (Datta and Banerji, 1974a). The presence of air sacs in the higher internodes—up to the 16th or 17th internode, 230-250 cm above the soil surface—of the deep-water varieties under deep-water conditions was noted. Air sacs are an essential characteristic of hydrophytes. Under field conditions, air sacs were observed only in the area of the 4th to 7th internodes.

Jaladhi 1 and Jaladhi 2 showed a higher degree of adaptability to deep-water conditions than did FR 43B. The characteristics of Jaladhi

1 and Jaladhi 2 that developed remarkably were length, diameter and thickness of internodes, diameter of lumen, number and diameter of air sacs, and moisture percentage.

Under normal field conditions, FR 43B showed greater number and length of internodes and diameter of air sac, more cells per unit area, and higher plant water content than the deep-water varieties. These results indicate a clear anatomical difference between the two rice types. The anatomical characteristics of Jaladhi 1 and Jaladhi 2 confirmed their adaptability to deep-water conditions, while those of FR 43B confirmed its suitability for normal field conditions (Datta and Banerji, 1974a).

SUMMARY

A vast area in West Bengal becomes submerged during the rainy season and remains so in varying degrees for the major period of crop growth. Deep-water conditions cause significant loss of rice yield. Morphological, physiological, and anatomical characteristics associated with adaptation to deep-water conditions have been examined and more work is in progress. Detailed information on the following aspects of deep-water rice varieties is presented:

1. Germination and seedling growth under submerged conditions
2. Growth and yield under deep-water conditions
3. Anatomical changes under deep-water conditions

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SCREENING METHODS

Screening deep-water rices for drought tolerance

S. K. De Datta and J.C. O'Toole

Millions of hectares of rice land depend solely on unpredictable monsoon rains for water supply. Monsoon rains often fail and drought sets in. Deep-water rice culture is an important system in those rainfed areas in the densely populated deltas, estuaries, and river valleys of India, Bangladesh, Burma, Thailand, Cambodia, Vietnam, and Indonesia. Dry seeding is fairly common and so is drought stress. Uncertain rainfall during March-April leads to frequent drought damage and poor stand. In Bangladesh, sowing starts in mid-March; however, the advent and amount of rainfall determine the actual date of sowing. In West Bengal, India, seed is broadcast in April-May on dry soil (Mukherji, 1975). In Thailand, deep-water rice is grown under dry conditions until the full force of the monsoon sets in anytime from June to August. During this period, rice frequently suffers from severe drought (Prechachart and Jackson, 1975). In Vietnam, farmers compare growing deep-water rice to gambling; those in deep-water rice areas often have to reseed once or twice if it does not rain for several days after seeding (Xuan and Kanter, 1975).

The positive side of the drought-stress problem in deep-water rice areas is the indication that natural selection for drought tolerance is acting in deep-water rices at the vegetative stage. This means that the seemingly mutually exclusive traits of drought and deep-water tolerance are inherent in rices grown under these harsh conditions, and can be

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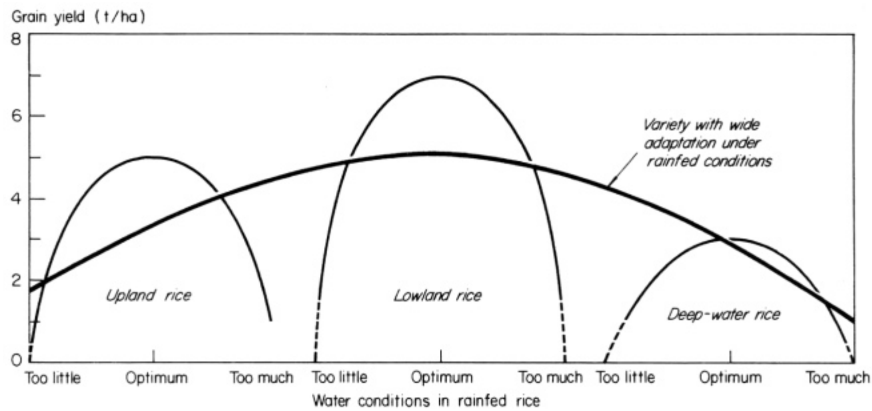


1. A concept for developing a variety of rainfed rice with drought tolerance and elongating capacity. IRRI, 1975.

combined in a single variety. This contention was experimentally substantiated by De Datta and Abilay (1975). Earlier results demonstrate that varieties having both semidwarf and floating traits, such as the IR442 plant type, can be developed. Such varieties would adjust their growth characteristics to fit moisture supply that is either too little or too much (Fig. 1). They would insure against total crop failure if the rainfall in a given year is not normal for the specific water and land management system. However, varieties with both drought tolerance and elongating capacity may have somewhat lower yield potential than do varieties bred for specific water and land management systems. Nevertheless, hybrids from floating and semidwarf varieties might stabilize yield during the atypical years (De Datta and Abilay, 1975). The incorporation of submergence and drought tolerance, and photoperiod sensitivity into such varietal types could further stabilize yields under certain deep-water conditions (IRRI, 1975a).

If drought tolerance is bred into rices meant for deep-water areas, early seeding will insure rapid stand establishment and reduce the risk that the sudden rise of floodwater may destroy young seedlings.

This paper describes some techniques for screening rices for drought tolerance. It also identifies rices with deep-water and submergence tolerance as well as drought tolerance.

GREENHOUSE TECHNIQUES

A new greenhouse technique was used that measures the reactions of rice to drought stress (Sarkar and De Datta, 1975). A 45-cm rooting depth was provided in containers made from gasoline drums. Fertilizers were incorporated into the soil. Rices were direct seeded in the dry soil.

For the moisture-stress treatment, rices were grown for 9 days with continuous moisture supplied through a perforated polyvinyl chloride (PVC) pipe installed at the bottom of the container. After 9 days, the moisture supply was discontinued, and the rices were grown for 73 days with no additional moisture until moisture tension (recorded by gypsum blocks at depths of 15 and 30 cm) rose to about 19 bars. Moisture content was gravimetrically determined, and data were then converted to soil moisture tension using the desorption curve. Moisture was then resupplied to study the recovery ability of the rices.

In another container, rice planted in dry soil and then grown under continuous saturation served as control.

All greenhouse trials used Moroberekan, an upland variety from Africa, as the susceptible control. In the 1975 trial, Moroberekan was completely killed when soil moisture tension exceeded 16 bars. IR442-2-58, which is derived from a cross with the deep-water rice variety Leb Mue Nahng 111, showed promise for drought tolerance. Similar results were reported earlier (De Datta et al., 1974, 1975).

In the 1976 trial, the soil moisture tension was allowed to rise to 30 bars. Leb Mue Nahng 111 had 100% survival; most rices either died or had low survival percentages (Table 1). Most IR442 lines died.

Table 1. Effects of high soil moisture tension (about 30 bars) at the vegetative stage (63 days without water starting 9 days after seeding) on the survival percentage of rice tillers. Greenhouse study, IRRI, 1976 dry season.

Variety or line[a]	Origin	Tillers (no./8 plants)	Survival (%)
IR442-2-59-2-3-3	Philippines	59	0
G11-Si-142 (5018)	Indonesia	39	0
IR442-2-58	Philippines	59	0
Dular	India	35	0
BKN 6986-147-2	Thailand	48	6
BKN 6986-108	Thailand	59	15
G11-Si-213 (5023)	Indonesia	60	25
IR1529-430-3	Philippines	29	31
B981-Si-35-1 (20016)	Indonesia	29	41
G14-Si-66-3 (20692)	Indonesia	39	41
B995-89-1 (20105)	Indonesia	50	48
IR4219-64-1-3	Philippines	32	50
B995-Si-12-3 (20069)	Indonesia	52	67
IR4215-41-3-2	Philippines	20	80
Leb Mue Nahng 111	Thailand	29	100

[a] Numbers in parentheses are IRRI germ plasm bank accession numbers.

Among the entries BKN 6986-108 and BKN 6986-147-2 from Thailand appeared promising for deep-water programs.

PHYTOTRON SCREENING

Because the probability of drought is limited to the early seedling and vegetative stages of deep-water rice, we developed a systematic procedure for evaluating seedling drought tolerance. Soil and atmospheric drought was simulated in growth chambers in the IRRI phytotron.

Pregerminated seeds were planted in trays in 15 cm of a soil-organic matter mixture. The mixture minimized soil cracking. A uniform basal application of fertilizer was made. The seedlings were grown in a greenhouse at day/night temperatures of 32/25°C for 10 days under well-watered conditions. The trays were then placed in a growth chamber with a programmed diurnal change in temperature and relative humidity. No water was applied during that period, and a reproducible sequence of soil moisture stress occurred with controlled evaporative demand. After specified exposure periods, the trays were returned to the greenhouse and rewatered. Three days later, the seedlings were scored for survival percentage. It was found that selection pressure could best be manipulated through the duration of the exposure period. Screening rices in this manner gave highly reproducible results because test conditions were controlled.

Earlier, rices from deep-water regions of Bangladesh and Thailand had exhibited high survival percentages; many surpassed the lowland Indonesian variety Sigadis, which was the control variety. We obtained seed of 206 deep-water rice varieties and varieties from other drought-prone regions for screening. After an initial screening at 7- and 10-day exposure periods in growth chambers, the survival percentage of 51 varieties and lines was found to exceed that of the control variety. Those 51 varieties were retested in 12- and 15-day exposure periods. Most of the outstanding rices identified during the more severe test conditions are deep-water rices (Table 2). The 15-day exposure time resulted in zero percent survival for most entries. The 12-day exposure showed several deep-water rices from Bangladesh with relatively high survival percentages. Their superior performance indicates tolerance to severe drought at the seedling stage. Assuming the continued use of current cultural practices in establishing deep-water rice crops, we believe that drought tolerance at the seedling stage should be incorporated into improved varieties. Table 3 gives the spectrum of response in rices of different geographical and hydrological origins. Many upland rices showed low survival percentage after only 7 days of exposure.

Table 2. Outstanding rices selected from 206 varieties tested for seedling drought tolerance at four growth chamber exposure periods. IRRI phytotron, 1976.

Variety or line	Origin [a]	Survival (%) after exposure for			
		7 days	10 days	12 days	15 days
BKN 6986-44	Thailand (DW)	95	95	5	0
KLG 6986-133-4-P	Thailand (DW)	100	90	10	0
KLG 6987-2-1-P	Thailand (DW)	93	75	10	0
Gonak Kay	Bangladesh (DW)	100	100	10	0
KLG 6987-59-P	Thailand (DW)	95	60	15	0
KLG 6987-108-P	Thailand (DW)	95	91	20	0
Goda	Bangladesh (DW)	100	100	20	0
Maijam	Bangladesh (DW)	98	97	25	0
Laki 192	Bangladesh (DW)	98	88	25	0
Sigadis (check)	Indonesia (RL)	98	83	26	0
Khao Dawk Mali 4-2-105	Thailand (RL)	100	75	30	0
Chanda Amon	Bangladesh (DW)	100	100	42	0
Fulkari 715	Bangladesh (DW)	100	95	45	0
Badal 672/2	Bangladesh (DW)	100	100	50	0
Goirol	Bangladesh (DW)	100	100	60	5

[a] DW = deep water; RL = rainfed lowland.

The capability of rice seedlings to germinate and establish themselves during drought conditions may be attributed to two broad categories of adaptation to soil and atmospheric drought—avoidance and tolerance. We feel that the screening method detailed here provides an estimate of the inherent drought tolerance of the seedlings of a variety. Our interpretation is based on the fact that the plants were uniformly and severely stressed. Measurement of the soil and plant water potential of the control variety confirms this interpretation (Table 4).

Table 3. Seedling survival of rices of varying hydrological and cultural origins after exposure to growth chamber conditions. IRRI phytotron, 1976.

Variety or line	Origin [a]	Survival (%) [b] after exposure for			
		7 days	10 days	12 days	15 days
Rikuto Norin 21	Japan (U)	0	0	–	–
Kinandang Patong	Philippines (U)	3	3	–	–
30-E	Liberia (U)	5	0	–	–
63-83	Ivory Coast (U)	65	5	–	–
Monura	Bangladesh (DW)	85	37	–	–
Rangi Khama	Bangladesh (DW)	95	90	5	0
Sigadis (check)	Indonesia (RL)	98	83	26	0
Goirol	Bangladesh (DW)	100	100	60	5

[a] U = upland; DW = deep water; RL = rainfed lowland. [b] Rices with survival percentage less than that of the check variety Sigadis at 10 days were not tested at 12 and 15 days.

Table 4. Change in water potential of soil and leaf tissue of control variety Sigadis in IRRI phytotron. 1976.

Days in growth chamber	Soil water potential (6 cm) (bars)	Leaf water potential[a] (bars)
1	– 1	– 8.9
2	– 1	– 3.2
3	– 1	– 4.3
4	– 6	–15.3
5	–16	–22.3
6	–29	–31.4
7	–38	–37.7
8	–46	–43.3
9	–53	–48.3
10	–60	–53.2

[a]Estimated by regression equation $\hat{y}$ = –11.1 + 0.701 soil water potential. (r = 0.95**)

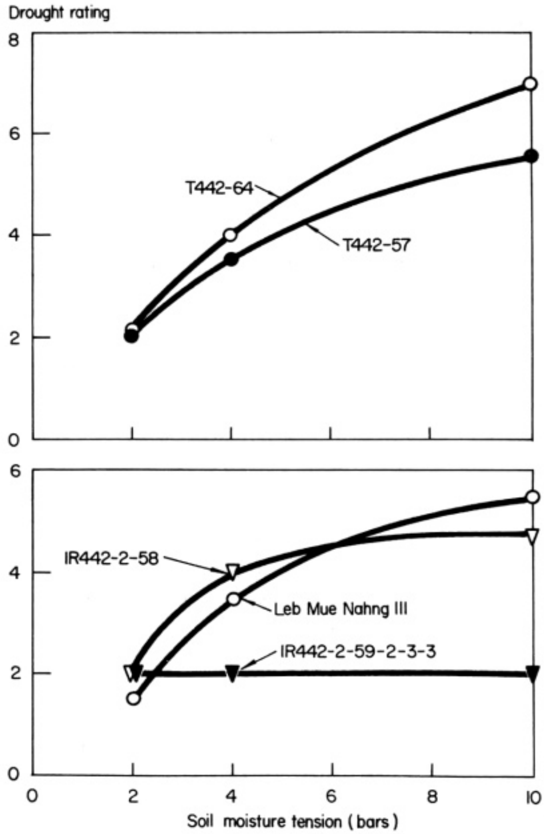
It is interesting to note that many traditional upland varieties with traits associated with drought avoidance (Chang et al., 1972; Yoshida, 1975) appear incapable of tolerating sustained moisture deficits in these test conditions (Table 3). Similar results were obtained with traditional upland varieties in greenhouse tests (Sarkar and De Datta, 1975).

Finally, we carried out tests to determine the effects of seedling age, soil fertility, and several pretreatment factors on the resulting survival percentage. Although the absolute survival percentage could be changed by varying those factors, the ranking among varieties was relatively constant. With this background information, we moved the screening procedure to a greenhouse because of limited space in the phytotron. The sample variance increased slightly, but with strict control of the critical steps in the test and repeated use of a check variety, the results agreed with those obtained in the phytotron.

FIELD SCREENING

Varietal differences in drought tolerance in the dry season were determined through field screening and scoring methods that were developed previously (De Datta and Vicencio, 1976). Tensiometers and gypsum blocks were installed at 10- and 20-cm soil depths to monitor severity of drought.

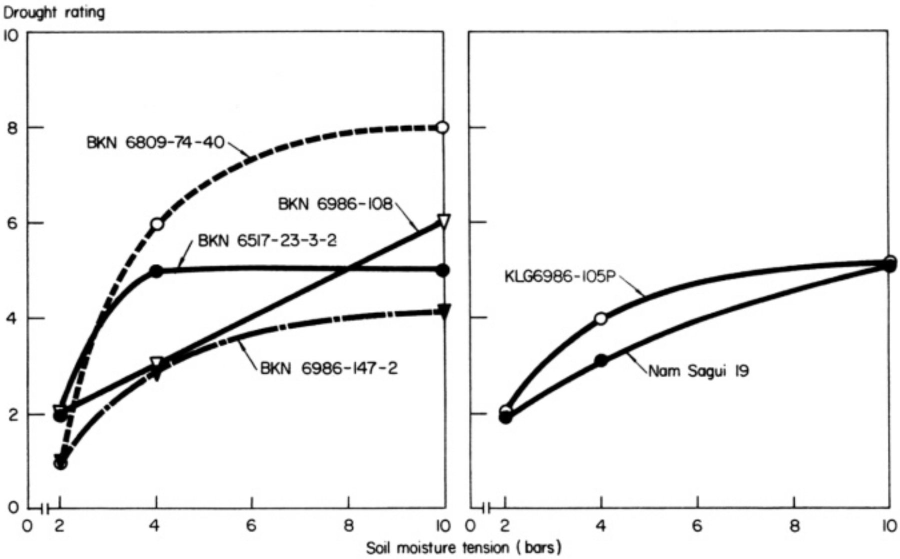
During the 1975 dry season, 1,003 were direct seeded; 1,016 were direct seeded in the 1976 dry season. The area was irrigated to saturation (0 cb) with overhead sprinklers at 3 days after seeding and subsequently at three weekly intervals until the seedlings were fully established. Irrigation water was withheld at 20 days after rice emergence. Soil moisture tension was measured daily. The rices were initially scored



2. Effects of levels of soil moisture tension on reaction to drought stress (1 to 9 scale: 1 = no stress symptoms; 9 = completely dead) during seedling and vegetative stages of field-screened rices. IRRI, 1976 dry season.

for drought tolerance at 49 days after rice emergence (29 days after irrigation water was withheld) using the Standard Evaluation System (SES) for Rice (1 = no symptoms; 9 = dead) (IRRI, 1975b). The growth stages of the lines were noted at scoring time. After moisture tension was relieved by rain or sprinkler irrigation, the rices were scored for recovery with the SES drought tolerance scale (1 = full recovery; 9 = no recovery).

Among the 2,019 rices screened in 2 years, several deep-water rices appeared highly promising. Leb Mue Nahng 111 had scores of 2 at 2 bars and 5 to 6 at 10 bars soil moisture tension, indicating good drought tolerance in field screening and confirming our greenhouse results (Fig. 2). The most outstanding result was obtained with IR442-2-59-2-3-3 which had a stable score of 2 at 2, 4, and 10 bars moisture tension (Fig. 2). It performed better than IR442-2-58 and T442-57 at



3. Effects of levels of soil moisture tension on the reactions to drought stress (1 to 9 scale: 1 = no stress symptoms; 9 = completely dead) during seedling and vegetative stages of field-screened rices. IRRI, 1976 dry season.

both 4 and 10 bars soil moisture tension. The stability of IR442-2-59 makes it useful in incorporating drought tolerance into rices for deep-water and rainfed areas. Nam Sagui 19, a variety grown in drought-prone areas in Thailand, also appeared promising (Fig. 3). The two BKN lines (BKN 6986-108 and BKN 6986-147-2) that performed well in the greenhouse screening also appeared promising in the field screening (Fig. 3).

The results demonstrate that techniques for screening large numbers of deep-water rices for drought tolerance during the seedling and vegetative stages are available. Several traditional deep-water rices and some deep-water semidwarfs showed considerable drought tolerance.

SUMMARY

An early date of seeding is desirable in rainfed deep-water rice areas to insure seedlings of sufficient height and age when elongation is required by rising water levels. However, the erratic onset of monsoon rains and the possibility of subsequent drought increase the farmers' risk associated with early planting. Thus, selection for drought tolerance at the seedling stage has the twofold advantage of increasing the probability of crop establishment and insuring plant survival in deep water.

Greenhouse, phytotron, and field screening techniques were used to identify varietal differences in response to drought at the seedling and vegetative stages.

The results illustrate the large differences among rice germ plasm of varying geographical and hydrological origins. They provide further evidence that drought tolerance and ability to elongate can be incorporated into the same variety. Several traditional varieties of deep-water origin as well as selected hybrids attest to the validity of this concept.

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DISCUSSION

JACKSON: Have you attempted to measure yield of these new lines under drought stress? What effect does drought stress have on elongation?

De Datta: In our field screening for drought tolerance, we did not measure the yielding ability of the varieties and lines. The outstanding drought-tolerant varieties or lines will enter into the International Upland Rice Observational Nursery or International Upland Rice Yield Nursery which would record yielding ability. We did not determine the effects of drought stress on elongation. Dr B.S. Vergara said his initial results indicate that elongating capacity is set back by drought stress.

VERGARA: It is interesting to note that in spite of the large tiller number and presumably large area for transpiration, BKN 6986-147-2 and BKN 6986-108 had relatively good survival under high soil moisture stress. The participants may be interested to know that BKN 6986-147-2 and BKN 6986-108 have shown outstanding performance in the IRDWON. Both lines have long growth durations.

De Datta: Both BKN 6986-147-2 and BKN 6986-108 are moderately tolerant to drought but in field studies BKN 6986-147-2 has higher tolerance than BKN 6986-108. In field screening IR442-2-59-2-3-3 showed outstanding stability under various levels of drought.

SARAN: Have you identified lines which have shown tolerance to both drought and submergence?

De Datta: A number of lines from IR442 crosses have drought tolerance and elongating capacity. Leb Mue Nahng 111 is another example that has both traits.

VERGARA: Do you plan to screen the future IRDWON for drought tolerance at seedling stage?

De Datta: Yes. In addition to IRDWON rices, we hope to screen other advanced breeding lines from various country programs.

Techniques to distinguish floating rice from nonfloating types in seedling stage

K. Hamamura and P. Saengpetch

Deep-water tolerance of rice is regarded as a genetic character that is generally expressed at a certain age, i.e., approximately 1 month after seeding and exposure to deep-water stress.

The authors studied the possibility of detecting elongation ability earlier than 1 month after seeding. They examined the morphological characteristics of young seedlings and, with the use of special techniques, forced potential characters of plants to appear at the seedling stage.

If identification of deep-water plants is possible at the early seedling stage, the technique will be useful, for it employs simple facilities and gives the desired information quickly.

MATERIALS AND METHODS

Most experiments reported here compare several varieties of true deep-water, medium deep-water, and nondeep-water rice forms on morphological bases and response to germination under darkness, deep seeding, soil hilling at the base of plants, and phytohormone treatments. The varieties used are in Table 1.

The morphological traits of 153 varieties were studied to test the reliability of the method for identifying deep-water rice (Table 2).

The seedlings were raised under normal pot culture. Morphological characters were observed when the seedlings were 7 to 10 days old.

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Table 1. Standard varieties used in tests of deep-water tolerance. Bangkhen and Huntra Rice Experiment Stations, Thailand, 1975.

Variety	Origin	Type
Deep Water No. 8	Bangladesh	True deep-water
Leb Mue Nahng 111	Thailand	"
Pin Gaew 56	"	"
Khao Nahng Nuey 11	"	"
Nahng Chalawng	"	"
T442-57	"	Medium deep-water
Tapow Gaew 161	"	"
Nam Sagui 19	"	"
Niaw Sanpatong	"	Nondeep-water
Khao Dawk Mali 105	"	"
Gow Ruang 88	"	"
Nahng Prayah 132	"	"
RD1	"	"
RD4	"	"
RD5	"	"

Table 2. Frequency distribution of length of the second leaf blade of 153 floating and nonfloating varieties of indigenous Thai rice. Bangkhen Rice Experiment Station, Thailand, 1975.

Type of variety	Length (mm) of second leaf blade[a]								Varieties examined (no.)
	20–25	25–30	30–35	35–40	40–45	45–50	50–55	55–60	
Floating rice	1	6	18	28	9	3			65
Nonfloating rice	2	2	7	22	23	24	7	1	88

Chi-square test for homogeneity: $c^2 = 34.24$ d.f. = 15 $P < 0.01$

[a] Measurements were made on 10 plants/variety at 5 days after seeding.

Mesocotyl elongation was observed by germinating seeds in darkness and by deep seeding. The basic assumption was that deep-water rice might have a longer mesocotyl than nondeep-water forms, since the structure of the mesocotyl is similar to that of the internode.

For the deep-seeding treatment, pregerminated seeds were sown 60 mm deep. Deep-water rice was expected to emerge faster and to have a higher emergence percentage than nondeep-water types.

When soil is kept moist and hilled 40 mm above the base of seedlings, internode elongation occurs within 3 weeks. The soil-hilling treatment was based on the assumption that deep-water types will show more internode elongation than nondeep-water forms (Saengpetch and Hamamura, 1975).

Responses to various phytohormones were examined by germinating seeds in test tubes in darkness (Hamamura and Prechachart, 1977).

Table 3. Relation between elongation ability and mesocotyl length after germination in darkness, Huntra and Bangkhen Rice Experiment Stations, Thailand, 1974–75.

Variety	Elongation ability[a]	Mesocotyl length[b] (mm)
Deep Water No. 8	5	5.6
Leb Mue Nahng 111	5	12.4
Pin Gaew 56	5	19.4
Nahng Chalawng	4	1.8
T442-57	3	1.1
Tapow Gaew 161	3	1.8
Nam Sagui 19	3	4.3
Khao Dawk Mali 105	2	4.1
Gow Ruang 88	2	3.1
Nahng Prayah 132	2	4.1
RD1	1	2.2

$r = 0.641$ d.f. = 9 $P < 0.025$

[a] 0 = no elongation; 5 = the best expression of elongation in 150 cm of water. [b] Means of 10 plants after 13 days of germination in darkness.

The relationships among phytohormones, their concentrations, rice varieties, and anatomy of seedlings are still under investigation.

RESULTS

A few typical results are in the appended tables and figures.

Morphological characters of seedlings. The length of the second leaf blade differed in the deep-water and nondeep-water types. Deep-water types had shorter second leaf blades. The finding was confirmed by examination of an indigenous Thai rice variety (Table 2) (Hamamura and Prechachart, 1975). When the ratios of second leaf blade to second leaf sheath were calculated, those for most deep-water forms were found to be less than 1.00.

Mesocotyl elongation. The mesocotyl length varied greatly, depending on the particular experiment. It was not necessarily related to variety. It appeared to be strongly influenced by the volume of the container used for testing and by individual properties of seeds, such as age and water content. In general, the relation between known floating ability and mesocotyl elongation was not clear, but some association appeared between elongation ability and mesocotyl length (Table 3,4) in germination tests in darkness and in deep seeding.

Deep seeding. Deep-water tolerance was strongly associated with percentage of emergence from deep seeding (Table 5). The difficulty in such a test was controlling excess soil moisture covering the seeds,

Table 4. Relation between deep-water tolerance and mesocotyl elongation after deep seeding. Huntra and Bangkhen Rice Experiment Stations, Thailand, 1974–75.

Variety	Deep-water tolerance[a]	Mesocotyl length[b] (mm)
Deep Water No. 8	5	24
Leb Mue Nahng 111	5	23
Pin Gaew 56	5	20
Khao Nahng Nuey 11	5	16
Nahng Chalawng	4	19
T442-57	3	12
Tapow Gaew 161	3	15
Niaw Sanpatong	2	13
RD4	1	14

$r = 0.765$ d.f. = 7 $P < 0.010$

[a] 0 = no elongation; 5 = the best expression of elongation in 150 cm of water. [b] Means of 10 plants or fewer that emerged from soil depth of 45 mm.

which can reduce emergence. Thus, special techniques have to be devised by breeders who wish to screen varieties or lines by such a test.

Soil-hilling treatment. Deep-water tolerance was reflected in long internodes after the soil was hilled up at the base of the plants (Fig. 1). The control plants showed little or no internode elongation.

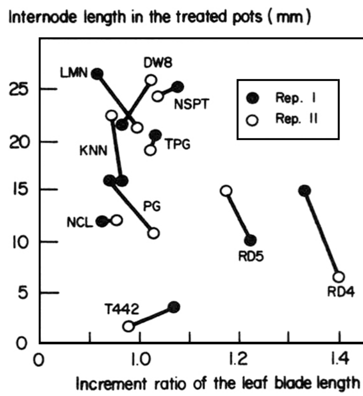
The control plants and those in treated pots planted to nondeep-water varieties differed. The difference was especially noticeable in the longer seventh, eighth, and ninth leaves in the treated pots. Such expression was not noticeable in the deep-water types. Consequently, both internode elongation and increment of leaf blade lengths (7th,

Table 5. Relation between deep-water tolerance and number of seedlings that emerged at soil depth of 60 mm. Bangkhen Rice Experiment Station, Thailand, 1975.

Variety	Elongation score [a] in pond tests	Plants that emerged (no.)
Deep Water No. 8	5	10
Leb Mue Nahng 111	5	10
Khao Nahng Nuey 11	5	9
Pin Gaew 56	5	6
Nahng Chalawng	4	5
T442-57	3	0
Tapow Gaew 161	3	5
Khao Dawk Mali 105	2	0
Nahng Prayah 132	2	0
RD1	1	0

$r = 0.904$ d.f. = 8 $P < 0.0005$

[a] Based on a scale of 1 to 5: 1 = little or no elongation ability; 5 = the best expression of elongation. Ten pregerminated seeds per variety were sown.



1. Internode elongation and increase of leaf blade length after hilling up of soil. Four cm of soil was put around the base of each treated plant at 10 days of age. Five weeks after treatment, the lengths of the fourth and fifth internodes and of the seventh to ninth leaves in both treated and control pots were measured.

8th, and 9th leaves) were used as criteria for separating deep-water from nondeep-water forms.

In Figure 1, both internode elongation (I) and increment of leaf blade length (ΔLB) are combined in one diagram. Deep-water types tended to locate in the area of long I and small ΔLB, whereas nondeep-water types were generally confined to the area of short I and large ΔLB.

Phytohormone experiments. The results of treating germinating seeds with gibberellic acid (GA), abscisic acid (ABA), and ethrel are in Table 6.

Gibberellic acid caused the first and second internodes, leaf sheaths,

Table 6. Effects of phytohormones on seedling characters of floating and non-floating rice varieties under controlled conditions.[a] Bangkhen Rice Experiment Station, Thailand, 1975.

Seedling character	Phytohormone treatments			
	Water (control)	GA_3 (10 ppm)	ABA (1 ppm)	Ethrel (100 ppm)
Root length (mm)	70.8	46.1	45.7	31.5
Roots (no.)	6.3	6.1	6.8	8.3
Mesocotyl length (mm)	5.4	15.2	9.7	4.7
Coleoptile length (mm)	33.4	38.9	28.4	34.0
First internode length (mm)	2.0	6.9	5.0	1.7
Length of first leaf (mm)	47.0	80.3	37.9	44.7
Length of second internode(mm)	18.5	73.3	38.2	10.6
Length of second leaf sheath (mm)	62.6	69.4	44.0	72.7
Length of second leaf blade (mm)	56.9	97.3	41.0	35.9
Leaves (no.)	1.8	1.7	1.9	2.3

[a] Measurements were made 13 days after germination in airtight test tubes in darkness. Data represent av. of 11 varieties, each having 10 plants. Ethrel releases ethylene gas when the pH of the solution reaches 4; however, pH was not adjusted in this experiment.

and blades to lengthen. The addition of ABA produced longer internodes, but shorter leaf sheaths and blades than in the control. Presumably, the combination of GA and ABA was responsible for internode elongation. Ethrel appeared to have an inhibitory effect in most cases, but its action could not be clearly defined in this experiment. We did not include the possible role of other regulators such as indoleacetic acid (IAA) and gibberellin-like substances as reported by Yamada (1954) and Yamaguchi (1974), respectively.

CONCLUSIONS

Takahashi et al. (1974) showed that GA_3 caused longer second internodes, second leaf sheaths, and blades of a Japanese rice. ABA produced longer second internodes but shorter second leaf sheaths and blades.

From these results, the authors postulated that deep-water rice has, or produces after certain stresses, relatively large amounts of GA and ABA. As a consequence, it produces long internodes, and short leaf sheaths and blades. Most results presented in this paper can be explained by this hypothesis.

The authors regard the soil-hilling treatment as the most reliable method at present to identify deep-water types, although it is mostly applicable to true breeding lines and varieties. For individual plant selection, the deep-seeding method may be the most practical.

Observation of the length of the second leaf blade and mesocotyl elongation has certain defects. For instance, it is difficult to distinguish deep-water types from nondeep-water dwarfs by the length of the second leaf blade since the latter also tend to have short second leaf blades. However, these methods may be useful to supplement the main test. Inouye and Xuan (1973) indicated difficulty in using mesocotyl elongation as a criterion to distinguish floating from nonfloating types more precisely.

SUMMARY

A deep-water rice plant may be distinguished by 1) its short second leaf blade, 2) rapid emergence from deep soil, 3) long mesocotyl from germination under darkness or deep seeding, and 4) long internodes with less lengthening of leaf blade after the soil is hilled up at the base of the plant.

These properties may be due to the relatively high contents of abscisic acid (ABA) and gibberellic acid (GA)—both major phytohormones in plants—and may explain the physiological basis of deep-water tolerance.

ACKNOWLEDGEMENT

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DISCUSSION

VERGARA : I think deep seeding has potentials in screening floating varieties. We will try it at IRRI. Is the second leaf blade the third leaf? Was the second leaf blade fully mature when you measured it? Five days after seeding?

Hamamura: I counted, in order from the base, the coleoptile, the first leaf, and the second leaf, so the second leaf here was the first leaf which had both complete leaf blade and leaf sheath. When comparison was made of the second leaf blade at 5 and 21 days of age in a preliminary test, most varieties showed no increase between the periods. Although 5 days was not enough to obtain a fully mature second leaf, this age was adopted for measurement to make the successive soil-hilling treatment as early as possible.

JACKSON: Do you consider the techniques used in your studies to have a practical application to selection for elongation ability?

Hamamura: The results are in the preliminary stage and further examinations may be necessary to obtain reliability of practical value. Correlations between the results of these tests and those of the deep-water pond tests, using hybrid populations, are needed.

HILLERISLAMBERS: I notice in Table 5 that T442–57 gives zero emergence. That means the test of seedling emergence would not be able to point out T442–57 as a line with elongation ability better than that of RD1; hence that would give problems in testing of lines in a breeding program. Would you recommend this test for evaluation of parental varieties rather than segregating lines?

Hamamura: I cannot give a conclusive score of emergence for T442–57 because the test is not replicated many times. But from my impression, T442–57 has somewhat less internode elongation and is rather close to the semidwarf parent in the early seedling stage.

NASIRUDDIN: Typical upland aus varieties of Bangladesh have more or less the same characteristics that you mentioned in your summary to distinguish floating from nonfloating types. It would be better if you could include typical upland varieties in your experiment.

Hamamura: I noticed quite a conspicuous internode elongation after soil hilling for the Bangladesh deep-water varieties. A paper on the difference between Thai and Bangladesh varieties of deep-water rice will appear next year in the Japanese Journal of Breeding 27(3).

Screening for submergence tolerance using a deep-water pond

C. Boonwite, C. Setabutara, B.R. Jackson,
C. Prechachart, and P. Anugul

During the monsoon season in Southeast Asia, the rice crop is frequently inundated for 1 to 30 days at varying stages of growth. Rice varieties that can withstand submergence—whether the water recedes immediately (1 to 10 days) or remains at a high level for much longer periods (30 to 90 days), as in the floating rice areas—can greatly reduce losses from flood.

A method for screening varieties tolerant to submergence has been reported by Vergara and Mazaredo (1975). However, their technique requires water tanks with special temperature and light controls, facilities that may not be readily available at experiment stations in Asia. Although the method is rapid, only a limited number of lines can be screened at one time. Furthermore, as a laboratory method, its conditions may not correspond to those encountered in nature. Therefore, information obtained under field conditions is needed to assess the merits of the laboratory method and to identify promising lines.

This paper discusses the results of screening lines at the seedling stage, when water recedes a few days after the plants are completely submerged. Other pertinent findings are the ability of certain lines to rapidly emerge through water—a desirable characteristic where the water does not recede quickly, as in floating and stagnant water areas—and elongation ability following submergence and recovery.

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MATERIALS AND METHODS

Three submergence tests were conducted in 1975 at the Klong Luang Rice Experiment Station, Thailand, with 50 entries per test: 43 deep water-tolerant hybrid lines from the crosses IR262/Pin Gaew and IR262/Khao Nahng Nuey 11, and seven check varieties. Both Pin Gaew 56 and Khao Nahng Nuey 11 parents are recommended Thai floating varieties capable of surviving water depths of 400 cm under natural conditions. The hybrid lines were previously selected for deep-water elongation ability and good plant type. The same deep-water pond was used for the tests, but each test is described separately because of its distinctiveness.

Test 1. Twenty pregerminated seeds of each entry were directly planted in single-row plots in a deep-water pond. The test used a randomized complete block design with four replications. At 13 days of age, the seedlings were covered with 45 cm of water for 7 days. On the 8th day the pond was drained, and plant recovery was observed. After a 7-day recovery period, the surviving plants (28 days of age) were resubmerged to a 100-cm depth for 6 days. Then the water level was lowered to 70 cm because the 100-cm depth was considered too severe. The water was kept at 70 cm for 11 days, then the pond was drained. The plants were allowed to recover for 10 days before survival percentage was recorded.

Test 2. Ten-day-old seedlings of each entry were covered with 70 cm of water for 5 days. On the 6th day the pond was drained; survival percentage was observed 10 days later. Since very few lines showed severe damage, the plants were resubmerged in 50 cm of water for 9 days. On the 10th day, observations on survival percentage were recorded. During the test, water temperature averaged about 30°C with a 2-degree fluctuation.

Test 3. The number of entries, experimental design, planting method and plot size were the same as those used in previous tests. The nature of the material was changed to include 17 entries selected for deep-water tolerance in Thailand, plus 29 IRRI lines selected for resistance to submergence. Four check varieties brought the entries to 50. Two checks were considered poor in tolerance to submergence; two were previously rated as good. The 10-day-old seedlings were submerged in 50 cm of water for 8 days, as is practiced in IRRI submergence tests (Vergara and Mazaredo, 1975).

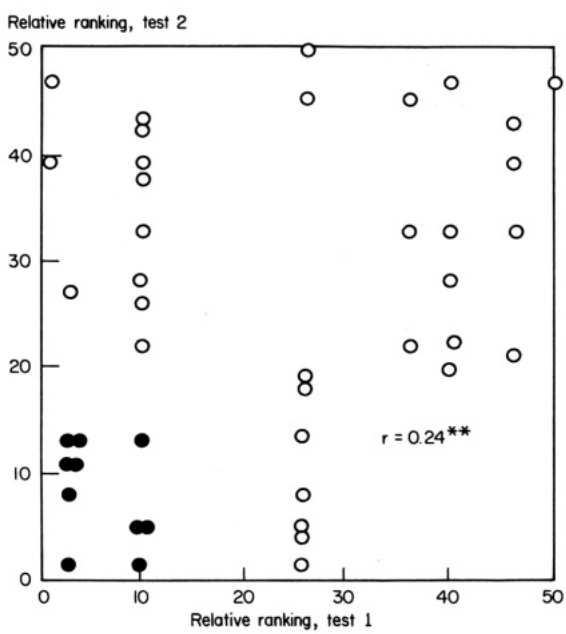
Seedling height, percentage of plants that emerged through the water, and rapidity of emergence were recorded. Nam Sagui 19 served as the principal check as it is the standard for evaluating submergence both in Thailand and at IRRI. Its ability to emerge through water in the seedling stage was first noted by Weerapat and Waraniman (1974).

RESULTS AND DISCUSSION

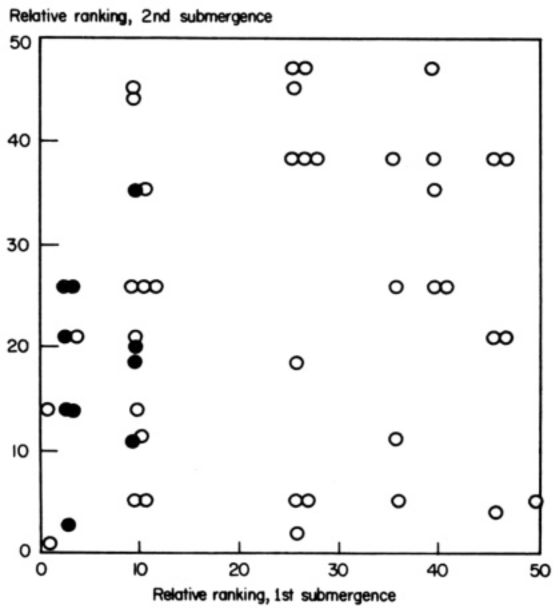
The breeding lines in Tests 1 and 2 had low correlation values that are, however, highly significant (Fig. 1). The results suggest that changes in growing conditions in Tests 1 and 2, both before and during submergence, greatly affected the relative rate of survival.

Under field conditions, flooding or submergence of the rice plant can occur at different possible times, depths, and durations. Screening for flood-tolerant lines under varying conditions is therefore desirable.

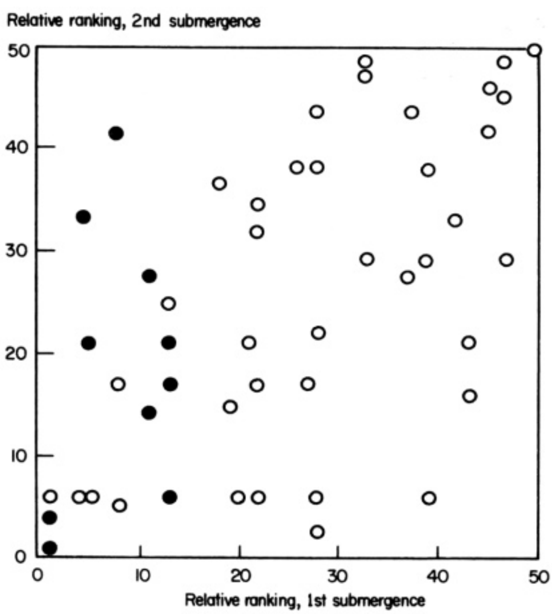
Even though the correlation (r = 0.24) between Test 1 and Test 2 was low, 10 good lines in Test 1 also showed acceptable performance in Test 2 (Fig. 1). That indicates that flood-tolerant lines can be selected under the conditions of the two tests. Thus, screening for flood tolerance under field conditions is possible. However, such a method can identify promising lines only under a given set of conditions, and may not give results strictly comparable with those of other breeders.



1. Recoverability ranking of 50 entries grown in submergence Tests 1 and 2. Klong Luang Rice Experiment Station, 1975. (Black dots indicate plants that showed good survival in both tests.)



2a. Recoverability ranking of 50 entries in Test 1 when submerged twice. Klong Luang Rice Experiment Station, 1975. (Black dots indicate plants that showed good survival in Tests 1 and 2.)



2b. Recoverability ranking of 50 entries in Test 2 when submerged twice. Klong Luang Rice Experiment Station, 1975. (Black dots indicate good survival in Tests 1 and 2.)

The erratic performance of the 40 other entries can be attributed to environmental variability. Basic studies on flood tolerance of rice seedlings have shown that plant age, water depth, duration of submergence, water turbidity or light intensity, water temperature, and nitrogen and carbohydrate content of the plant can affect submergence tolerance (Palada and Vergara, 1972). With all those factors affecting the tests, lines with good tolerance can be expected to possess several desirable characters associated with good flood tolerance. Possibly the 10 lines identified in the present tests have some of each characteristic necessary to overcome the effects of flooding.

Retesting the best lines for submergence may further eliminate those with fewer desirable characteristics necessary for flood tolerance (Vergara and Mazaredo, 1975). To test this hypothesis, the plants that survived both Tests 1 and 2 were resubmerged for periods from 9 to 17 days. Resubmergence after recovery eliminated 4 to 5 of the 10 best lines (Fig. 2a, b). That suggests that survival after initial recovery is different from that after resubmergence. Subjecting the lines to two independent tests for submergence tolerance appears to be a better procedure.

In the two screening tests, the following proved highly tolerant of submergence:

Line	Cross
BKN 6986-42	IR262 × Pin Gaew 56
-58	”
-108	”
BKN 6987P-42-4	IR262 × Khao Nahng Nuey 11
-107-3	”

In Test 3, 10 of the 29 lines that had shown good submergence tolerance at IRRI were among the top 15; most had poor elongation ability, although two had an elongation score of 3 (Table 1). The remaining IRRI lines had relatively poor submergence tolerance but generally good elongation scores. The finding agrees with that of Vergara and Mazaredo (1975) that elongation ability and submergence tolerance are separate characteristics, for most floating rice varieties thus far tested have poor submergence tolerance. Recent field observations in West Bengal, India, also showed that floating rice varieties generally had poor submergence tolerance (B.R. Jackson, personal communication). The observation is supported by research conducted by Jailuek (1975).

Recovery from submergence, whether 4 or 10 days after flooding, did not depend on original plant height nor on ability to emerge from the water (Table 1). The increase in plant height may be detrimental

Table 1. Some characteristics of lines from the third submergence test. Klong Luang Rice Experiment Station, Thailand, 1975.

Selection, check	Height[a] (cm)	Emergence through water			Survival recoverability[c]		Height[d] (cm)	Elongation score[e]
		4th day (%)	8th day[b] (%)	Rank	%	rank		
Selection								
KLG6987-118-3P	21	1	62	20.5	92	1	72	0
KLG6987-223-2P	23	0	34	44	90	2	73	1
KLG6986-133-4P	17	0	4	49	87	3	66	0
KLG6986-146-5P	16	0	2	50	85	4	71	0
BKN 6986-108	20	3	48	30	84	5	86	3
KLG6986 - 105P	20	18	61	22.5	77	12.5	78	2
-160P	22	6	67	16.5	77	12.5	80	3
KLG987-32-3P	26	67	83	3	65	27.5	105	4
-171-2P	21	44	82	4	63	32	102	5
-191P	21	36	79	6	34	48.5	92	4
Check								
Nam Sagui 19	23	60	88	1	68	24.5	96	3
T442-57	20	8	60	24.5	66	26	80	3
Anlong Phuom #4	22	27	60	24.5	42	45	111	5

[a] At 9 days age prior to submergence. [b] Eight days after submergence. [c] Percent of original planting that survived submergence and had regrowth 10 days after removal of water. [d] At 48 days of age following recovery 30 days after submergence. [e] 0 = no elongation; 1 = elongation similar to RD1; 2 = better than RD1 but poorer than T442-57; 3 = similar to T442-57; 4 = better than T442-57 but poorer than PG 56; and 5 = elongation similar to that of PG 56. Surviving plants had water added at rate of 10 cm/day to a depth of 100 cm.

since the culm and leaf sheaths tend to be long and weak. When the water recedes, the seedlings lodge and sometimes stick to the mud. Plants that do not elongate are sturdier and remain erect as the water recedes.

In deep-water rice areas where water rises abruptly and plants are submerged, a different type of tolerance is needed. The plant should be able to withstand submergence and at the same time rapidly elongate above water that will not quickly recede. This type of tolerance that is found in Nam Sagui 19 may be closely associated with its ability to elongate the leaf sheaths and blades.

The test described in this paper can be easily modified by changing the age of the seedlings, and the duration and depth of submergence. Changing these parameters allows approximation of the conditions that plants are subjected to in the particular area where they are utilized.

SUMMARY

A field method for screening rice breeding lines or varieties for tolerance to submergence is presented. Twenty pregerminated seeds of each entry were directly planted in single rows in a pond. At 7 to 13 days of age, the seedlings were completely covered with 45 to 70 cm of water for 5 to 7 days. Seven days after the pond was drained, the lines were scored for recovery, with the number of plants with green leaves as basis for computing survival percentage or recovery.

The lines were ranked according to survival percentage. The best ones in the first test were also best in the second test where treatments were slightly different. It is suggested that lines screened for submergence should be independently tested twice to obtain more reliable information.

Lines that were consistently tolerant to submergence in this study are:

BKN 6986-42, BKN 6986-58, BKN 6986-108, BKN 6987P-42-4, BKN 6987-107-3, BKN 6987-92-2, BKN 6987-161-6, BKN 7022-52, BKN 7021-85, BKN 7022-6, KLG6987-118-3P, KLG6987-223-2P, KLG6987-133-4P, KLG6986-146-5P, KLG6986-105P, and KLG6986-160P.

Lines showing tolerance to submergence generally had poor elongation ability. That suggests that elongation is not a necessary character in areas where water recedes after a few days.

The method is rapid and allows screening of large numbers of lines at one time in a pond of appropriate size.

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DISCUSSION

SUBIYANTO: Would it be possible to find a particular line or variety with both tolerance of submergence and ability to elongate?

Boonwite: Yes. The hybrid deep water-tolerant line BKN 6986–108 is also tolerant of submergence.

SIWI: What is the relation between submergence tolerance and elongation ability?

Boonwite: We do not know the exact relation between submergence tolerance and elongation ability. From the three tests we found that some lines, such as BKN 6986–108, had good submergence tolerance and slightly good elongation. But most floating rices had poor submergence tolerance.

Screening for rapid elongation ability in small water tank

A. Mazaredo and B.S. Vergara

Rice varieties differ in their ability to elongate above the water level as expressed in both length of individual internodes and number of elongated internodes. Their survival in areas where floodwater exceeds 50 cm and stays in the field for more than 1 month greatly depends on their ability to stay above water, mainly through internode elongation.

In the deep-water areas, the water level usually begins to rise when the plants are 6 weeks old. A rapid increase in water depth before this time kills most plants. Since most varieties can elongate only after 6 weeks of growth, plants for internode elongation tests should be at least 6 weeks old.

A convenient test for elongation ability is needed to breed better varieties for deep-water areas. In the absence of complex facilities, plants can be tested in a small water tank.

MATERIALS AND METHODS

The screening involved 573 rice varieties or lines in a 100-cm-deep water tank. Leb Mue Nahng 111 was included in all tests for comparison.

Two grams of seeds of each variety were washed thoroughly in several changes of water; seeds that floated were discarded. The clean seeds were then soaked for 24 hours. After soaking they were thoroughly washed, drained, and covered with wet tissue. They were incubated for 24 hours at 30°C.

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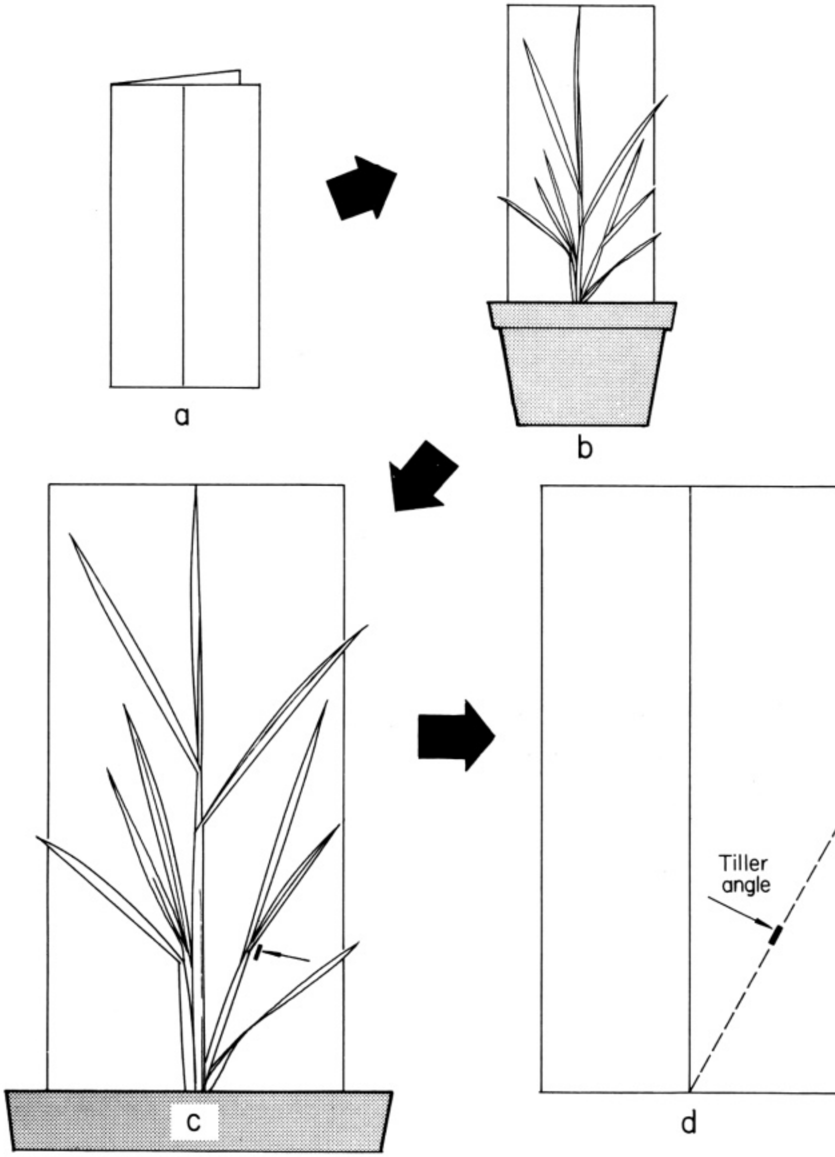

1. Measuring tiller angle. a) Fold a sheet of typing paper lengthwise and draw a vertical line in the center of one side. b) Align the base of the line with the base of the plant's main culm. c) Mark on the paper a point beside the first primary tiller farthest from the main culm. d) Draw a line from the base through the mark to show the tiller angle.

Four grams ammonium sulfate (21% N), 2 g muriate of potash (60% K_2O), and 2 g solophos (20% P_2O_5) were thoroughly mixed with 4 kg of fine-textured soil. The soil mixture was placed in 4-liter plastic pots, with the bottom holes uncovered. The pots were watered until water flowed out of the holes. Five pots were used for each variety; four seeds were planted in each pot.

The plants were grown in the greenhouse, with a photoperiod ranging from 16 to 24 hours to prevent panicle initiation before the test started. Plants grown during the summer months did not need artificially extended photoperiods.

Ten days after seeding (DS), the seedlings were culled to leave the two healthiest in each pot. The angle of the first tiller of each plant was measured 32 DS by the method illustrated in Figure 1. At 39 DS, plant height was measured, the tillers were counted, and the pots were randomly arranged in the deep-water tank with 30 cm water above them.

At 40 DS, the water depth was increased by 30 cm. At 41 DS the tank was filled to a 100-cm depth. At 47 DS the tank was drained and the internode on the main culm was measured.

The following scoring system was used in reporting elongation ability :

Score	*Elongation ability*
1	Internodes are 60 cm and longer
3	40 to 59 cm
5	20 to 39 cm
7	1 to 19 cm
9	No elongation, plants are dead.

ADDITIONAL INFORMATION

The varieties in Tables 1 and 2 showed rapid internode elongation. Khama 380, which is short, has erect tillers, a relatively large number of tillers, and good internode elongation.

Even when not submerged, rice can elongate in the internodes, especially at panicle initiation. Care must be taken that the variety is not tested in the reproductive stage, since internode elongation will occur regardless of the water treatment.

Very slow increase of water depth can cause most varieties to elongate. This particular test screens for rapid internode elongation with a rapid increase in water depth.

Elongation of leaf sheaths and leaf blades causes the plants to emerge faster from the water. Faster emergence helps the plants to survive. Elongation of only the leaf sheaths (no internodes) of 2- to 3-week-old plants may be advantageous, but the resulting plants are generally weak

Table 1. Varieties (out of 573 screened) with rapid internode elongation.[a] August 1975.

Variety	Tiller angle (°)	Plant ht (cm)	Tillers (no.)
Aswina	20	111	7
Badal 106	23	107	3
Badat 672/2	28	99	4
Bawoi Jhak	24	110	7
Bhoro Diga	24	92	3
Dholamon 39/3	19	82	5
Dholamon 51/1	22	80	5
Dholamon 64/3	19	81	5
Fulkari 368	30	86	4
Fulkari 715	30	97	4
Gowai 38/13	20	85	5
Gowai 50/9	24	79	5
Gowai 84	20	79	6
Gowai 476	21	77	6
Habiganj Deep Water 1	23	109	6
Hybrid 10/1	20	89	4
Kalamon 21/7	21	76	4
Kalamon 113	18	75	4
Kalamon 243	15	75	4
Kalimekri 77/5 (6527)	20	103	3
Kalimekri 391	19	90	4
Karkati 87	14	108	3
Khama 49/2	20	92	4
Khama 49/8	18	92	4
Khama 55/22	16	78	6
Khama 380	20	84	8
Laki 192	27	137	6
Laki 491	31	118	6
Laki 544	23	120	5
Lal Amon	18	128	6
Matia Amon	17	95	–
Matiamon 73/23	19	122	7
Rayada R16-10	31	90	–
Shuli (26527)	26	103	–
Sungwala	24	108	–

[a] All from Bangladesh. Varieties from Thailand, India, Cambodia, and Vietnam showed poorer elongation ability than did the Bangladesh varieties. Plants were grown inside the greenhouse; tiller angle was measured on the 35th day; plant height and tiller number were taken on the 42nd day.

and eventually die if the water level remains at 100 cm for more than 10 days.

If possible, the researcher should measure not only the internodes but also the angle and number of tillers of most deep-water rice varieties when screening for rapid internode elongation.

Table 2. Varieties (out of 197 entries) with rapid rate of elongation.[a] September 1976.

Variety	Tiller angle (°)	Plant ht (cm)	Tillers (no.)
Ban-Oh	18	97	10
Banto	29	112	9
Bir-Co-Shoa-Yen-Tsan	19	97	21
Bir-Fan-Goo	29	106	15
Bir-Hsu-Tsu-1	29	104	18
Cau-Sow-Daw	26	94	10
Chan Chu Cho	21	85	12
Ching Kao Chan	34	107	11
Dhola Saitha 363-726DA30	25	81	11
Eun-Chwan-Sa-Tiao-Z	23	85	11
Funchow-Thou	32	98	14
G-Qua-Shun	25	87	19
Hsin-Huan-Thou	31	88	20
Hsu-Dau-Sen-Tsan	28	117	11
Kendal Mordo	21	83	13
Kit Min	32	97	14
Kogbati 3	34	79	15
Lao Shu Ya	36	99	14
Lit-S-Thou	34	101	22
Lung-An-Shuang-Chiang Pai	20	91	20
N.A.R.B. White Rice	30	97	13
Nen-Oh	21	104	18
Os Wied	23	96	14
PI 161053-2	27	111	11
Si-Li-Ku	29	84	17
Thou-46-16	20	103	15
Thou-Dau-Bir-Goo	22	105	13
Thou-Hsu-Dau	24	94	20

[a] Plants were grown outside the greenhouse; tiller angle was measured on the 35th day of the test; plant height and tiller number were taken on the 42nd day of test.

DISCUSSION

OHTA: I propose that we establish an international scoring system for elongation ability. Two different systems were reported in this workshop: one by Dr. HilleRis-Lambers et al. and Dr. Ohta et al., and one by Miss Mazaredo and Dr. Vergara.

Vergara: In this connection, we would like the following scientists to work on a scoring method acceptable to all deep-water rice workers: Mr. Ohn Kyaw, Dr. M.S. Ahmed, Dr. S.K. De Datta, Dr. R. Subiyanto, Dr. D. HilleRisLambers, Dr. Y. Ohta, and Mr. N. Supapoj.

SUBIYANTO: Certain varieties can elongate earlier than others. How would you minimize the effect of the time the water level begins to rise on the varietal differences in elongation time?

Mazaredo: Water level was increased only after 6 weeks of growth; the tested varieties had sufficient vegetative growth. If the water depth is increased 4 weeks after sowing. some varieties with good elongation ability, like Leb Mue Nahng 111, will have very poor internode elongation and would therefore be considered a poor elongator.

Screening rice for elongation ability in large deep-water ponds at the Huntra Experiment Station in Thailand

S. Sophonsakulkaew, S. Karin, N. Supapoj, and K. Kupkanchanakul

Local deep-water rice varieties generally differ from ordinary varieties, not only in their elongation ability but also in their long, narrow, light green leaves, weak straw, spreading bases, and low tillering. These traits also are believed to prevent current deep-water rice varieties from producing high yields. Higher yielding forms that have short or intermediate stature are being crossed with deep-water varieties to help solve the problem.

A suitable method for screening for elongation ability under controlled conditions is required to successfully select plants with good elongation ability, good plant type, and high yield.

The information here represents continuous elongation testing since 1968. The first sound basis for this testing was reported by Yantasast (1971), who used T442 lines and established that elongation genes could be successfully transferred from floating rices to dwarf types. Setabutara et al. (1975) modified the scoring for their test.

FACILITIES AT HUNTRA

Experiments are conducted in 16 deep-water ponds at the Huntra Station (Fig. 1). The ponds are located near a water reservoir, free from shading trees, and at an elevation that ensures drainage.

Laboratory and seed-storage facilities are adjacent to the ponds.

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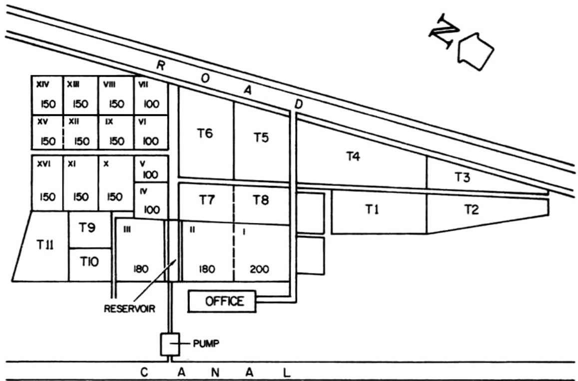

1. Sixteen deep-water ponds, occupying 1.7 ha, and their maximum sustainable water depths (cm). Eleven rice fields, T1-T11, occupy 1.7 ha and have water control up to 50 cm deep. Fifty hectares of rice fields across the road are subject to natural flooding. Huntra Rice Experiment Station, Ayutthaya.

Pond description. The pond sizes vary from 20 × 20 m to 40 × 40 m to accommodate different-size experiments. Maximum water depths vary from 2 to 3 m. The ponds are separated by dikes at least 1.5 m wide at the top, 5 m at the base, with side slopes 45 to 60° from horizontal. The soil contains sufficient clay to hold water.

The ponds were dug from the higher elevation sites. The fertile layer of soil was deeper than the ponds, so topsoil did not have to be removed and replaced.

Water supply and pumps. The ponds have concrete drain pipes approximately 15 cm in diameter, located 10 cm above the bottom. The drains slope about 10° to prevent blockage from soil settling in the drain. Mobile pumps are used if drainage is too slow.

The main water supply is natural; it is pumped from the canal to the reservoir, then supplied to the ponds and fields. The reservoir helps assure a constant supply of water. During natural flooding, water is pumped from outlying fields. Floodwater is much less turbid than canal water and allows observation of plants under water.

Maintenance of dikes. Pressure on the dikes can be very strong when the ponds are full. That is why the ponds cannot be filled to the top. To prevent erosion, the dikes must have slopes that are not too steep. Some grass should be allowed to grow on the upper slopes.

Huntra Station employs about 15 people to maintain the ponds and to repair them once or twice a year.

Assessment of facilities. The Huntra setup works well, but it should not be blindly copied. Drainage and water supply are felt to be a major problem. If facilities were being built anew, each pond should have direct access to water sources and drains, instead of relying on water pumped via adjacent ponds. In places where wages are high, the large labor requirement may make permanent reinforcement of dikes a better solution.

Artificial testing conditions were created because natural flooding at the station does not allow control of the water level. Lack of water level control may result in the inability to screen in years of modest natural flooding, or in the destruction of a whole nursery of valuable and irreplaceable breeding materials in years of extraordinary flooding. Ponds with water control allow breeders to subject to low water stress materials intended for areas with modest flooding, and to test other materials in appropriately deep water. In addition, the ponds allow testing during the dry season.

TESTING METHODS

Different testing methods have been tried through the years and modifications were made not only on the scoring system but in the culture of the plants before treatment.

Planting methods. Direct seeded or transplanted plants can be tested for elongation ability. The choice of planting method depends upon convenience.

Direct seeding. Five grams of pregerminated seeds, previously soaked for 12 hours and incubated for 24 hours, are planted in a seedbed. Seedling rows are 125 cm long. The seedbed is prepared wet like that used for growing seedlings before transplanting. It is kept moist by water sprinkled two to three times a day for approximately 5 days until the seedlings become established. At 30 days after seeding, the water level is raised.

Transplanting. Fifteen- to 20-day-old seedlings are transplanted in 125-cm rows. They are kept 10 cm apart within rows, and are allowed to grow for 2 weeks after transplanting before the water depth is increased.

Observations before increasing water depth. Since most farmers transplant 30-day-old seedlings, height measurements are taken at this age, just before the water depth is increased. Jaileuk (1975) showed that the greatest expression of superior seedling height in floating rice occurs

Table 1. Scoring system for elongation performance of deep-water rice as used in Thailand since 1974.

Elongation rating	Description of elongation performance
1	Similar to RD1
2	Better than RD1 but poorer than T442-57
3	Similar to T442-57
4	Better than T442-57 but poorer than PG 56
5	Similar to PG 56

after seedlings reach 30 days of age. Plant heights are measured at two locations in each plot, one near the front and one in the middle, and the average of the two readings is taken.

Percentage of stand at 30 days of age is recorded for plots with 80% or less stand. The percentage is estimated visually and then given at intervals of 20 percentage points.

Schedule of increasing water depth. The water depth is first increased at 30 days for direct-seeded plots, and at 30 to 35 days for transplated materials. The water is increased first to a depth of 25 cm. The depth is increased at the rate of 10 cm every other day until the desired final depth is reached.

Scoring and check varieties. The varieties RD1, T442-57, and Pin Gaew 56 are planted every 20 rows as checks. Reliable information on their performance has been gathered from many tests. The system given in Table 1 has been used since scoring was started in 1974. More study is required to identify suitable check varieties for the 2, 4, and ratings above 5.

Optimal stages for elongation scoring. The frequency of observations on elongation ability depends on the objectives of the experiment. For F_3 breeding materials, only one observation is usually made at a water level where the nonfloating check RD1 is completely submerged, but usually before T442-57 is under water.

For other experiments and for varieties or stable lines, more observations are often desired. Key stages are

1. When the RD1 check is completely covered with water (The water depth at which this occurs is around 90 cm depending on the season. RD1 shows greater tolerance for flooding in the dry season.)
2. When the T442-57 check is getting covered with water
3. When the desired maximum or possible water depth is reached

In experiments to segregate lines for elongation, the percentage of stand must be recorded when elongation is scored.

The maximum water depth is maintained for about 2 weeks to accurately rate each line and permit formation of nodal roots in case some materials are transplanted. Usually lines that perform like or better than T442-57 are collected for transplanting into shallow-water conditions (under 50 cm). The top parts of the plant (cut at the second node from the top) are allowed to grow into normal plants. After this step, some selection on plant type, resistance to pests and diseases, duration to flowering and so on, is done before harvesting for the next generation.

PROPOSED SCALE

The scoring system described in Table 1 continues to be used although several scales have been developed. The proposed scale is biological; its points of reference are the three varieties and their elongation performances.

It is impractical in a breeding program to subject lines to three different rates of water increase concurrently. At Huntra testing is done only at depth scales of 6, 7, and 8. Table 2 reproduces two scales from the Standard Evaluation System of Rice, published by the International Rice Research Institute (IRRI). The water-depth scale expresses adaptation to the maximum water depth at which the variety can be grown, and the rate of elongation expresses the amount of elongation per day. The two scales are felt to be more appropriate in characterizing established varieties and stable lines if enough ponds are available for simultaneous testing at more than one water depth and at more than one rate of water increase.

More check varieties are needed at times to obtain reliable information. For example, an ordinary tall variety without elongation ability would help establish a standard water depth above which the survival other tall varieties would be attributed to elongation ability. Another

Table 2. Scales for assessing deep-water performance of rice, Standard Evaluation System for Rice, IRRI, 1975.

Elongation In Deep Water (Elon)	SCALES	
	Water depth	*Rate of elongation per day*
Note: Some rices have the ability to elongate and grow in areas annually flooded to varying depths. This scale gives the depth of water (cm) in which varieties can elongate and/or grow to maturity under natural or artificial conditions. Specify conditions under which the data were recorded. Two digits are used. *At growth stage:* 4–6	1 500 cm or more 2 400 cm 3 300 cm 4 250 cm 5 200 cm 6 150 cm 7 100 cm 8 50 cm 9 No elongation	1 Slow (less than 5 cm) 5 Intermediate (5–15 cm) 9 Rapid (more than than 15 cm)

imperfection is that only a few plants of an entry may survive. If genetic segregation can be held responsible, there is no problem. But environmental factors evidently operate as well, and in such cases there would be a need to interpolate between the 1 and 5 scores with percentages to arrive at a single score for quick comparisons. That has not been sufficiently worked out.

FACTORS INFLUENCING ELONGATION PERFORMANCE

Many more problems may arise in an experimental pond than in an ordinary paddy field. Some control of the following factors is possible, but no control measure can remove the need for several experiments before individual varieties and lines can be correctly judged.

Soil leveling. The ponds must be carefully leveled. Precision in experiments on elongation ability will suffer if the bottom of the pond is uneven, with deep and shallow spots. An uneven surface causes very dry to very wet soil, and uneven germination. Moreover, plots growing on high spots may show better elongation ability than those growing on lower spots.

Soil heterogeneity. The soil is often heterogeneous in fertility or in compaction in newly dug ponds. In old ponds the previous planting plan and treatments also affect subsequent growth. When experimental material is grown on soil with varying fertility, unequal growth affects elongation ability.

The soil can be homogenized through redistribution and fertilization. Check varieties should also be used frequently and yield trials should include appropriate blocking.

Excessive rain. In the wet season, rain may cause unequal and decreased germination through rotting. The only remedy is to pump the water out of the seedbed as soon after the rains as possible. By elevating the plots or strips about 10 cm above the rest of the field, and by leveling the soil, the seedbed can be kept drier.

Rain often bruises young seedlings, especially in the early stage before water has covered them enough to protect them.

Water quality. The main water supply for the deep-water ponds is the outside canal. The canal water is quite turbid and lets in only a small amount of light. Water from outlying flooded fields is used in some ponds. Floodwater is much clearer than canal water, and enables plants to perform better in elongation tests.

Damage from crabs. Crabs damage rice shoots at almost every stage of growth. They are a problem in experimental ponds used continuously for several seasons.

Chemicals such as Sumithion or g -BHC can be applied to crabholes. Not using the pond for about 3 months to dry it also helps.

Sunlight. Insufficient radiation reduces elongation ability. Consequently, experiments in the wet season generally show less elongation than those in the dry season. That is another reason why check varieties are indispensable for interpreting results of experiments.

Expected flowering dates. Problems occur if the period of water increase and elongation testing coincide with panicle initiation. That happens either when there is a long wait before the water is increased or when very early flowering materials are included. Plants in the generative stage, helped by the usual internode elongation after panicle initiation, may first give good elongation. But they can not sustain elongation if the water continues to rise after flowering.

Height. Materials to be tested for elongation ability are best separated according to plant height. If short and tall lines are planted together, short lines will show shorter foliage above the water, and will score lower for elongation. By grouping for height, short lines with some elongation ability can be retained without inadvertently losing them through comparison with tall lines.

TESTING IN PONDS AS PART OF VARIETAL IMPROVEMENT

Since no morphological characteristic has shown good correlation with elongation ability, a test for elongation should be an integral part of a breeding program for deep-water rice.

Frequency of testing. Elongation testing is done every other generation because selection objectives other than elongation ability can better be tested in shallow-water fields and because space and labor are not adequate to test every generation.

Selection for elongation ability. Selection for elongation ability uses at least two methods. One method is to grow lines in the deep-water pond and in a shallow-water field. Those field plots that correspond to lines with outstanding performance in the pond are harvested.

For early-generation materials a more efficient selection method is to remove the top stem pieces, including two nodes, from plants with good elongation, and transplanting them from the pond into a nearby shallow-water field. That allows regeneration into normal plants from which some selection for plant type, etc., is possible before harvesting.

Optimal generation for starting selection in deep water. Crosses with floating parents of doubtful elongation ability are usually put into deep-water testing as early as the F_2 to conserve labor and space. If previous experience indicates that the floating parent is good, testing is done in a shallow-water field to select for other traits and to group plants according to height before deep-water testing. Of course, the procedure is also very much determined by the availability of space in ponds or fields at the moment of decision.

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DISCUSSION

HAMAMURA: Do you feel you need a pond with water depths of 300 to 500 cm or more?

Sophonsakulkaew: I don’t think it is necessary. Generally, water depths in farmers’ fields are less than 200 cm. Our primary objective is to produce hybrid varieties with good elongation and high yielding abilities. The water depths we have are all right for discarding lines with poor elongation ability.

Screening for kneeing ability

B.S. Vergara, R. Visperas, J. Peralta,
E. Shuwisitkul, S. Karin, and S. Sophonsakulkaew

Plants usually lodge after the internodes have elongated and floodwaters have receded. Varieties for deep-water rice areas must have kneeing ability to keep the first three leaves above the water level. That prevents decay of the leaves and provides better leaf arrangement. It also bears the panicle above the reach of fishes and prevents damage to the seeds.

The test for kneeing ability is best conducted on plants that are at least 2 months old.

MATERIALS

A puddled and leveled field, and rice plants at least 60 days old or older are needed for the test.

Testing procedure. On the first day, dig carefully around the base of each rice plant and pull out the plant gently. Have four hills for each variety. Label each hill.

Place the hills horizontally on the puddled field. Randomize the varieties to be tested. Maintain a water depth of 2 cm. The plants tend to move around or roll if the water is too deep.

On the 8th day, score for kneeing ability using the scoring system in Figure 1.

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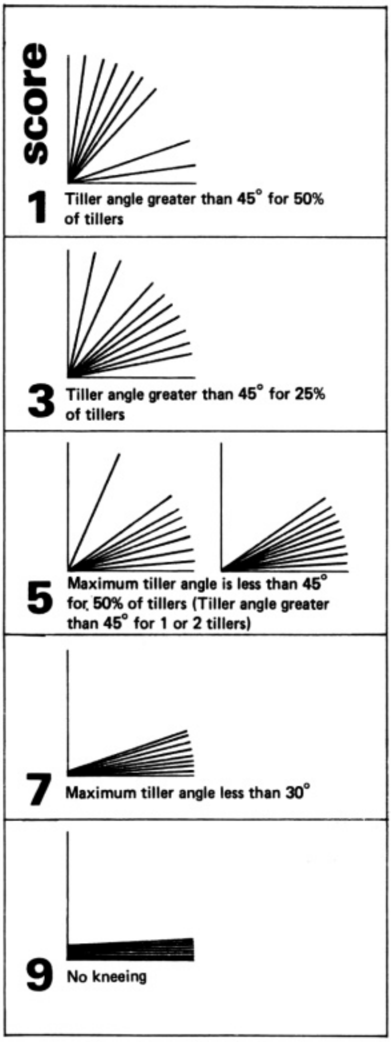

1. Scoring system for kneeing ability.

Six of the 50 entries from the 1976 International Deep Water Rice Observational Nursery had good kneeing ability (scores 1 to 3 on a scale of 1 to 9).

ARC 5955
BKN 6986-29
BKN 6986-59-12
BKN 6986-58-1
BKN 6987-225
BKN 6986-71

COUNTRY REPORTS

Progress of deep-water rice research in Bangladesh

S.M.H. Zaman

Deep-water rice has been cultivated in Bangladesh since time immemorial. At the moment, it is cultivated in approximately 2 M ha in 18 of 19 districts.

About 16 % of the total rice area is in broadcast aman or in deep-water rice. It is 12% of the total rice production in Bangladesh. The yield of clean rice varies from 0.8 to 1.0 t/ha.

In the districts of Faridpur, Sylhet, Tangail, and Pabna, deep-water rice is the main crop. The people suffer when rice is damaged by unusual floods.

Because of the crop's economic importance, research on deep-water rice began as early as 1917 in the Agricultural Experimental Station, Dacca, and in 1934 at the Deep Water Rice Research Station, Habiganj, Sylhet district. From 1917 to 1936, the Second Economic Botanist in Dacca conducted research on deep-water rice, while the First Economic Botanist conducted research on other rice groups. In 1937, deep-water rice research became the responsibility of the First Economic Botanist. In the same year, the Habiganj station was established by the Government of India. In 1944, the station was taken over by the Government of Assam, which managed it until 13 August 1947. On 14 August 1947, it was transferred to the Government of East Pakistan. After the partition of India, the designation First Economic Botanist was changed to Economic Botanist (Cereals) and the Habiganj Deep Water Rice Research Station was put under that officer. On 1 October 1970, the

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Bangladesh Rice Research Institute (BRRI) was established. It now carries on all aspects of rice research.

This article traces the progress of research from 1917 to 1975.

VARIETAL IMPROVEMENT

At one time, an estimated 1,500 to 2,000 indigenous varieties were cultivated in various deep-water areas of Bengal and Assam. The collection consisting of 170 varieties in 1917 grew to 784 in 1924. The varieties came from Dacca, Mymensingh, Comilla, Faridpur, and Pabna (Bengal Dep. Agric., 1910–40).

Up to 1940, the Dacca Station had no deep-water area for testing breeding materials. It used a few acres of leased lowland at the nearby Mirpur area for the purpose. When a new area was acquired for the Agriculture College in 1939, about 2 ha of lowland subject to a flood depth of 200 to 300 cm was placed at the disposal of the Economic Botanist.

From 1917 to 1950 at Dacca Station, varietal improvement was based mainly on pure line selection. The lines were first classified according to tolerance for a flood level of either below or above 150 cm. Priority was put on the selection of lines tolerant of a flood level above 150 cm. By 1937, as many as 630 pure lines capable of resisting floods of up to 210 to 300 cm were isolated. By 1938–39, Baisbish, Gabura, Gutak, Notpasha, Lalkanai, Dulia, Jhuli, and Bagrai strains had been identified as highest yielders among the materials suited to a flood depth of 300 cm. Of the 8 best, Baisbish (FAO Genetic Stock No. 519) and Gabura (FAO Genetic Stock No. 531) were recommended for mass production in 1940. The mean paddy yield of each was about 2.8 t/ha. The rice was white and medium in size (Alim et al., 1962). In late 1940, Maliabhangar (FAO Genetic Stock No. 541), a pure line suitable for flood depths of 200 to 250 cm, was selected as a special variety because of its deep purple vegetative parts.

Sooner or later, deep-water rice fields become infested with wild deep-water rice that affects the yield of commercial varieties. The wild rice plant has green vegetative parts and thus can be easily weeded out when the deep purple Maliabhangar is grown in the infested fields. However, because of Maliabhangar's high susceptibility to stem borer and low flood tolerance, it is grown in a very limited area.

A breeding method similar to that used at Dacca was followed at Habiganj station. From a total of 917 pure lines (collected mostly from Sylhet and nearby areas), varieties Katyabagdar (Habiganj Aman I), Godalaki (Habiganj Aman II), Gowai (Habiganj Aman III), Dudhlaki

(Habiganj Aman IV), and Dhola Aman (Habiganj Aman V) were released in 1950. Habiganj Aman I was suitable for a flood level of only 150 cm. However, its earliness and medium fine grain have enabled it to remain popular. Habiganj Aman III and V were suitable for a flood depth of 350 cm; Habiganj Aman II and IV tolerated a flood level of 240 cm. All had yields that ranged from 2.8 to 3.0 t/ha (Alim et al., 1962).

In both stations, morphological studies on vegetative and reproductive parts were meticulously carried out. Pure lines were classified on the basis of those characteristics. Submergence tests were carried out as a routine procedure. The effects of period and depth of submergence at various plant ages on the rate and total elongation of leaf sheath, leaf blade, and internodes; number of nodes; tillering; and nodal root formation were continuously studied to isolate breeding materials whose vegetative parts elongated faster under maximum submergence.

Correlation studies were done on culm length and number of tillers, panicle length and number of grains per panicle, and culm length and flowering date. Each set of characteristics showed a correlation coefficient of + 0.6 to + 0.9. The correlation between the growth rate of the culm and the total air space of the internode gave values that ranged from + 0.398 to + 0.405, indicating lack of association between the two characteristics (Alim et al., 1962). Physiological studies were limited to measurement of linear growth under varying depths of submergence, flowering habit, and seed dormancy.

When further selection from pure lines did not produce other superior varieties, hybridization was initiated at Habiganj in 1942 and at Dacca almost a decade later. The major objectives were 20 to 25% higher yield and flood resistance. The breeding materials were selected pure lines and wild rice with desirable traits. At Dacca, Maliabhangar's susceptibility to stem borer was considerably reduced by genes from wild species. At Habiganj, in addition to typical deepwater rice varieties, transplanted aman varieties such as Latisail and Nizersail were used in the hybridization program as gene sources for higher yield. Habiganj Aman VI was developed by crossing Dhola Aman with wild deep-water rice. From the progeny of the cross Laki × Gowai, Habiganj Aman VII was developed. Habiganj Aman VIII was a selection from La1 Aman. By 1960, all those varieties had been developed and released.

Practically no attempt was made to breed for disease resistance or tillering habit either at early seedling stage or at postflood stage. No genetic work on the inheritance of tolerance to submergence and elongation of leaf sheath, leaf blade, and culm was carried out.

Investigations on land preparation, dates of seeding, seeding rate, dry and wet seeding, etc. produced useful results (Alim et al., 1962).

Cultivation of long-stemmed (not deep-water type) aus (summer) varieties mixed at various proportions with deep-water rice was tested. Under shallow flood level (below 200 cm), mixed crops gave higher outturn than single crops of aus or deep-water rice (Alim et al., 1962).

Pregerminated seeds sown on puddled fields gave higher yield than dry-seeded ones in heavy-textured soils. Early seeding in March, well ahead of the probable date of the advent of flood, always gave better results than late planting. Seedlings 5 to 6 weeks of age could withstand flood much better than younger seedlings.

Uprooting of deep-water rice plants by strong water currents during June and July did not lower the yield, but late uprooting in September did.

Fertilizers did not produce consistent results. In some experiments, the application of fertilizers at the time of final land preparation gave yields higher than those of the unfertilized plots. In others, the results showed no significant difference between fertilized and control plots. It appears that the response of deep-water rice to fertilizers depends on the following factors :

1. Soil moisture level during the preflood period
2. Length of the period between seeding and advent of flood
3. Plant population
4. Weeds
5. Variation in flood levels and rate of rise of flood level
6. Silt content of the floodwater

Unless all those factors remain favorable, the response to fertilizer will generally remain indistinct.

The chemical composition of deep-water rice soils was studied under both submerged and dry conditions. The soil survey of the deep-water area shows 10 major physiographic units (Bangladesh Directorate of Soil Survey, 1967–72). Soils adjacent to major rivers are usually light textured and more fertile than the heavy clay types, which lie away from the main flood-bearing rivers. The quantity of silt carried by flood and its chemical nature were also investigated. The silt is rich in nitrogen, potassium, and calcium. Deposited nutrients, in kilograms per hectare, were N (62.6), P_2O_5 (15.7), K_2O (89.1), and CaO (35.7) (Islam and Hafizur Raman, 1956).

DISEASES AND INSECT PESTS

Most major diseases of rice are found in deep-water rice. However, no major outbreak of any fungal or bacterial disease has been reported.

Ufra, the most serious disease of local deep-water rice, was reported in the early part of the century and during the early twenties by the Imperial Mycologist of India. Butler (1921–22) found that the causal organism was a nematode. He studied the disease thoroughly and found it endemic to deep-water, areas of Faridpur, western Comilla, and parts of Dacca, and recurrent in areas with poor drainage. Drainage, burning of stubble, and thorough fall plowing that subjected the soil to weathering prevented the recurrence of the disease.

Most known insect pests are present in deep-water rice, but the most damaging have been the stem borers, rice hispa, and ear-cutting caterpillars.

Crabs, snails, swimming rats, and rodents have also caused significant damage in certain areas.

Among the nonparasitic agents, the water hyacinth is one major weed which can destroy the deep-water rice crop.

RECENT DEVELOPMENTS

Between 1960 and the establishment of BRRI, no emphasis was given to research on deep-water rice. The recurrent, devastating floods of 1954, 1955, and of later years demonstrated conclusively that unless special attention is given to flooding, production in flood-affected areas will decrease.

Germ plasm collection has been intensified, with special attention given to Rayada and indigenous, deep-water rice. At the moment, the total collection at Habiganj and Dacca stands at 775.

Breeding work with local and exotic deep-water rice varieties and those with high yield potential is conducted to incorporate into the hybrids a broader spectrum of genetic factors for flood resistance and high yield.

Active collaboration in breeding has been established among the breeders of BRRI and Thailand, through the International Rice Research Institute, for regular interchange and testing of progeny lines developed at BRRI and Thailand. The breeders have access to foreign deep-water varieties and advanced progeny lines obtained through the International Rice Deep Water Observational Nursery.

Breeding materials are being screened for mesocotyl elongation under submerged conditions. Preliminary results indicate that varieties differ considerably in mesocotyl length.

Initial tests show that a type of relay cropping may allow double cropping in flooded areas where now either boro (winter) or deep-water rice can be grown. By adjusting the rows of boro crops, deep-water rice seeds can be direct seeded in the wet soil between rows at initiation of the dough stage of the grain. After the boro harvest, the seedlings of deep-water rice begin to grow.

The Soil Fertility and Soil Testing Institute, with the cooperation of BRRI, conducts fertilizer-*cum*-variety trials in farmers' fields in deep-water areas.

Investigations on varietal resistance to *ufra* disease and its control are also going on under natural field conditions.

In the low-lying flooded areas of BRRI, a battery of field tanks with water control devices is nearing completion and will be available to researchers by February 1977. It will enable BRRI scientists to accelerate screening of progeny lines at desired flood depths.

The international seminar on deep-water rice held at BRRI in 1974 caught the attention of international agencies. Some have shown interest in assisting BRRI in strengthening deep-water rice research.

SUMMARY

Research on deep-water rice in Bangladesh was initiated as early as in 1917 at Dacca Agricultural Experimental Station. In 1934, the Government of India established another research station at Habiganj, Sylhet.

At the start, both stations used indigenous germ plasm to develop varieties with higher yields and flood resistance. Hybridization work to develop superior varieties with higher resistance to flood began at Habiganj in 1942 and at Dacca in 1952. Flood-resistant genes from local, wild deep-water rice were extensively used by breeders at both Habiganj and Dacca.

Botanical characteristics of the collected germ plasm were studied in detail at both stations. Attempts were made to find correlation among the major yield-contributing and flood-resistant characters. However, no record of any genetic work is available.

Detailed agronomic experiments related to tillage, seeding rate, dates of seeding, use of wet and dry fields for seeding, transplanting, mixed cropping of deep-water rice and aus at various proportions of seeds, etc. were done at Habiganj station.

Physiological studies on the rate of linear growth, seeding at various

dates, duration and depth of submergence, flowering habit, and seed dormancy were recorded.

Fertilizer trials were carried out with variations in moisture level of the soil, time and depth of flooding, silt content of the floodwater, etc. The chemistry of submerged soil and of related soil elements was studied by the agricultural chemists.

The diseases and insect pests of deep-water rice were investigated. Among the major insects were stem borers, rice hispa and ear-cutting caterpillar. Almost all known diseases of the rice plant have been recorded in deep-water rice. A nematode causes the most damaging disease. Measures for its control were developed and effectively applied.

In the recent past, research on varietal improvement, variety-*cum*-fertilizer interaction, physiology, and mixed and relay cropping has been streamlined.

International cooperation is now feasible. Use of exotic germ plasm in breeding programs has revealed brighter prospects for the development of a new breed of varieties with high yield potential for deep-water areas.

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DISCUSSION

ESCURO: You mentioned that susceptibility of Maliabhangar to stem borer was considerably reduced by transferring genes from wild species. What species of wild rice was used as parent? In incorporating borer resistance and other desired traits from wild rice, did you have any problem with linkage with undesirable traits from wild rice?

Zaman: Instead of "wild species," it should be "wild variety." *O. sativa* var. *fatua* Prain is the wild rice commonly found in Bangladesh. It has high flood resistance. Its high photoperiod sensitivity, faster leaf sheath elongation, and ability to survive in uprooted condition are desirable characters. In the hybrids, shattering ability and long awns are common. Apart from them, desirable combinations can also be easily found.

IKEHASHI: You stated that the susceptibility of the variety Maliabhangar to stem borer was considerably reduced by transferring genes from wild varieties. Is there any wild rice variety that is more resistant to stem borers than cultivated rices? Do you have any plans to use the wild variety for stem borer resistance in BRRI?

Zaman: Several lines from the cross Maliabhangar × wild variety were developed with higher resistance to stem borer than the parent variety Maliabhangar has. The wild rice (*O. sativa* var. *fatua* Prain) crosses freely with deep-water rice and produces fertile hybrids.

ZAN: *Ufra* disease was mentioned in your paper. Is the disease still prevalent in your country and, if so, what is the estimated percentage of disease incidence and damage?

Zaman: The disease is still prevalent and can be found in parts of Faridpur, Comilla, and Dacca districts, specially in areas with poor drainage system. The extent of the disease is about 2%.

ZAN: Apart from drainage, burning of stubble, and fall plowing, what other measures do you suggest to control the disease?

Zaman: No other suitable method is available except to grow resistant varieties.

ZAN AND PARK: Have any attempts been made to determine if there is any variety resistant to this nematode?

Zaman: At the moment only one resistant variety has been identified, but more tests are needed to confirm its nature and degree of resistance. BRRI is regularly screening materials against *Ufra.* We may soon find more materials resistant to *ufra.*

BORIBOON: Weed is a problem in deep-water paddy field. How do you control populations of weeds such as waterhyacinths and sedges?

Zaman: In most areas, weed is controlled by weeding before the advent of the flood. Rice is followed by legumes, wheat, potato, etc., which also help to control weeds. During floods, waterhyacinths sometimes severely damage crops. Farmers usually grow a strip crop of jute, *Sesbania, Esconominae indica,* and some species of *Ipomea* along the river banks to act as natural barrier to the waterhyacinths.

IKEHASHI: To what extent should the tolerance of rice for saline water be considered in the decision to recommend varieties for the coastal areas of Bangladesh?

Zaman: In the coastal areas of Bangladesh the tide does not stay long. The usual water depth ranges from a few cm to a maximum of 30 cm. The local, tall, transplanted aman varieties are grown in such areas. Tidal influence is felt even up to 50 to 60 miles from the sea coast. During the rainy season (300 cm rain during June-Sept.), the flooded area has too much water (> 200 cm), but salinity is not a problem. BRRI has a program of developing salt-resistant transplanted aman and aus varieties. At the moment DA 29 is the only salt-tolerant transplanted aman variety in Bangladesh.

JACKSON: Could Habiganj I be classified as a semifloating rice? As I recall, it does not have a spreading base like typical floating varieties. Isn't it also relatively early compared to Habiganj VIII?

Zaman: Habiganj Aman I is not considered a typical deep-water rice variety. It is suitable for growing in areas where the flood level is less than 200 cm. No, it does not have a spreading base. It is earlier than Habiganj Aman VIII.

VERGARA: I am interested in knowing who in Bangladesh is working on elongation capacity based on mesocotyl length of the germinating seed under submerged conditions. Did you get results similar to those from Hamamura's deep seeding screening method?

Zaman: The Physiology Division of BRRI has done some work on mesocotyl elongation. Longer mesocotyls have been found in all rice groups. It is not a special characteristic of deep-water rice alone.

Deep-water rice in Burma

O. Kyaw, P.B. Escuro, and K. Zan

Rice is the staple diet of Burma's entire populace. It is also the largest export item, contributing over 53% of the national foreign exchange earnings. As the most important crop in Burma, it is planted in some 5.4 M ha of a gross sown area of 9.40 M ha for all crops. Rice is grown in most parts of the country—the coastal plains and Irrawaddy delta with an annual rainfall of 2,500–5,000 mm, the Central Plains with a rainfall as low as 760 mm, and the northwest and northern hilly regions (elevation over 1,200 m) with an annual precipitation of 1,500–2,000 mm. Table 1 shows rice among other major crops in Burma.

RICE GROWING SYSTEMS IN BURMA

Rice is grown as a lowland crop on about 96% of the total rice area (5.4 M ha). Practically all rice-growing lands in the high-rainfall areas of southern Burma are rainfed. The irrigated area, 17% of the rice hectarage, is generally found in the drier parts of central Burma.

Lowland rice. Lowland rice is generally sown first in nursery beds and later transplanted in the field. Early maturing, photoperiod-insensitive varieties are grown in the irrigated areas. In the rainfed lowland regions, medium maturing, photoperiod-insensitive or slightly sensitive varieties are grown under ordinary lowland conditions. Under shallow to medium deep-water conditions, medium late to late maturing,

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Table 1. Hectarage, yield, and percent of sown area of seven crop groups in Burma, 1974–76.

Crop	1974–75			1975-76		
	Area (thousand ha)	Yield (thousand t)	Sown area (%)	Area (thousand ha)	Yield (thousand t)	Sown area (%)
Cereals	5,697.2	8,689	59.98	5,706.2	9,245	60.44
Rice	5.177.3	8,448	54.50	5,203.6	9,062	55.11
Wheat	91.8	63	0.97	93.9	56	1.00
Maize	201.9	79	2.13	196.7	75	2.08
Other cereals	226.2	99	2.38	212.0	52	2.25
Oil crops	1,751.9	554	18.44	170.7	537	18.08
Groundnut	674.2	459	7.10	686.4	404	7.27
Sesamum	1,055.9	94	11.11	997.6	132	10.57
Sunflower	3.6	1	0.04	4.0	1	0.04
Others	28.2	–	0.19	19.0	–	0.20
Peas and beans	722.4	280	7.60	670.2	245	7.10
Black mung bean	66.4	23	0.70	49.0	14	0.52
Burma white bean (butter beans)	73.2	36	0.77	63.5	35	0.67
Burma red bean (Sultani/pya)	56.3	20	0.59	53.4	20	0.57
Gram	151.0	66	1.59	155.8	67	1.65
Pigeon pea	79.7	28	0.84	67.2	24	0.71
Others	295.8	107	3.11	281.3	85	2.98
Industrial crops	424.1	1,285	4.47	409.6	1,695	4.34
Cotton	219.3	42	2.31	208.0	37	2.20
Jute	64.4	40	0.72	59.9	37	0.64
Sugarcane	45.7	1,185	0.48	53.0	1,605	0.56
Rubber	85.4	15	0.90	83.8	14	0.89
Virginia tobacco	5.3	3	0.06	4.9	2	0.05
Food crops	180.9	179	1.91	192.2	198	2.04
Potato	10.9	45	0.12	11.3	54	0.12
Onions & garlic	24.7	109	0.26	23.9	111	0.25
Chilies	58.7	25	0.62	66.8	22	0.71
Vegetables	82.1	–	0.86	85.0	–	0.90
Spices	4.5	–	0.05	5.2	11	0.06
Plantation crops	357.3	47	3.77	363.8	47	3.85
Tea	51.0	46	0.54	51.0	46	0.54
Coffee	2.8	1	0.03	2.8	1	0.03
Coconut	18.6	–	0.20	19.0	–	0.20
Toddy palm	27.1	–	0.29	27.1	–	0.29
Fruit trees	156.2	–	1.64	157.4	–	1.66
Others	101.6	–	1.07	106.4	–	1.13
Miscellaneous	365.8	–	3.85	392.6	–	4.15
Nonedible medicinal plants	365.8	–	3.85	392.6	–	4.15
Total	9,499.6	11,034	100.00	9,441.6	11,967	100.00

tall to very tall, photoperiod-sensitive varieties are grown, depending on the expected maximum water depth and rainfall duration.

In medium deep-water areas, pregerminated seeds are directly seeded on puddled soil early in the rainy season. The water level in those areas rises fairly early so that transplanting becomes difficult.

In deep-water areas, typical deep-water varieties are grown. The seeds are dry-seeded at the onset of the rainy season so the plants can grow as the water rises with increased rain intensity.

Where salinity from tidal water is a problem during the late rainy season, pregerminated seeds are also sown early so that the plants can withstand the intrusion of saline water later in the season.

Upland rice. Upland rice occupies about 4% of the rice area. The area includes lands for shifting cultivation in hilly regions and for typical upland rice cultivation where the field is prepared dry and then dry seeded at the start of the rainy season (usually late May and early June). The yield of upland rice is low (1 t/ha). The main problem appears to be lack of adapted high yielding varieties and poor cultural management, particularly inadequate weed control, and low fertility.

RICE VARIETAL IMPROVEMENT

Rice varietal improvement in Burma, which probably started in the early part of British rule, resulted in the identification and release of traditional varieties, most of which are still being grown. The varieties are medium to late maturing and generally are photoperiod sensitive. Though locally adapted, their yields are low and generally are not responsive to moderate applications of fertilizers.

Role of high yielding varieties. After the introduction of short statured, early maturing, and high yielding varieties (HYV) starting in 1967, the average yields of lowland rice gradually increased. The new varieties include IR8, IR5, a later introduction from the International Rice Research Institute (IRRI), C4-63 from the Philippines, and recent introductions from national programs of south Asian countries. Below is the trend in area grown to high yielding varieties. The 1976–77 data are provisional.

	1975–76		*1976–77*	
Varietal group	*Area* (thousand ha)	*Percent*	*Area* (thousand ha)	*Percent*
High yielding varieties	419.6	8.2	580.0	11.4
Local improved varieties	1281.2	24.9	1820.0	35.6
Others	3442.4	66.9	2805.6	53.0

Recently Shwewatun and Seintalay, two new varieties developed from the national breeding programs, were released. They are being grown successfully.

Factors limiting expanded adoption of HYV. Expansion in adoption of HYV is limited to irrigated areas and rainfed lowland areas with moderate to high rainfall because:

1. The plants are too short to suit even the shallow-water conditions of Southern Burma.
2. The short life cycle of HYV does not fit the growing conditions in southern Burma where the rain period extends up to 6 months.
3. There is as yet no improved variety of upland, cool-temperature, or saline-water rice that has been adequately tested and found adapted to growing under those stress conditions.
4. High input requirements including fertilizers, labor, and pesticides, are needed for most HYV.

REQUIREMENTS OF DEEP-WATER VARIETIES

Out of 5.40 M ha grown to rice in Burma, 79% is in rainfed lowland rice. Most varieties are grown under ordinary lowland conditions or in shallow waters. However, water depth in large areas (about 9% of sown hectarage) can not be controlled during the rainy season because of poor drainage and lack of embankments along rivers. Those areas are found in Pegu, Rangoon, and Irrawaddy divisions, and in Karen, Mon, and Arakan States, all in southern Burma. Their average annual rainfall ranges from 2,000 to 5,000 mm in a period of 6 months (May to October). Adapted varieties are either tall statured or floating, depending on the water depth. For the vast, shallow-water areas (water of less than 50 cm deep), traditional, medium late, tall lowland varieties are grown successfully. If lodging resistance is incorporated into them, high yields can be attained with improved cultural management.

In medium deep-water fields (50 to 200 cm water depth), the seeds are pregerminated and either sown directly in puddled soil or grown first in nursery beds and transplanted at 6 to 8 weeks of age. The plant then grows with gradual increase in floodwater. Varieties suited to these areas are very tall, late maturing, and highly photoperiod sensitive. Yields of 1 to 2 t/ha can be expected under those growing conditions.

In typical deep-water areas (over 200 cm deep), daily increase in water depth varies from 5 cm to 30 cm depending on rainfall intensity and duration. Maximum water depth is estimated at 300 to 400 cm. Only deep-water or floating varieties are grown. Seeds are dry seeded at the start of the rainy season (April to May) and the plants elongate with the rising floodwater about 1 to 3 months later. Harvesting is done by farmers on boats if the variety matures while the water is still deep; otherwise, the crop is harvested after the flood recedes or when the field dries up. Yields under these conditions range from 0.6 to 1.0 t/ha. If varieties with suitable maturity, relatively high tillering capacity, and ability to elongate with rising floodwater can be developed, the yields can be increased substantially.

In southern Burma sudden floods occur when torrential rains fall for a prolonged period. Vast areas are submerged and the rice crop is badly damaged if the plants remain under water for over a week. If varieties that can withstand submergence for longer periods under various depths can be developed, yields in these flood-prone areas can be increased.

PRESENT CULTIVARS FOR MEDIUM AND DEEP WATER

Practically all varieties now grown in medium deep to deep water are selections from traditional varieties. They are late maturing and highly sensitive to photoperiod (Table 2).

Table 2. Popular varieties grown in medium deep to deep water in Burma, 1976.

Variety	Days to maturity[a]	Adaptation
Elwe	175	Deep water
Kaukya	175	"
Taungdi	163	"
Tadaungpo	167	"
Yamanine	177	"
Yepwa	168	"
Khaukleik	165	"
Sitpwa	168	"
Yodaya DW	180	"
Kamakyi	174	Medium deep water
Ngakywe	188	"
Meedonhmwe	200	"
Pawsanhmwe	187	"
Theedat	184	"
Seingyi	182	"
Lawthawgyi	172	"
Kalagyi	160	"
Khayangya	166	"
Mandalay Ngasein	187	"
Hmawbi Ngasein	183	"

[a]Based on mid-June seeding.

The yield of deep-water rice in Burma can be increased by the use of high yielding adapted varieties and by improved cultural practices.

Varietal improvement. In the past, work to improve deep-water rice varieties was limited to selections from existing indigenous varieties. No regular program was followed. At present, varietal improvement aims to develop high yielding varieties that can be directly seeded or sown in seedbeds at the start of the rainy season (May) and harvested when the flood recedes (October). Such varieties should be able to withstand submergence for 1 to 2 weeks and should be able to elongate rapidly with floodwater that rises to about 300 cm. They must also possess some resistance to bacterial leaf blight and stem borers, which are serious pests in Burma.

Screening of introductions and national collections. The first logical step in varietal improvement is collecting indigenous varieties and screening for adaptability to deep water. Because of limited seed, the nine deep-water varieties in the national collection are being grown only for observation of agronomic characters under ordinary lowland conditions. A total of 50 entries—from the International Rice Deep Water Observational Nursery (IRDWON)—are being grown with five local deep-water and one improved lowland varieties, under both ordinary lowland and medium deep-water conditions (maximum depth of 1 m) at Yezin. The following characteristics are being observed:

1. Survival percentage about 1 week after maximum water depth has been attained in the deep-water nursery
2. Number of days from sowing to heading
3. Important diseases and insects
4. Plant height at harvest
5. Phenotypic acceptability at maturity
6. Number of productive panicles at harvest
7. Lodging

Performance testing. Nine deep-water varieties that are being increased will be grown in 1977, along with selections from the IRDWON, under both ordinary lowland and deep-water conditions at Yezin and, possibly, at one other location regularly subject to flooding. Grain yield and agronomic and grain traits will be determined. Selections from the 1977 plantings will be grown in two or more locations in 1978, with larger plots and more replicates. Highly promising selections from the tests will be recommended for release and seed increase.

Hybridization between local selections and selected introductions. Local rice researchers started hybridization among local deep-water varieties in 1971. Several crosses were made between the local floating rice Sitpwa and T442 lines received from IRRI. In 1973, a few more crosses were performed between tall, late, photoperiod-sensitive, lodging varieties and improved varieties IR24, IR1364, and C4-63. The local deep-water varieties Elwe, Sitpwa, and Kaukya were selected in the 1975 wet season and crossed with the improved varieties IR20, IR26, IR28, IR30, IR34, and IR2153-26-3-5-2, known to have multiple resistance to major diseases and insects. In the 1975 dry season, four introduced deep-water varieties (T442-57, T442-65, T442-158, and T442-148-29), susceptible to bacterial leaf blight and neck blast, were crossed with eight improved lowland varieties that possess insect and disease resistance and relatively high tillering ability. Only 32 F_1 seeds developed from 11 crosses performed. The F_1 seeds matured too late for growing in the 1976 rainy season; they will be sown early in the 1976-77 dry season to produce adequate seeds for growing the F_2 generation in the 1977 rainy season.

Seeds from two F_2 crosses involving Nam Sagui, a variety known to be highly tolerant to submergence, were received recently from IRRI's International Rice Testing Program (IRTP). For lack of space in the deep-water field, they are being grown under ordinary lowland conditions for selection of agronomic characters. Plant selections will be grown next year in the deep-water field.

Panicle selections from the 1975 F_4 generation of a previous deep-water rice cross (T442-121-24/Sitpwa) were grown in progeny rows in the deep-water field at Yezin in the 1976-77 rainy season for further selection. Promising uniform lines will be included in the preliminary tests of deep-water lines in 1977. Plant selections from segregating rows will again be grown in progeny rows in deep water for further selection in 1977.

Table 3 summarizes the present status of deep-water rice hybridization in Burma.

Seed production for promising selections. During the first year of performance tests at some locations, panicles will be selected from promising entries. They will be grown in progeny rows in the next season for breeder seed to save time in seed increase of any entry that may eventually be recommended for release after the second year of the test.

Cultural management studies. Local studies on the cultural aspects of deep-water rice seem quite limited. The following studies are suggested:

Table 3. Present status of deep-water rice hybridization at the Agricultural Research Institute, Yezin, Burma, 1976.

Cross	Combination	Generation	Population
X 76-39	T442-57/IR26	F_1	3 seeds
X 76-40	T442-57/IR30	F_1	2 seeds
X 75-41	T442-57/IR2070-747-6-3-2	F_1	3 seeds
X 76-42	T442-57/IR2070-423-2-5-6	F_1	1 seed
X 76-43	T442-65/IR2071-588-5-6-4	F_1	7 seeds
X 76-44	T442-65/IR2070-747-6-3-2	F_1	5 seeds
X 76-45	T442-1-58/IR2070-24-1-4-5	F_1	3 seeds
X 76-46	T442-1-58/IR2071-669-3-4	F_1	4 seeds
X 76-47	T442-1-58/IR2071-588-5-6-4	F_1	2 seeds
X 76-48	T442-1-58/IR30	F_1	1 seed
X 76-49	T442-148-29/IR2070-24-1-4-5	F_1	1 seed
X 75-101	Elwe/IR26	F_1	4 plants
X 75-102	Elwe/IR28	F_1	1 plant
X 75-103	Elwe/IR34	F_1	5 plants
X 75-111	Sitpwa/IR2153-26-3-5-2	F_1	11 plants
X 75-112	Sitpwa/IR28	F_1	27 plants
X 75-113	Sitpwa/IR30	F_1	6 plants
X 75-114	Sitpwa/IR34	F_1	46 plants
X 75-115	Sitpwa/IR26	F_1	18 plants
X 75-117	Sitpwa/IR20	F_1	1 plant
X 75-119	Kaukya/IR28	F_1	18 plants
X 75-120	Kaukya/IR30	F_1	25 plants
X 75-121	Kaukya/IR34	F_1	10 plants
IR8234	Nam Sagui/IR1721-11-6-8-3-2// IR2061-213-2-16 [a]	F_2	225 plants
IR8235	Nam Sagui/IR2031-724-2-3-2// IR2061-213-2-16 [a]	F_2	225 plants
X 73-14	D25-4/IR24	F_4	457 progeny rows
X 73-16	D25-4/C4-63	F_4	300 progeny rows
X 73-18	Ngakywepyu/IR24	F_4	507 progeny rows
X 73-20	Ngakywepyu/C4-63	F_4	478 progeny rows
X 73-22	D25-4/IR1364	F_4	303 progeny rows
X 71-1	Sitpwa/T442-121-24	F_5	500 progeny rows

[a] Seeds received from International Rice Testing Program in 1976.

1. Biweekly planting of medium late maturing and late deep-water varieties from the start of the rainy season until the field begins to be flooded naturally from rainfall
2. Dry seeding vs. transplanting of medium late maturing and late deep-water varieties seeded at the same time at the onset of the monsoon rains
3. Dry seeding rates of medium late maturing and late deep-water varieties planted at the start of the rainy season
4. Transplant spacings using the two varieties of the dry seeding study

All the tests will be conducted in the 1977 wet season in a simulated deep-water field at ARI or in a deep-water station where water can rise to a maximum of 200 cm. The results can indicate the best method, and the optimum time and rate of planting of deep-water rice of different growth durations.

DISCUSSION

HAMAMURA: Do you have any information on grain length of indigenous Burmese deep-water rices? In the case of Thailand, indigenous Thai local varieties tend to have short grains.

Ohn Kyaw: Almost all deep-water varieties except Yodaya have short grains.

DE DATTA: 1. I am not sure we have seeds of varieties mentioned in Table 2. If you can send us about 50 g seed of each by December, we shall be happy to test them for drought tolerance. 2. In Table 3, are No. 7–10 T442-1-58 or something else? Maybe you or Dr. Jackson can comment on this.

Ohn Kyaw: 1. The varieties mentioned have been included in our national collections sent to IRRI's germ plasm bank in 1975. However, we will try to send them if they are available. 2. Those are T442-1-58 lines. According to Dr. Ben Jackson, they have better elongation ability than IR442-2-58.

Progress of deep-water rice research in Bihar, India

S. Saran

Among India's rice-growing states, Bihar has the largest area in rice. But in production the state occupies a comparatively low position. The limited land area is under tremendous population pressure (more than 6 M) accentuated by frequent floods and drought. Irrigation is not sufficient to offset the hazards imposed by the vagaries of the monsoons.

Rice is grown under varying conditions of rainfall, latitude, climate, and soil. Southwest monsoons occur with a well-marked seasonal rhythm, concentrating the precipitation in warm humid weather coinciding with the rice-growing season. The rice matures during the relatively dry season. From June to October, the monsoon brings about 900 mm of rain to the western border of the state and 1,800 mm near the northeastern corner.

North Bihar, especially northeast of the Burhi Gandak River, has about 1,200 mm of rain. It is estimated that 0.5 M ha is planted to deep-water rice in Bihar, where water depth ranges from 50 to 400 cm. Another 1.5 M ha of rice area is called shallow-water, poorly drained lands. In such lands, water depth varies from 25 to 50 cm. One characteristic of Bihar's deep-water situation is that in most places the water stagnates in the field throughout the crop period.

GEOGRAPHICAL DIVISIONS

The state can be broadly divided into three geographical units:

1. North Bihar plains comprising areas north of the Ganges River and extending to the Nepal border

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2. South Bihar plains in lands south of the Ganges and extending to the border of Chotanagpur hills

3. plateau-*cum*-hilly region of Chotanagpur, south of the southern plains

DEEP-WATER RICE AREAS

Deep-water rice areas lie mostly in north Bihar. Heavy rains in the catchment areas at the foothills of the Himalayas bring huge quantities of water to the rivers that flood many parts of north Bihar. The rivers in north Bihar, especially Kosi, have changed their courses because of floods and silting over the centuries. The result is several saucer-shaped depressions called *chaur.* Deep-water rices are grown in *chaur* lands. Flooding starts in June–July, but peak floods generally occur in August–September. The water depth varies from 50 to 400 cm. The water starts receding in October, but most areas remain waterlogged until December–January.

Flashfloods occur in many parts of the Gangetic plains in July–September, submerging the rice crop for 1 to 20 days. Varieties possessing tolerance to complete submergence are required in such situations.

RICE CULTURE

Two rice groups in the poorly drained lowlands have been identified: traditional tall indica varieties, which are transplanted in the early monsoon period (June–July) to shallow-water or medium deep-water areas (25–50 cm), and floating rices which are direct seeded in February–April in *chaur* lands after the water recedes from such areas. The water depth ranges from 50 cm to 400 cm in deeper zones. Both rice groups are photoperiod sensitive, and are harvested in November–December.

Low yields are due to the following factors:

1. dependence on the monsoons
2. natural hazards such as drought and flood
3. poor yield potential of local varieties
4. losses due to shattering, harvesting, and transport
5. poor management practices including weed control, water control, cultural operations, etc.
6. little spread of local improved varieties

EARLIER RESEARCH WORK

Although systematic work on the varietal, manurial, and cultural aspects of the rice crop began in 1914 in Bihar, an elaborate and comprehensive rice research scheme was started only in 1932. It had the following objectives:

1. To make a complete botanical and agricultural survey of rice varieties of the state
2. To isolate unit species or pure lines of varieties grown in Bihar
3. To improve cultural and manurial practices in rice cultivation
4. To conduct genetic studies on quantitative and qualitative characteristics of rice
5. To evaluate new economic genotypes through hybridization

The main rice research station was located at Sabour. Since 1955–56, four regional research institutes have been established at Patna, Sabour, Ranchi, and Pusa. Patna has become the main Bihar rice research station. A number of substations were established in the different agroclimatic regions. Bihar has actively participated in the All India Coordinated Rice Improvement Project program since 1965. In 1975, the Ford Foundation agreed to cooperate on a project to study poorly drained rice lands (including deep-water) in Bihar. The project is based at Pusa in north Bihar.

Early work has evaluated some improved varieties—BR 14, BR 15, and BR 46—for deep-water situations:

1. BR 14, a selection from Jessaria rice of north Bihar, is highly photoperiod sensitive and has good elongation capacity. It can withstand floods of up to 400 cm. It flowers in the third week of October, and has an average yield of 1 to 1.5 t/ha.
2. BR 15 is a selection from Metachang rice of Bengal. It resembles BR 14, except that it has a light purple husk and is fully awned.
3. BR 46 is also derived from Jessaria rice of north Bihar, but is genetically different. It resembles BR 14 in flowering, elongation capacity, and yield, but has coarse grain quality. The spikelets are awned.

Varieties for shallow-water, poorly drained lands have also been identified:

1. BR 7 is a selection from Kessore rice of Bhagalpur district. It is photoperiod sensitive, and flowers in the last week of October. The average yield is 2 to 3 t/ha.
2. BR 8 is another selection from Kessore rice of Bhagalpur district. It resembles BR 7, but has medium coarse grain.

Varieties such as Latisail and Patnai 23 from W. Bengal, Manoharsail from Assam, and T141 from Orissa have done remarkably well in the shallow-water, poorly drained lands of Bihar.

Flashfloods are common on both sides of the Ganges. For areas where such floods are frequent, e.g. parts of Darbhanga, Mazaffarpur, and Champaran districts in north Bihar, BR 13 and BR 49 are very useful. Originally numbered FR 13A and FR 43B, they were introduced from Orissa, and can withstand complete submergence up to 10 days.

RECENT RESEARCH WORK

A collection of about 500 germ plasm accessions from local deep-water rice areas was made in the early 1960's. From this genetic stock the highly promising pure line 64–117 has been identified. It was derived from the "chenab" rice of the Siwan district in north Bihar. This variety has consistently yielded 10 to 15% higher than BR 14 and BR 46. It is photoperiod sensitive and possesses very good tolerance to flooding. It can withstand complete submergence for 7 to 10 days after the tillering stage. The variety has done extremely well in farmers' plots in north Bihar.

A modest hybridization program involving semidwarf varieties and local floating rices was initiated in 1968. Some crosses are IR8/BR 14, IR8/BR 46, IR8/Barobor, Pankaj/BR 14, and BR 8/BR 14.

Several promising derivatives from the cross IR8/BR 14 have been identified. They have yielded 15 to 50% higher than the local types when the growing conditions are less adverse. But with submergence or drought of longer duration, local varieties have scored better. One promising line from the cross BR 8/BR 14 has also done extremely well under medium deep-water conditions (50 to 150 cm) in Bhagalpur region south of the Ganges.

Pankaj has shown great promise in shallow-water, poorly drained lands of Bihar. It has withstood complete submergence for 5 to 7 days in the posttillering stage. Pankaj and the crosses of semidwarfs and local types often behave erratically under adverse conditions because of photoperiod insensitivity or weak photoperiod sensitivity.

FUTURE PROJECTIONS

More work is needed on the following aspects of rice cultivation in poorly drained areas:

1. Combining the photoperiod-sensitive characteristic with high yield and improved plant type
2. Identifying improved varieties for shallow-water, medium deep-water and deep-water situations
3. Incorporating resistance to bacterial leaf blight and stem borer into deep-water rices
4. Combining nonshattering character of the grains in deep-water rices

5. Determining the most effective method, time, and rate of seeding
6. Determining the most effective method, time, and rate of fertilizer application
7. Evaluating other cultural practices such as spacing

SUMMARY

About 0.5 M ha is planted to deep-water rice in Bihar. In another 1.5 M ha, the water depth is less than 50 cm, but the water stagnates throughout the crop period. Yields of deep-water rices are very low in Bihar (0.5 to 1.0 t/ha). Improved varieties have not spread as widely as desired, but the recent breeding program has led to the isolation of some promising lines. The pure line selection 64–117 has done extremely well compared with the recommended varieties BR 14 and BR 46. Pankaj has found favor with farmers in shallow-water, poorly drained lands. Photoperiod sensitivity must be combined with high yield, improved plant type, and resistance to bacterial leaf blight and stem borers. Nonshattering quality, tolerance to flooding, and elongation capacity are equally important characteristics of deep-water rice. Improvement in rice agronomy is badly needed.

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DISCUSSION

Jackson: How does the extent of the deep-water area in Bihar compare with that in West Bengal?

Saran: In Bihar we have about 0.5 M ha of deep-water land. Dr. S.K. Datta informed me that in West Bengal they have about 0.2 M ha of deep-water land.

Choudhury: Since the deep-water problems in West Bengal, Bihar, and Orissa are more or less the same, how closely are you working with those states?

Saran: At present the cooperation is not very close. But we hope to develop more regional cooperation in the future.

Jackson: What facilities do you have for deep-water testing in Bihar?

Saran: We do not have simulated conditions for deep-water testing. But a modest beginning has been made at Patna where some tanks have been dug to test deep-water material. At Pusa station in north Bihar we propose to develop elaborate facilities for deep-water research work. But we are carrying on deep-water research work under field conditions at Pusa and north Bihar where deep-water lands exist.

DE DATTA: You did not mention anything about Panidhan 1 and Panidhan 2, which were released in Bihar. I understand these varieties, which were selected locally from IR442 cross, have been named and released in Bihar. Please comment.

Saran: IR442 lines have shown susceptibility to bacterial leaf blight. The farmers have preferred Pankaj variety to IR442 lines because of its higher yield. Thus, IR442 lines have not spread in Bihar.

VERGARA: How early and how fast can BR 14 elongate?

Saran: Elongation records have not been determined in BR 14. But under field conditions, BR 14 has been observed to grow up to 400 cm.

CHOUDHURY: Varieties recommended for Bihar are given BR numbers; Bangladesh varieties are also given BR numbers. What can we do to avoid any confusion with these numbers?

Saran: I think some way should be found to distinguish the two sets of varieties to avoid confusion.

Breeding improved rice varieties for tidal swamp culture in Indonesia

S. Subiyanto, H. Noorsyamsi, and H.M. Beachell

There are an estimated 7 M ha of tidal swampland in Indonesia. Three million hectares along the coast of East Sumatra and 2 M ha in South and Central Kalimantan are suitable for rice cultivation. Of these areas, only 110,000 ha in South Kalimantan and 40,000 ha in Central Kalimantan were in cultivation before 1969.

During the first Five Year Plan (1969–70—1973–74), the Government reclaimed an additional 23,000 ha in South and Central Kalimantan and 10,000 ha in South Sumatra. Major reclamation areas of the second Five Year Plan (1974–75—1978–79) include 200,000 ha in South and Central Kalimantan and 300,000 ha in South Sumatra.

The water levels of some areas near rivers in South Kalimantan are under strong, “direct” influence of tides; others are under only limited, “indirect” influence. One tidal swamp area which covers 55,000 ha appears to have more specific constraints (soil problems, water depths and varietal adaptation) than other areas.

The areas of direct tidal influence may extend to 10 km from the river. Day-to-day tidal fluctuations add to varying seasonal water levels depending on location along a river. The difference between maximum and minimum daily tide levels may be as much as 250 cm. The annual rainfall at Pulau Petak in South Kalimantan ranges from 2,000 to 3,000 mm. It is distributed throughout the year, with January receiving the highest (400 mm), and August the lowest (50 mm).

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The soils at Pulau Petak are derived from fluviatile deposits that are reasonably high in value for agricultural use. The profile is generally moderately deep, with greyish or brownish oxidized surface layers over grey ripe subsoil. The texture is clayey and mostly nonstructured. The soil is slightly acid, and its nutrient content is low to fair. The cation exchange capacity is high to very high, with generally low to medium base saturation. The pyrite content is low in the oxidized layer and mostly low to medium in the reduced subsoil.

The seedbeds of the main crop (long-season local varieties) are sown in October or November and transplanted up to three times at intervals of 30 to 50 days. Harvest is in August or later. An early crop of a medium early (photoperiod-insensitive), improved-plant type variety, such as Pelita I/1 or C4-63, is sometimes sown in September or October. It is harvested in standing water around February. Harvest coincides with the last transplanting of the long-season local varieties which occupy the fields from which the early crop is harvested. The early-crop varieties are frequently double transplanted.

Varietal improvement should be intensified for developing replacements for the long-season local varieties, and for the present improved-plant type varieties that are planted in September or October in areas with direct and indirect tidal influence. Improved varieties for the long-season crop either must be photoperiod sensitive or have a long basic vegetative period (bvp) or both. They should mature at about the same time as long-season varieties (August to September) regardless of seeding date and number of transplantings. Weather and soil moisture favor the period August to September for harvesting.

CHARACTERS TO BE CONSIDERED

Elongation ability. Moderate elongation ability in rising water at early stages of growth, and intermediate plant height (Pelita height) are desirable traits to breed into long-season varieties.

Plant height. Varieties of intermediate plant height—about the height of Pelita—or slightly taller genotypes with genes for elongation and for survival when fully submerged have their greatest impact in those areas where water depths seldom exceed 100 cm. They will also be useful in areas not classified as deep-water areas but where flooding is apt to occur sometime during the year.

Acceptable flowering date. Genotypes that are either photoperiod sensitive or have relatively long bvp are required so the crop can be transplanted and harvested during favorable weather and water conditions. The last suitable transplanting date usually occurs in March or just before water depths increase. Seedlings from one or more transplantings must be well advanced because water is relatively deep at that time. The most favorable harvest weather occurs in August and September, so the period from final transplanting to maturity should be from 145 to 170 days. The floral initiation period occurs during the shortest day lengths of the year. Since several transplantings are required, the total growth duration of the long-season varieties would sometimes approach 250 days.

Short-season varieties are photoperiod insensitive, requiring about 140 days from seeding to maturity. They are seeded during the longer days of the year (Sept.–Oct.). Early maturing, short-season varieties (120 days) might be desirable in the areas with more favorable water regimes. Since seedlings are frequently transplanted in rather deep water, long-season and short-season varieties must have good seedling and early vegetative vigor, and perhaps elongation genes.

Grain quality. The most important grain characteristics are intermediate amylose content, clear translucent grain appearance, and dormancy. Medium-long grain is generally preferred although grain size and shape are not specific.

Awns and threshability. Varieties must be awnless because threshing by foot is the common practice. Firm threshability is necessary because of the panicle harvesting methods practiced.

Diseases and insects. Improved resistance to tungro, bacterial leaf blight, blast, grassy stunt, brown planthopper, and green leafhopper is needed.

Tolerance for adverse soil conditions and local adaptation. Crosses between long-season, locally adapted varieties and Thai varieties originating from acid sulfate soil areas may provide tolerance for adverse soil conditions.

Vegetative vigor and tillering. Traditional deep-water varieties have excellent seedling and early vegetative vigor. Those traits must be retained, along with vigorous vegetative growth and nodal tillering. Relatively high tillering is necessary, particularly the ability to tiller from the nodes when plants are submerged.

BREEDING PROGRAM

Early work. Before 1946, the Bayar varieties—Bayar Putih, Bayar Melintang, and Bayar Kuning—were considered the most suitable for tidal swamp areas. In 1968, after selection within the existing varieties, Bayar Putih 462/10, Bayar Melintang 10/l3, and Bayar Kuning 195 were recommended for propagation. More recent varieties are generally

Table 1. Elongation ability, survival ability, and growth duration of deep-water lines from Thailand, grown at Banjarmasin in 1976.

Variety or line	Rate of elongation[a]	Recovery from submergence[b] 4 wk	9 wk	Growth duration (d)
BKN 6987-160-1	G (8)	I (4)	I (4)	140
BKN 6986-141	I (6)	P (8)	P (8)	131
Pin Town	G (7)	G (3)	I (4)	150
Tek Chuey-159	I (6)	I (5)	P (8)	143
BKN 6987-128-2	G (8)	G (3)	I (6)	143
NCL/Sigadis	P (2)	I (4)	p (7)	161
BKN 6986-108	G (8)	G (3)	I (6)	131
BKN 6986-45	G (9)	I (6)	P (8)	141
BKN 6987-117-1	G (8)	I (4)	I (4)	141
BKN 6986-1	I (6)	G (2)	G (3)	131
BKN 6986-70	G (8)	G (3)	I (6)	143
BKN 6986-58	G (9)	G (2)	P (8)	143
Nahng-Pahya-132	I (5)	G (3)	G (3)	159
Puek Nam 43	I (5)	G (2)	I (4)	161

[a] G = good; I = intermediate; P = poor. Numbers in parentheses are from the scale in Standard Evaluation System for Rice, 1976: 1 = slow (less than 5 cm); 5 = intermediate (5-15 cm); 9 = rapid (more than 15 cm). [b]Seeded 21 January, transplanted 22 February. Numbers in parentheses are from the scale in Standard Evaluation for Rice, 1976: 1 = less than 1% dead plants; 3 = 1–5%; 5 = 5-25%; 7 = 25–50%; 9 = more than 50%.

tall, have medium tillering ability, and can tolerate the deep-water and adverse soil conditions of the area. In the experiments, Pelita I/l and C4-63 showed satisfactory performance as short-season varieties.

Recent work. During the 1975–76 wet season, 104 entries were grown in observational plots. The entries consisted of progenies from various crosses involving T442-36, Pelita I/2, B9c-Tk-23-5-5-3, C4-63, IR442-2-58, Pelita I/l, and other introduced varieties. The entries generally showed very little damage from diseases or insects except bacterial leaf blight, but many appeared to be resistant. A few entries showed some susceptibility to problem soils. Approximately 40 promising lines were kept for further selection.

During the 1975–76 wet season, 14 deep-water rice varieties or lines from Thailand were evaluated in 0.5 ha in Banjarmasin (Table 1). The experimental land is under direct tidal influence, which caused a maximum rise and fall in water depth of 60 to 70 cm every 24 hours. The soil is acid sulfate, typical of the tidal swamp region.

The seeds were sown 21 January 1976, and transplanted 22 February to determine their adaptability to local conditions. When first transplanted the seedlings were submerged for 3 to 4 hours daily during high tide for at least 1 week before they became tall enough to remain above the high water level.

Plant counts were made periodically to determine survival ability under the stress of rising and falling water depths, and the ability to tolerate acid sulfate soils. Breeding lines from Thailand that appeared particularly promising were BKN 6987-117-1, BKN 6986-1, and BKN 6987-160-1. Lines showing poor submergence tolerance included BKN 6986-58, BKN 6986-45, and BKN 6986-141. In spite of their known ability to elongate under Thailand conditions, they performed poorly in increasing water depths possibly because of the acid soil condition. The traditional variety Tek Chuey-159 showed from 5 to 25% submergence survival and was rated 8 (poor).

In a nearby planting, Bogor lines originating from the crosses B922c (B9b-TK-23-5-5-3/T442-36), and B1050c (Pelita I/2/T442-36) appeared outstanding. They were also grown under deep-water conditions in Thailand, and several showed elongation ability equal to that of T442-57. IRRI varieties IR29, IR30, and IR32 were almost dead, but IR34 seemed to grow well. The local Thai variety Nam Sagui 19 appeared to be well adapted and looked better than C4-63, which is being planted as a short-season variety in the tidal swamp areas.

A date-of-seeding experiment involving four varieties was started on 9 February 1976 to determine photoperiod response. The experiment was seeded about every 15 days for 1 year. The seedlings were grown in pots, with a single 21-day-old seedling transplanted into each pot with two replications. The day lengths of the shortest and longest days (June 21 and December 22, respectively) in Banjarmasin, at 3°20's and 114°30'E, showed a maximum difference of only 23 minutes (Smithsonian Meteorological Tables, 1968). The shortest daylight period (June 21) was 11 hours, 56 minutes, while the longest (December 22) was 12 hours, 19 minutes. These figures do not include civil twilight period which varies from 21 to 23 minutes per day at different times of the year.

The data on seeding dates are presented in Table 2. C4-63 showed a slight photoperiod response between the February 9 and May 12 seeding dates; plants seeded on May 12 headed 88 days after seeding, while those seeded on February 9 required 96 days. The day length at 10 days before floral initiation of C4-63 seeded on February 9 was 12 hours 5 minutes (March 31); that for the May 12 seeding was 11 hours 56 minutes (June 24). A difference of 8 days in floral initiation between the two seeding dates was recorded with only 9 minutes difference in day length during the critical photoperiod (10 days before floral initiation).

In the case of the tidal swamp varieties no consistent relationship appeared between small day length differences and the number of days from seeding to flowering. No difference was noted in day length at critical photoperiod for Lemo at four seeding dates. The critical photo-

Table 2. Date-of-seeding experiments, started Feb. 9, 1976, Banjarmasin.

Variety and seeding date	Flowering		Critical day length[a] (45 d before flowering)			
	Days after seeding	Date	Days after seeding	Date	Day length[b]	Minutes longer than shortest day (no.)
Lemo						
Feb. 9	–	–	–	–		–
Feb. 23[c]	146	July 18	101	June 3	11 h 56 min	0
Mar. 8	134	July 20	91	June 7	11 h 56 min	0
Mar. 22	147	Aug. 16	102	July 4	11 h 56 min	0
Apr. 5	135	Aug. 18	90	July 4	11 h 56 min	0
C4-63						
Feb. 9	96	May 15	51	Mar. 31	12 h 05 min	9
Feb. 23[c]	91	May 24	47	Apr. 10	12 h 04 min	8
Mar. 8	93	June 9	48	Apr. 25	12 h 01 min	0
Mar. 22	91	June 21	46	May 8	11 h 59 min	3
Apr. 5	86	June 30	41	May 16	11 h 59 min	3
May 12	88	Aug. 8	43	June 24	11 h 56 min	0
May 26	91	Aug. 25	46	July 11	11 h 56 min	0
Bayar Putih						
Feb. 9	145	July 3	100	May 19	11 h 59 min	3
Feb. 23[c]	–	–	–	–		
Mar. 8	–	–	–	–		
Mar. 22	141	Aug. 10	96	June 26	11 h 56 min	0
Apr. 5	135	Aug. 18	90	July 4	11 h 56 min	0
Bayar Kuning						
Feb. 9	133	June 21	88	May 7	11 h 59 min	3
Feb. 23[c]	123	June 25	78	May 11	11 h 58 min	2
Mar. 8	110	June 26	65	May 12	11 h 58 min	2
Mar. 22	147	Aug. 16	102	July 2	11 h 56 min	0
Apr. 5	135	Aug. 18	90	July 4	11 h 56 min	0

[a]The period 45 days before flowering is critical for day length. Floral initiation is estimated to be 35 days before flowering. [b]Day length based on duration of daylight data from Smithsonian meteorological tables. Civil twilight period is not included. [c]When transplanted 15 Mar., tidal swamp varieties should not mature before August.

period of Bayar Putih and Bayar Kuning on the different seeding dates differed by only 3 minutes. As we approach the longer days, differences in photoperiod response, if present, will become evident. On the basis of data obtained to date (Table 2, 3), tidal swamp varieties exhibited a long basic vegetative growth period when critical photoperiod occurred on days of the year with the shortest day lengths.

Another experiment using introduced deep-water varieties (traditional) from Thailand, India, Bangladesh, Vietnam, and Cambodia (Table 3) was conducted at Banjarmasin, using two seeding dates (1 June 1975 and 13 May 1976). Seedlings were transplanted 21 and 22 days after seeding for the 1975 and 1976 experiments, respectively. The flowering dates for the 1975 experiment varied from July 24 to August

Table 3. Date-of-seeding experiments in pots, Banjarmasin, South Kalimantan, Indonesia, 1975 and 1976.[a]

Variety	Origin	Flowering 1975 Date	Flowering 1975 Days after seeding	Flowering 1976 Date	Flowering 1976 Days after seeding	Plant ht (cm) 1975	Plant ht (cm) 1976	Tillers (no.) 1975	Tillers (no.) 1976	Varietal type (water depth)
Khao Med Lek	Thailand	x	x	x	x	117	150	11	13	Medium
Leb Mue Nahng 111	Thailand	24 July	53	x	x	56	100	12	10	Medium
Sai Bua	Thailand	x	x	x	x	114	160	8	12	Medium
Po Ngern	Thailand	x	x	–	–	95	–	12	–	Medium
Habiganj Aman I	Bangladesh	–	–	8 July	56	–	128	–	24	Floating
Habiganj Aman II	Bangladesh	4 Aug.	64	21 July	69	66	121	12	11	Floating
Habiganj Aman VIII	Bangladesh	x	x	–	–	97	–	14	–	Floating
Habiganj Aman VIII	Bangladesh	–	–	9 Sept.	119	–	119	–	15	Floating
DM 53	India	31 July	60	16 July	64	64	131	20	16	Nonfloating
Kekowa Bao	India	x	x	10 Sept.	120	78	120	10	15	Medium
Kalar Harsall	India	x	x	x	x	102	160	24	21	Medium
Laki 192	India	29 July	58	14 July	62	59	132	20	19	Floating
Gowai 84	India	27 Aug.	87	6 Sept.	116	64	125	20	17	Medium
Tau Binh C	Vietnam	–	–	9 Sept.	119	–	145	–	15	Floating
Baisbish	Bangladesh	13 Aug.	73	7 Sept.	117	97	170	20	16	Medium
Saran Kraham	Cambodia	x	x	x	x	115	145	17	15	Medium
ARC 5955	India	20 Aug.	80	–	–	97	–	24	–	Nonfloating
HBU SWI		24 July	53	–	–	46	–	20	–	Floating

[a] — = plants did not survive; x = did not head at 121 days after seeding. 1975 experiment seeded 1 June, transplanted 22 June; 1976 experiment seeded 13 May, transplanted 4 June.

27. The experiment was discontinued after September 30 (131 days after seeding) because varieties that had not headed did not appear to be approaching the flowering stage. Critical day length period (45 days before flowering) varied from 11 hours 56 minutes (the shortest day of the year) to 12 hours 0 minute (August 20). In spite of a difference of only 4 minutes, only 8 of the 18 varieties flowered. Those that did not flower (7 varieties) either require day lengths shorter than 11 hours 56 minutes to trigger floral initiation, or have a rather long bvp. Information on the bvp of these varieties was not available to the authors; nevertheless, it did not seem likely that they would require more than 90 to 100 days. Although a few inconsistencies were noted in the two experiments (Leb Mue Nahng, Gowai 84, and Baisbish), the 1976 experiment more or less confirmed the results of the 1975 experiment.

The experiment will be seeded again in November 1976 when the longer day lengths of the year occur.

Future work. Additional crosses will be made between local Bayar varieties (Bayar Putih, Bayar Kuning, and Bayar Melintang) and promising deep-water lines—BKN 6986-108, BKN 6987-160-1, BKN 6987-128-2—and also some promising Bogor lines (from B1050 and B922) to combine proper photoperiod sensitivity or bvp, grain quality, elongation ability at early stage of growth, and intermediate plant height. Crosses with IR34 and other lines should be made to introduce resistance to important pests and diseases.

Kwatik, a local variety widely grown in the tidal swamp areas of Sumatra, reportedly has tolerance to certain soil toxicities or deficiencies. Farmers prefer it because it is less apt to show sterility than most other varieties. Kwatik will be used extensively in the hybridization program. The F_2 and later generations from these cross combinations will be screened in the deep-water tank at Muara for elongation ability, and in the tidal swamp areas for problem soils.

Seed from surviving plants of populations sent to Thailand for screening under deep-water conditions will be grown at Banjarmasin in 1976. Segregating F_2 and F_3 populations of crosses could be planted around October in a field with direct tidal influence. PB 8 (IR8) and T442-57 should be planted as checks to measure the realized deep-water stress. The F_2 and F_3 of hybrid populations from new crosses will also be tested in the same way; in addition they will be grown in the deep-water tank at Muara or elsewhere. Incorporating elongation ability into new varieties may reduce or even eliminate the need for multiple transplantings.

Date-of-seeding experiments extending throughout the year will be conducted at several latitudes (Banjarmasin, Sumatra, and Bogor) to determine photoperiod reactions of leading, long-duration varieties grown in the tidal swamps of Kalimantan, Sumatra, and elsewhere. In Sumatra, tidal swamp rice is grown on or very near the equator. Additional experiments, along with the work now in progress at Banjarmasin, should provide the necessary information on photoperiod response of the tidal swamp varieties. Hybrid populations will be screened for photoperiod or bvp reaction by seeding on one or more dates starting in early February. Lines that mature before mid-July or early August will be discarded.

REFERENCE

SMITHSONIAN INSTITUTION. 1968. Meteorological tables. Misc. Coll. 114.

DISCUSSION

VERGARA: You stressed the importance of seedling and early vegetative vigor. Do you have any plans of screening for seedling vigor? By seedling vigor, do you mean tall seedlings?

Subiyanto: Screening for seedling vigor will be conducted. Seedling height is part of seedling vigor.

ESCURO: What is the primary reason for transplanting rice more than once in deep-water areas?

Subiyanto: There are several reasons for double transplanting in the deep-water areas:

1. To adjust to the availability of water at the early part of the season.
2. To have tall seedlings for transplanting at the existing water depth. Water comes in early and rapidly during the start of the cropping season.
3. Double transplanting is related with the available labor force.

SARAN: In Table 1. rate of elongation is given; what do you mean by that? Is that rating for total plant elongation or elongation rate for a particular period of plant growth?

Subiyanto: The elongation rate is for a particular period, as described in the Standard Evaluation System for Rice, 1976.

BOONWITE: I would like to know what are the good varieties from Thailand planted in your country.

Subiyanto: BKN 6987-160-1, BKN 6987-117-1, and BKN 6986-1 perform well, except that they are susceptible to bacterial leaf blight.

HAMAMURA: To which group of rice do Bayar, Kwatik, and Bogor lines belong? To Bulu or Tjereh?

Subiyanto: They belong to indica (Tjereh).

SINANUWONG: What is the pH of the soil?

Subiyanto: It varies among locations, but it averages around pH 4.0. Newly opened land has lower pH, and more established areas have a higher pH.

SINANUWONG: And how deep is the pyrite below the surface?

Subiyanto: Pyrite can be found close to the surface, at 30 cm or deeper, depending on the thickness of the organic surface layer.

SINANUWONG: Do you have any saline or acid sulfate problem in the tidal swamp areas?

Subiyanto: Yes, the saline or acid sulfate problem occurs during the dry season and along the coast.

SINANUWONG: Do you have any plan to improve the varieties for the saline or acid sulfate areas?

Subiyanto: Tolerant varieties need to be found for these areas.

Performance test of Thai floating or deep-water rice introduced into the Mekong Delta

Y. Ohta, V.T. Xuan, and N.T. Hung

About 0.5 M ha or about one-fourth of the cultivated rice area of the Mekong Delta in Vietnam is known as the floating-rice area. It is planted mainly to floating or deep-water rice varieties. To escape the floods, short-term IR varieties, such as IR20, have been planted. They are seeded at the beginning of the rainy seaon (May-June) and harvested just before submergence. Sometimes they are seeded just after the water recedes and harvested before the land dries up. However, that practice is confined to only certain areas, and the rest is planted to only floating or deep-water rice. Yields are as low as 0.8 to 1.2 t/ha, and eating quality is poor. The improvement of floating rice is very important to those areas.

Breeding lines and varieties of floating or deep-water rice were introduced from Thailand by the International Rice Research Institute (IRRI)/Vietnam team. Some are being studied by the University of Cantho staff and students in sites that provide a wider range of topography for performance tests. This paper deals with the results obtained during the 1974 rainy season.

MATERIALS AND METHODS

The experiments used 49 breeding lines at either F_5 or F_6, and 14 cultivars. The local variety Nang Tay Nut (= Nang Tay C) served as check (Table 1). The breeding lines (BKN stands for Bangkhen) are:

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Table 1. Performance of the introduced floating or deep-water rice at Long Xuyen (LX) and Sa Dec (SD) in the Mekong Delta. 1974 wet season.[a]

Breeding line or cultivar	Elongation ability[b]			Tiller-ing[c]		Heading[d]				Panicle length (cm)		Grain (no. /panicle)		1000-grain wt (g)	
						LX		SD							
	T	LX	SD	LX	SD	F	H	F	H	LX	SD	LX	SD	LX	SD
BKN 6986-22	1	1	3	P	G	E	E	B	B	21	22	84	101	25.1	22.8
-31	3	3	3	G	M	E	E	B	B	17	20	43	111	25.0	24.5
-43	4	4	4	G	M	C	D	A	B	16	nd	42	nd	25.8	nd
-44	4	5	4	G	P	C	D	A	B	16	nd	47	nd	25.5	nd
-45	4	2	1	M	G	F	F	B	C	23	26	120	106	21.2	17.9
-54	4	5	4	G	M	B	C	A	B	17	nd	59	nd	25.4	nd
-52	4	5	4	M	P	C	D	A	B	18	nd	67	nd	23.3	nd
-57 a	1	4	2	M	G	D	D	A	A	16	20	42	46	23.2	21.5
b		3		G		C	C			17		42		27.5	
-58	1	3	2	M	G	D	D	B	B	17	16	45	61	21.1	19.3
-64	2	3	4	M	G	E	E	B	C	24	26	141	102	24.8	24.0
-66	1	3	3	M	G	D	E	B	C	21	25	108	126	23.0	20.9
-67	2	2	3–4	M	G	E	E	B	C	24	23	129	111	23.5	20.7
-70	4	4	4	G	M	E	F	B	C	21	24	103	114	21.6	20.0
-82 a	2	5	4	G	M	C	D	B	C	18	26	60	145	28.0	22.8
b		4		M		C	D			17		52		24.6	
-114 a	2	2–3	5	P	M	C	D	B	C	16	25	50	105	28.7	29.6
b			3		M			B	C		22		64		25.3
-127	4	5	2–3	P	P	C	D	A	B	22	27	71	65	29.3	28.1
-136 a	3	3	4	M	M	B	C	A	B	23	nd	72	nd	25.3	nd
b			1		M			A	B		16		18		24.0
-140	2	4–5	2–3	G	M	B	C	A	B	18	nd	82	nd	22.4	nd
-141	3	4	5	G	M	D	D	B	B	21	nd	109	nd	24.5	nd
-156 a	4	2–3	5	M	M	C	D	A	A	nd	nd	nd	nd	nd	nd
b			3		M			A	A		14		49		27.6
BKN 6987-1 6	5	3	5	P	M	C	C	B	B	21	nd	75	nd	25.8	nd

Continued on opposite page

Table 1 continued

Breeding line or cultivar	Elongation ability[b]			Tiller-ing[c]		Heading[d]				Panicle length (cm)		Grain (no. /panicle)		1000-grain wt (g)	
						LX		SD							
	T	LX	SD	LX	SD	F	H	F	H	LX	SD	LX	SD	LX	SD
-18	5	3–4	5	P	P	C	C	A	B	20	nd	68	nd	24.2	nd
-28	4	4	5	P	P	C	C	A	B	16	nd	43	nd	28 5	nd
-57	4	3–4	4	M	G	D	D	B	C	nd	25	nd	107	nd	27.7
-62	3	3	4– 5	P	M	D	E	B	C	nd	22	nd	85	nd	23.3
-68 a	4	2	5	P	G	D	E	B	C	nd	19	nd	34	nd	25.5
b			3		M			B	C		20		33		23.6
-79	4	3	4	M	M	C	E	A	B	nd	23	nd	41	nd	19.9
-15	4	3–4	4–5	G	M	D	D	B	B	20	nd	63	nd	26.2	nd
Khao Nahng Nuey 11		4	nd	M	nd	G	H	nd	nd	26	nd	89	nd	20.3	nd
Khao Puang 32		5	nd	G	nd	G	G	nd	nd	25	nd	164	nd	29.9	nd
Po Ngern 71-27-3		5	nd	G	nd	G	G	nd	nd	27	nd	142	nd	24.9	nd
Jam Pah 133		4	nd	P	nd	F	F	nd	nd	28	nd	178	nd	23.1	nd
Nahng Chalawng		3	nd	P	nd	H	H	nd	nd	22	nd	70	nd	26.2	nd
Gow Ruang 88		3	x	M	x	E	E	x	x	27	x	155	x	30.1	x
Khao Pahk Maw 148		3–4	x	M	x	E	E	x	x	19	x	44	x	31.6	x
Nahng Mon S-4		3	x	M	x	E	E	x	x	29	x	201	x	21.6	x
Nang Tay Nut[e]		4	x	M	x	F	F	x	x	25	x	205	x	23.1	x

[a]x = not grown at Sa Dec; nd = no data [b]T = in Thailand. Elongation ability is scored as follows: 1 = like semidwarf; 2 = better than semidwarf; 3 = like deep-water rice; 4 = like recommended floating rice; 5 = better than recommended floating rice. [c]G = good; M = medium; P = poor. [d]F = first heading; H = more than half headed; A = before Sept. 15; B = during 2nd half of Sept.; C = 1st half of Oct.; D = 2nd half of Oct.; E = 1st half of Nov.; F = 2nd half of Nov.; G = 1st half of Dec.; H = 2nd half of Dec. [e]Nang Tay Nut (= Nang Tay C) is not introduced; it is a check representing local cultivars.

BKN 6986-22-82: F_6 from IR262 × Pin Gaew 56
BKN 6986-114-156: F_5 〃 〃
BKN 6987-16-28: F_6 from IR262 × Khao Nahng Nuey 11
BKN 6987-31-82-15: F_5 〃 〃

IR262 originated from the cross Peta × Taichung Native 1, and Pin Gaew 56 is a Thai floating cultivar.

Twenty-one other breeding lines, including 13 from Huntra Station, and 6 other Thai varieties were omitted from the table because of poor germination and poor stand early in development, and because of certain accidents.

Since the University is not located in the floating-rice area, two experimental sites were established in two villages (Fig. 1):

1. Binh Hoa village, Chau Thanh district, An Giang province, at the northern suburbs of Long Xuyen town. The site is close to the Bassac River main stream, and is affected directly by the river water level.

2. Long Thang village, Duc Thanh district, Sa Dec province (renamed Dong Thap province after the Revolution). The site is between the Mekong River main stream and the Bassac River main stream. The water level is affected indirectly by the rivers.

Cultivation practices followed the traditional local ways : no artificial irrigation, no drainage, no fertilizer, no pesticides, and no weeding (except for one hand weeding a month after sowing at Long Xuyen). The sites were plowed in May and harrowed several days before sowing. The seeds were sown on 16 June 1974 at Sa Dec and on 22 June at Long Xuyen, just after the rainy season began. Two air-dried seeds were sown in a place; each breeding line had 20 places spaced 25 cm between plants and 50 cm between rows.

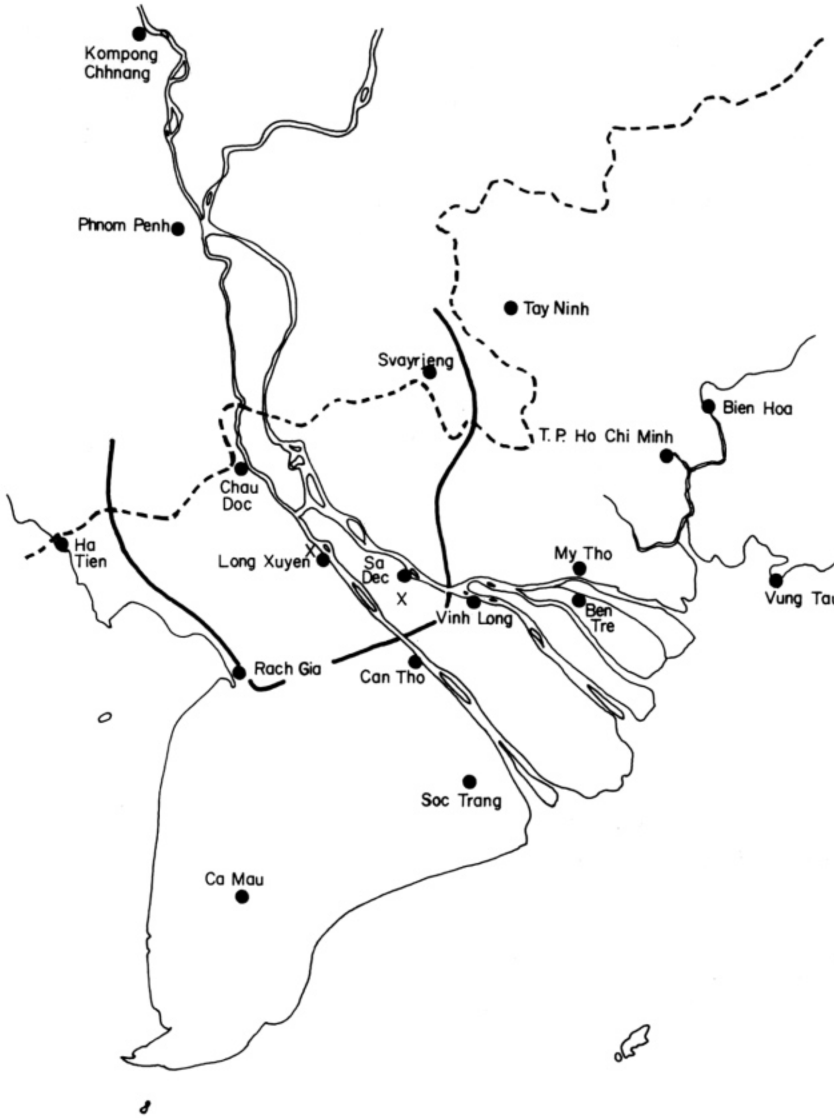
Field observations, measurements, and harvesting were carried out at both sites about every 2 weeks from 23 August to 27 December 1974. The Sa Dec site was in the heart of the military conflict at the time.

RESULTS AND DISCUSSION

Table 1 summarizes the results. Data on leaf blade color and number of leaves were collected but are omitted from the table.

Elongation ability was scored using the standard 5-point scale in Thailand.

Elongation ability was expressed quite differently at the two sites and differently from that in Thailand for most of the lines and varieties tested. The difference was caused partly by the fact that the highest water level from late October to early November was about 90 cm at



1. The southern part of Vietnam showing the two sites of the experiment, 1974.

Long Xuyen and 110 cm at Sa Dec. The usual water level is around 200 cm. Elongation ability did not show in such low water level, at least for certain lines.

Another remarkable difference between Long Xuyen and Sa Dec was in heading time. Generally speaking, plants at Sa Dec flowered earlier than those at Long Xuyen. The difference may have been caused by the difference in growth during the early stages due to rainfall (both time and amount), flooding (both time and increase of water depth), etc. With the present results, it is not possible to draw any conclusion as to which lines and varieties show promise of adapting to a wide range of environments.

Since the experimental sites were actually a portion of farmers' fields for commercial cultivation and were far from the campus, we had much difficulty in conducting the experiments. However, we were lucky to raise seed from most of the lines and varieties.

SUMMARY

Performance tests of floating or deep-water rice lines and cultivars introduced from Thailand were conducted in the 1974 rainy season at two sites in the Mekong Delta. The results are reported briefly.

Progress in deep-water rice-research in West Africa

M.A. Choudhury and H. Will

Annual flood zones distributed along the major rivers (Niger, Gambia, Casamance, and Hadejia) of West Africa make up the main deep-water rice areas in Africa. Low-lying, flooded plains with heavy rainfall on the Atlantic coast and on the western side of Lake Chad also cover a substantial area. Statistics are lacking, but it is estimated that most deep-water rice areas in Africa are located in West Africa.

DISTRIBUTION OF DEEP-WATER RICE IN AFRICA

In the Niger valley, deep-water rice is grown in about 132,000 ha in Mali, in 5,000 ha in Niger, and in 30,000 ha in Nigeria (WARDA, 1975). However, the potential areas are much larger. The total estimated possible areas for deep-water rice in the mentioned areas are 500,000 ha in Mali, 5,000 ha in Niger, and 100,000 ha in Nigeria (Fig. 1). Other low-lying flooded plains and coastal areas with high rainfall where the rice is grown or can be grown are made up of about 10,000 ha in Senegal, 8,000 ha in Gambia, and 12,000 ha in Sierra Leone. Mauritania and Benin also have some possible deep-water areas, but statistics are not available. Thus, the total area that can be used for growing deep-water rice and where no other crop can be grown at the moment is around 635,000 ha. Besides deep-water rice, flooded rice is grown in about 320,000 ha in West Africa. Flooded rice areas are those with less than 60 cm of floodwater; deep-water rice areas are those with a water depth of more than 60 cm.

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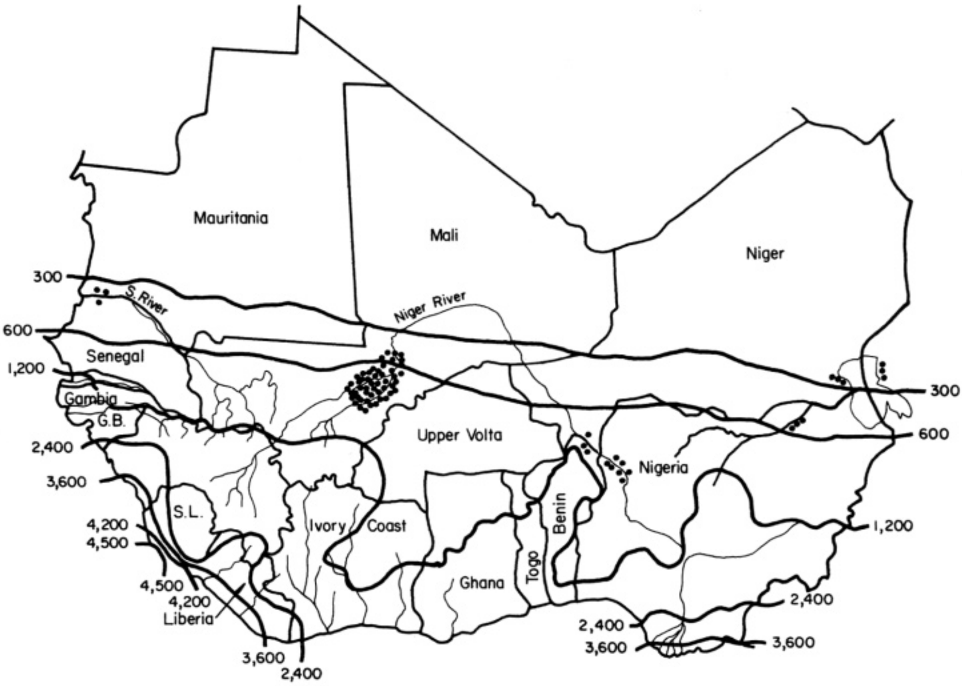

1. Rainfall (in mm) pattern and deep-water rice distribution, West Africa.

FLOODING

The annual rainfall, land contours, and rivers of the West African region contribute to regular annual flooding. The people of the deep-water areas have adapted their living conditions and farming systems to the annual flooding; nevertheless, their crops are frequently damaged by or lost to the floods. The floodwater is derived from local seasonal rain and runoff from rivers. The greatest amount of runoff can be expected anytime in August, September, or October. Flooding in the area may start as early as the end of July or as late as early October. Usually, the flood sets in between the middle of August and the beginning of September. The water may start subsiding anytime from the end of October, depending on the onset of flood.

The rainfall in the deep-water areas is generally spread from June to October, with most of the rain falling from July to September. In the deep-water areas of Mali and Niger, rainfall may be as low as 300 mm, while in those of other countries over 1,200 mm of rain can fall (Fig. 1). The major source of flood is the major rivers in the forests of Guinea where 150 to 180 days of heavy rainfall in a year can occur. The flood duration may vary from a few days to 105 days, depending on rainfall pattern and topography. The rate of water rise varies from 2 to 10 cm per day after the onset of flood. Deep-water rice is grown at the maximum water depth of 2.5 m. The field usually dries up in January.

CULTIVATION PRACTICES

Most deep-water rice varieties grown by the farmers of West Africa belong to *O. glaberrima.* They generally are grown on poorly prepared lands. The land is prepared by hand or with cattle after the first rains—usually in July—and dry seeds are broadcast. Under normal conditions, plants are 4 to 6 weeks old at the time the floodwater begins to inundate the field.

In certain areas, especially in Nigeria, cultivation is mechanized. Dry seed (75–90 kg) is either broadcast or drilled in rows.

Weeding is done manually. Traditional *O. glaberrima* varieties have some photoperiod sensitivity and they generally initiate panicles in November. Harvesting is done in January when the field becomes dry. Early harvest is done by harvesters in canoes.

Farmers recognize and maintain different deep-water varieties for different growing conditions. Varieties of longer duration and greater elongation ability are grown in deeper areas. Short-duration varieties are used in shallow areas.

The fertility level of deep-water areas is annually enriched by silt deposition.

YIELD CONSTRAINTS

Oryza glaberrima varieties are adapted to local growing conditions, but they yield poorly because of a low number of tillers, disease susceptibility, and shattering. However, they are resistant to drought at early growth stages and adapted to sudden flooding. They also manifest seed dormancy. A grain yield of about 4 t/ha can be obtained under good conditions along the north of the region.

In West Africa, deep-water rice occupies well over 10% of the rice area that contributes only about 7% of the total rice production. Its average yield is about 900 kg/ha (WARDA, 1975). Certain yield constraints directly or indirectly affect total rice production in the deepwater areas :

1. Low yield potential of present varieties. The grains of most widely grown *glaberrima* varieties shatter badly in the field. The varieties also suffer from blast disease. Because of low selection pressure, improvement at the farm level has not advanced. Domestication of new types was inadequate mainly because of undependable growing conditions.

2. Inadequate rain early in the season
3. Prolonged drought after sowing
4. Poor land preparation
5. Inadequate weed control
6. Heavy infestation of wild rices
7. Blast susceptibility
8. Stem borer damage
9. Harvesting losses
10. Grain shattering
11. Lack of improved cultural practices
12. Lack of extension information on local improved varieties

The performance of deep-water rice has always been uncertain. Farmers who grow them face an uncertain future. Most will have no choice but to continue growing the crop and depending on it.

RESEARCH IN AFRICA

In the past, research on deep-water rice, compared with that on nondeep-water types, received very little attention. Only very recently have such research programs been defined in any country. Deep-water rice gained some importance during the last few years in the affected countries mainly because it involved large areas and populations. Now some progress is evident.

Mali. In Mali, the Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres (IRAT) started deep-water rice research at Ibetemi in 1950. The activity began with the introduction of a few *Oryza sativa* varieties. Since 1961, about 300 *sativa* varieties—mostly from Thailand, Vietnam, and Cambodia—have been introduced and tested for adaptability and yield. Five varieties—Malobadian, Indochina G, Nang Kiew, Khao Gaew, and Mali Sawn—were selected. Their yields ranged from 3.7 to 4.5 t/ha in water regimes of 1.2 to 3 m. Some produced higher yields under controlled nondeep-water conditions. Poor soil preparation, weeds, and insect damage were constraints to optimum yields of the varieties Khao Gaew, Malobadian, and Indochina G (Martin, 1974). Advanced-generation progenies of the crosses D52-37/Malobadian and Mali Sawn/Phar Com En retained the deep-water habit and produced more panicles and better grains (Martin, 1974). A mutation breeding program of 1971 failed because no treated seed germinated. Recently, developing varieties suited to shallow water depths, 50–60 cm of water, and those with high drought tolerance has been emphasized. Tests were done in areas with varying levels of water.

Between 1965 and 1975, limited studies were conducted on cultural practices, such as rate of seeding, spacing, rate of growth, water rise, depth of flooding, and response of different varieties to fertilizer application. Some information on deep-water rice insects and their control was also gathered, but detailed information is lacking. In 1975, BH_2, × 228 and some of the T442 strains were found drought tolerant under natural drought conditions. At present, one expatriate agronomist of IRAT is working at the Ibetemi Experimental Station. The varieties Malobadian, Indochina G, Nang Kiew, Khao Gaew, and Mali Sawn were recently released for commercial production.

Niger. In 1961, IRAT initiated some research work on deep-water rice at Kolo. Some Indochina varieties were tested from 1961 to 1964. Their low yields could not be explained (Sekou, 1974). Some Thailand varieties introduced from Mali were tested from 1966 to 1970. Their performance was better; the variety 61–5 gave the highest yield of 3.4 t/ha. However, they were unacceptable in Niger because they matured later than the local varieties by about 30 days. In 1971 some early maturing varieties collected in Mali were tested. Nang Kiew matured in 106 days and yielded 5 t/ha; the local variety Demba Heira yielded 3.6 t/ha. Some other *sativa* varieties from the Mali program were tested in adaptation trials. A head row selection was made from D52-37 to improve it. Some *O. glaberrima* germ plasm collected in Niger is maintained at Kolo.

Nigeria. The deep-water rice experiment station, staffed with an agronomist, was established in 1954 at Birnin-Kebbi by the Nigerian Government. Research was carried out by senior scientists stationed at Badeggi and Moor Plantation. Yield trials with 36 *O. glaberrima* varieties in 1959–61 showed that the 180- to 220-day varieties Badane, Tatan, Don Boto, and Farin Iri were adapted to 120 cm of water depth. The 150- to 180-day varieties Kauchi, Tamba, and Tan Irin Gari were adapted to shallow depths (Patil, 1974). Yield trials with eight *O. sativa* varieties from Indochina failed to give good results in 1968–69, except Tisei, which gave 3.4 t/ha. In two other trials conducted in 1962–67, Mali Ong, Godalaki, and Indochina Blanc were identified as high yielding, early maturing deep-water types.

Eleven interspecific crosses were made in 1959, and selection for elongating ability and nonshattering white grains was done till F_9 in 1971, with the use of bulk and pedigree methods (Patil, 1974). Four crosses among *O. sativa* varieties were made in 1961. The hybridization program released strain FRRS 43/3 in 1971 to replace Mali Ong, which had earlier been recommended for deep-water conditions. A high degree of sterility was observed in the F_1 and F_2 generations by crossing *O. sativa* and *O. glaberrima.* However, more promising selections are expected to come from interspecific crosses in the near future.

Guinea and Sierra Leone. Some intraspecific crosses were done in Sierra Leone in the mid-fifties. The work, which was associated with that in Nigeria, failed because of the low combining ability of the species. Selection work on introduced *sativa* varieties in Guinea and Sierra Leone led to the release of Indochina Blanc for production purposes in those two countries.

WARDA

The West Africa Rice Development Association organized the first coordinated variety trial on deep-water rice in the region in 1973. The entries were composed of selected materials from Mali and Nigeria. In 1974, the coordinated trial was repeated with additional entries. Results of the 2 years' work were very encouraging. The same trial, conducted in 1975, resulted in very poor seedling stand at all locations

Table 1. Grain yield and life cycle of deep-water rice varieties in coordinated trials, 1973–75. West Africa Rice Development Association.

Variety	Grain yield (t/ha) per life cycle (d)			
	1973[a]	1974[b]	1975[c]	Av.
Neang Khaew 5	–	4.62/163	1.78/164	3.20/163
Nang Kiew	2.92/170	4.88/163	1.73/165	3.17/166
Kading Thang	3.16/170	–	–	3.16/170
Khao Gaew	2.90/167	4.71/163	1.68/166	3.09/165
Mali Ong	3.08/142	4.28/142	1.46/136	2.94/140
Demba Heira	1.72/170	4.09/140	–	2.90/155
Cu La	3.24/156	4.09/160	1.23/158	2.85/158
Malobadian	3.09/159	4.08/141	1.06/136	2.74/145
Indochina Blanc	2.57/166	4.05/161	1.54/158	2.72/161
Taow Boon N'gern	2.35/159	4.09/162	1.51/162	2.65/161
Puang N'gern	–	3.73/161	1.44/155	2.58/158
IR442-2-58	3.49/143	2.64/132	1.62/156	2.58/143
Indochina 70	2.45/161	3.78/161	1.27/157	2.50/159
Indochina G	2.19/135	3.46/161	1.32/157	2.32/151
Mali Sawn	2.08/183	3.24/173	1.27/173	2.19/178
FRRS 43/3	–	2.50/161	1.62/156	2.06/158
Indochina 24	1.90/153	2.55/162	1.35/157	1.93/157
Khao Nahng Nuey 11		2.86174	0.98/173	1.92/173
Demba Heira A	1.72/170	–	–	1.72/170
Indochina A	1.70/155	–	–	7.70/155
T442-90	–	–	1.32/156	1.32/156
T442-36	–	–	1.26/156	1.26/156
T442-57	–	–	1.24/157	1.24/157

[a]Av. of 3 locations in Mali and 1 location in Niger. [b]Av. of 3 locations in Mali and 2 locations in Niger. [c]Av. of 3 locations in Mali and 3 locations in Niger.

because of initial drought, followed by heavy rain (Table 1). Since no conclusive result was obtained, the trial is being conducted this year also in Mali, Nigeria, and in Niger. A new coordinated trial on deep-water rice will begin in 1977 with promising varieties of the region and some from the first International Rice Deep-Water Observational Nursery.

RESEARCH PLAN ON DEEP-WATER RICE

To attend to the problem of deep-water rice, WARDA initiated a regional research project for the crop at Mopti in Mali. Funding will be mainly by USAID (over $2M), with some from Saudi Arabia. The project, which allows for greater investment in infrastructure—houses, laboratories, offices, land development, etc.—has started at an experimental level. Initially it will have a team leader, his deputy, four junior scientists, and support staff. Its main research priorities are as follows:

1. Varietal improvement work. The development of high yielding varieties with fertilizer responsiveness, rapid elongation abilities, submergence tolerance, basal tillering and aerial noding, drought tolerance at early growth stages, insect resistance, and appropriate maturing periods.
2. Insect control. Identification of genetic material resistant to stem borers and other major insects, and evaluation of insecticides
3. Weed control. Identification of the most economical methods of weed control, and herbicide evaluation
4. Agronomy. Concentration on land preparation, method of sowing, time and rate of fertilizer application, and use of animals
5. Technology transfer to farmers
6. Mechanization for deep-water rice cultivation

SUMMARY

It is estimated that most deep-water rice areas of Africa are located in West Africa. The total area for growing deep-water rice is around 635,000 ha; that for growing flooded rice is about 320,000 ha. The major rivers in the Guinea forests, where 150–180 rainy days with heavy rainfall in a year is common, are the major sources of flooding. Deep-water rice is grown at the maximum water depth of 2.5 m. Most varieties grown by deep-water rice farmers belong to *Oryza glaberrima.* Farmers recognize and maintain distinct varieties for different growing conditions, but yields are low because the varieties have poor yielding ability. The average yield is 900 kg/ha.

In Mali, deep-water rice research was initiated by the Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres (IRAT) in 1950. Varieties from Southeast Asia were introduced. Five selected varieties yielded from 3.7 to 4.5 t/ha in water regimes of 1.2 to 3 m. Hybridization and mutation were not successful. Some work was done on agronomic aspects. In 1975, some varieties were identified as drought tolerant. In Niger, IRAT started some research in 1961 by introducing African and Asian varieties from Mali. Late maturing varieties were found to be unsuitable in Niger. Among the early maturing ones, Nang Kiew was most suitable. Some *O. glaberrima* germ plasm was collected. In Nigeria, the government started deep-water rice research in 1954. Thirty-six *O. glaberrima* varieties were thoroughly tested for adaptability, maturity, etc. Only one of the earlier tested Indochina varieties showed good performance. Three of the later tested varieties showed promise. The interspecific hybridization program developed FRRS 43/3 and released it in 1971. The West Africa Rice Development Association (WARDA) has been coordinating variety trials on deep-water rice in Mali, Niger, Sierra Leone, and Gambia since 1973. It has started an ambitious research project on deep-water rice at Mopti in Mali to study varietal improvement, insect control, weed control, mechanization, technology transfer, and agronomic aspects of the crop.

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DISCUSSION

SARAN: Have the wild rices in West Africa been identified? If so, what species are found?

Choudhury: O. longistaminata and *O. barthii* are the two major wild species in West Africa. But there may be more. A thorough survey of the area is needed.

SARAN: Do you think that the drought resistance characteristic of wild rices of your area may be incorporated into the deep-water rices of other locations?

Choudhury: Because of species differences, it will be very difficult to use wild species in the breeding program, but it is possible. However, at the moment it is not necessary to use wild species for drought tolerance, since this character is common in cultivated deep-water rice varieties.

PARK: Wild rices apparently have drought tolerance and survive well under severe stress conditions. Have you thought of the possibility of utilizing some good characteristics in the wild rice? If so, what would be the traits?

Choudhury: We don't plan to use wild rices since the characters we want to improve are available in cultivated varieties. Using wild rices in breeding programs has its own problems.

JACKSON: There is an old saying, "if you can't beat them, then join them." Shouldn't the breeders start looking for good types of *Oryza glaberrima* rather than introduce new varieties?

Choudhury: On a short-term plan we are introducing and testing *O. sativa* varieties for quick identification and release. In our long term-plan, we will use *O. glaberrima* varieties, in addition to *O. sativa* varieties, for varietal development.

HILLERISLAMBERS: You mentioned several disadvantages of *O. glaberrima* varieties. Presumably, the *sativa* introductions are better. What is the reason why some farmers still prefer *O. glaberrima* varieties?

Choudhury: Information on better varieties is not available to most farmers. Farmers generally prefer *O. sativa* varieties to *O. glaberrima* varieties.

HAMAMURA: Easy threshability is supposed to be a necessary character for very primitive farmers who go to the fields by boat and collect seeds by threshing the panicles on the boat. Can you please comment on this.

Choudhury: As farm and cultivation practices are fast changing, it is important to develop varieties resistant to shattering.

BOONWITE: Most deep-water varieties have long awns and would be difficult for farmers to thresh. Do you have any comment on this?

Choudhury: Farmers don't like long awns, but the awn is correlated to some extent with deep-water conditions. Complete elimination of awns may be difficult. Anyway, all deep-water rice farmers are used to awned grains.

ZAN: In Table 1, the 1973 and 1974 yield figures are comparatively much higher than those of 1975. Yields in 1975 are extremely low. May we know why?

Choudhury: Due to adverse environmental conditions, such as late rain at the beginning followed by severe drought, the plant populations in the 1975 trials were reduced at almost all locations.

DE DATTA: What was the water depth at which you had the WARDA-coordinated trials in 1973–1975? I notice that IR442-2-58 did fairly well (2.58 t/ha for 3 years average) in your trials.

Choudhury: Water level was around 100 cm.

DE DATTA: We have trained two of your staff for weed research. I hope you can use them for weed research in deep-water rice. Another one is being trained now.

Choudhury: One of the trained scientists is now working at Mopti on weed control. Others were trained for other projects.

RECENT DEVELOPMENTS

Yield and fertilizer response of new deep-water rice lines at three water levels

T. Kupkanchanakul, B.R. Jackson, C. Prechachart,
K. Kupkanchanakul, E. Shuwisitkul, and S. Nuchoy

Efforts to obtain new, high yielding rice varieties tolerant of deep water, under way in Thailand for the past 8 years, have produced several advanced lines of improved plant type with elongation ability. Much information has been gathered about elongation ability, plant height, and maturity of the new lines, but agronomic performance has not been extensively studied. The present experiment may help fill the knowledge gap.

This study was designed to find answers to two major questions:

1. How do the new deep-water lines yield at different water depths?
2. Can a yield response to fertilizer be obtained at water depths beyond those at which the present high yielding varieties are commonly grown?

Answers to those questions are essential if transferring deep-water characteristics to semidwarf forms is to become more than an academic exercise.

MATERIALS AND METHODS

Three small ponds at the Huntra Rice Experiment Station were used in an experiment with six varieties, three water depths, and two levels of soil fertility. The six varieties are named and described below:

T. Kupkanchanakul, Rice Researcher; *B.R. Jackson,* Plant Breeder, The Rockefeller Foundation, and IRRI Representative in Thailand. G.P.O. Box 2453, Bangkok, Thailand, *C. Prechachart.* Head, Deep-Water Rice Branch, Rice Division, Department of Agriculture, Bangkhen, Thailand, *K. Kupkanchanakul, E. Shuwisitkul, S. Nuchoy.* Rice Researchers, Ministry of Agriculture and Cooperatives, G.P.O. Box 2453, Bangkok, Thailand.

1. BKN 6986-108-13, semidwarf from IR262-43-11A/Pin Gaew 56, fair elongation ability.

2. BKN 6987-128-2-3, semidwarf from IR262-43-11 A/Khao Nahng Nuey 11, fair elongation ability.

3. BKN 6986-141-11, intermediate stature, from IR262-43-11A/Pin Gaew 56, fair elongation ability.

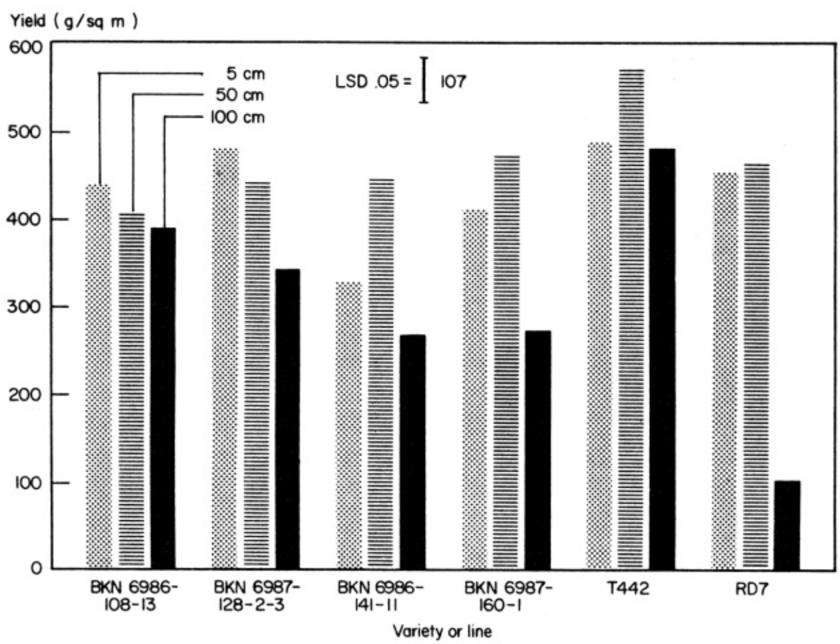
4. BKN 6987-160-1 , intermediate stature, from IR262-43-1lA/Khao Nahng Nuey 11 , good elongation ability.

5. T442-57, semidwarf from IR95/Leb Mue Nahng 111. It served as the deep-water prototype for comparing lines 1 through 4. It had been subjected to extensive testing and at one time was considered for release as a recommended variety for medium deep-water areas.

6. RD7, Thailand's most recent semidwarf release, not recommended for flood-prone areas. It was included to compare yield and fertilizer responsiveness of entries 1 to 5 under shallow water (5 and 50 cm) conditions.

Entry 5 and sister lines of entries 1, 2, and 3 were included in the 1976 International Rice Deep Water Observational Nursery (IRDWON).

The experiment was planted in a split-plot design. Each pond was



1. Yields of six varieties and experimental lines of rice grown at three water depths. Huntra Rice Experiment Station, Thailand, 1976 dry season.

divided into two main plots: one was unfertilized, and the other received NPK at the rate of 37 kg elemental NPK per hectare. The main plots were separated by a small levee to minimize lateral movement of fertilizer. Each main plot contained the full array of six varietal entries, planted in three replications in randomized complete block design. Each plot had eight rows, each 5.5 m long; the plants were spaced 25 × 25 cm. All entries were started in the seedbed, and transplanted to assigned plots in the ponds as 30-day-old seedlings. Three seedlings were planted per hill.

Thirty days after transplanting, the water levels in two ponds were raised at the rate of 5 cm per day until their respective depths were 50 and 100 cm. Water was maintained at the two levels until harvest. The time to 50% flowering was observed for each basic plot. Plant heights were determined at maturity. Yield was obtained from each entire plot and from a 1-sq m sample within each plot. Yield data are at 14% moisture content.

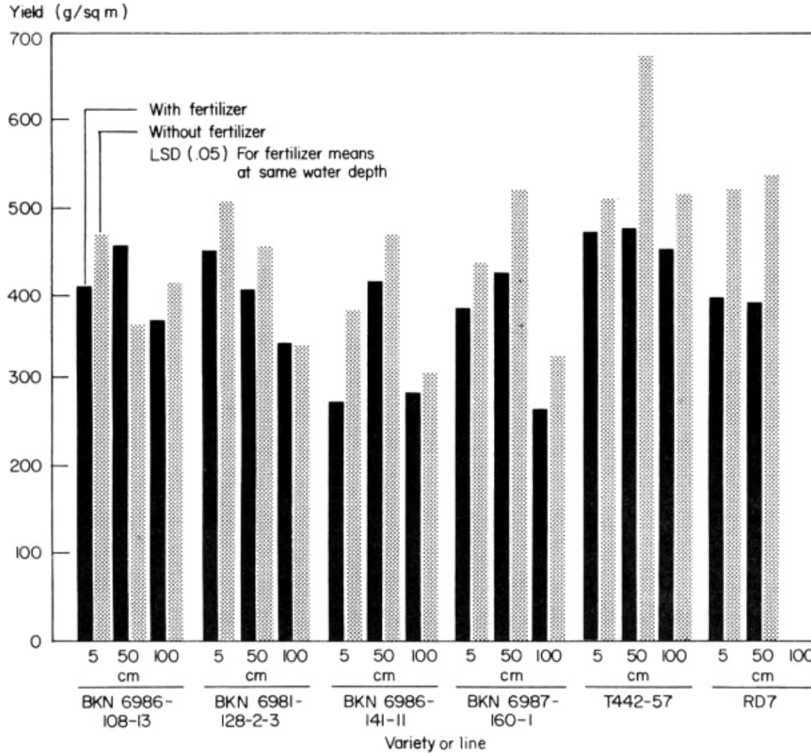
Yield component data on the 1-sq m sample and on plant height before maturity were obtained, but are not discussed in this report.

The authors gratefully acknowledge the statistical analysis performed by the statistics section of the Planning Division.

RESULTS AND DISCUSSION

Figure 1 shows grain yields from 1-sq m of each of the six varietal entries at the three water depths. At the 50-cm water depth, only BKN 6986-141-11 showed significant increase in grain yields when compared with that at 5 cm. The positive response of BKN 6986-141-11 may not be accidental. It can be explained by its intermediate plant height and weak straw, and the beneficial effect of physical support provided by the water. The rest of the entries did not show any significant increase or decrease in grain yield with increase of water depth to 50 cm. RD7, which is for shallow-water conditions, did not show any significant change in grain yields when grown at 50 cm.

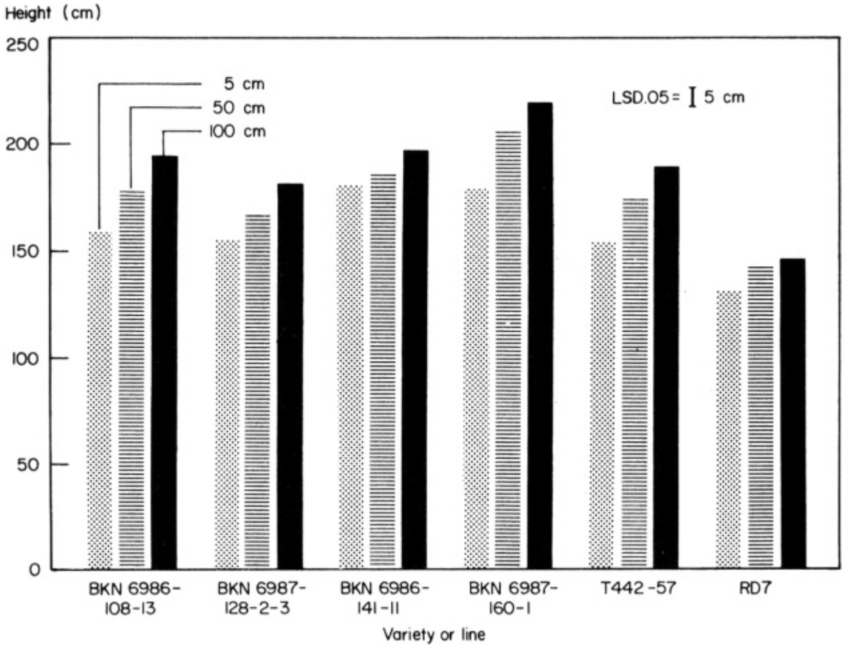
Varietal differences in grain yield were marked between the 5- and 50-cm water depths, and they seem to be unaffected by the elongation ability of each variety. The yields of the two semidwarf entries with elongation ability, BKN 6986-108-13 and BKN 6987-128-2-3, were comparable to the yield of RD7 at 5 cm. These findings suggest that yield potential does not have to be sacrificed when incorporating elongation ability into high yielding, “nonfloating” varieties. This point is discussed in more detail in another paper of this Workshop (Sirikant et al., 1977).



2. Fertilizer responses of six entries grown at three water depths. Huntra Rice Experiment Station, Thailand, 1976 dry season.

The yields of BKN 6987-128-2-3 and BKN 6987-160-1 at 100 cm showed marked reductions when compared to those at 5 cm. The three other entries with elongating ability showed no significant decreases, but RD7 was almost completely destroyed. The advantage of having elongation ability at this water depth was clearly shown when T442-57 and BKN entries were compared with RD7. The data suggest that such forms may have an advantage when flooding for long periods of time is a problem.

Figure 2 shows the response to added N fertilizer of the entries at different water depths. Most treatments showed an increase in grain yield with added N. However, the increases were not statistically significant except at 50 cm. At this depth, T442-57 and RD7 showed a significantly positive response to added nitrogen. The BKN entries' responses to the added nitrogen were not significantly positive, regardless of the water depth. At 5 cm, RD7 failed to show the anticipated degree of fertilizer response. This observation and the relatively high yields even without added fertilizer suggest that the unfertilized soil was quite fertile.



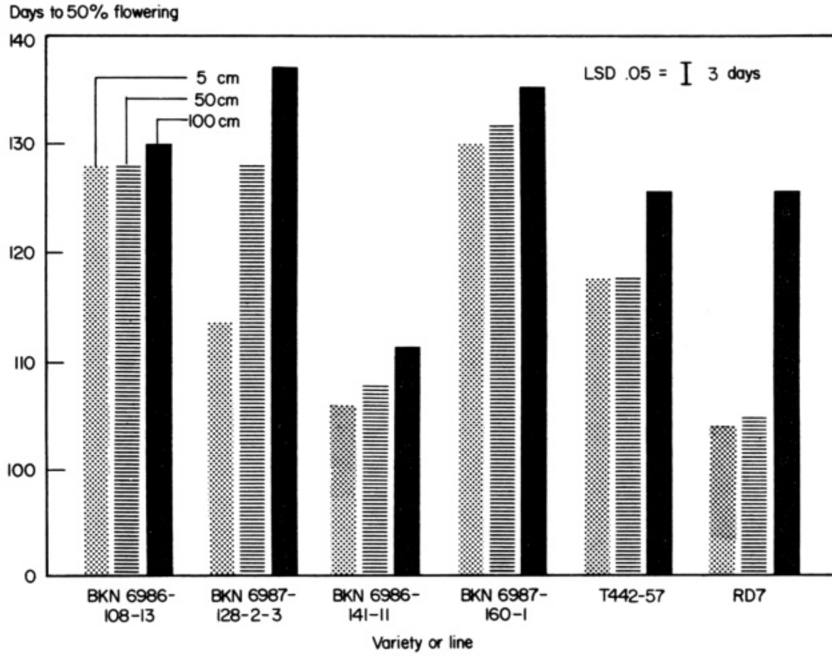
3. Plant height of six experimental lines and varieties grown in 5, 50, and 100 cm of water. Huntra Rice Experiment Station, Thailand, 1976 dry season.

Nevertheless, the positive response obtained with T442-57 suggests that fertilizer can increase grain yields even under medium deep-water conditions.

Of all characteristics measured, plant height was the most consistently affected by water depth. All entries, except BKN 6986-141-11, had significantly taller plants at 50 cm than at 5 cm (Fig. 3). However, BKN 6986-141-11 is relatively tall, so that 50 cm of water did not completely submerge it even at the early stages of growth.

At the 100-cm water depth, all entries except RD7 had significant increases in plant height. RD7 apparently reached its possible plant height under that condition. The height response to water depth is easily seen as an expression of elongation ability; the observation corresponds with previous knowledge about the elongation ability of the entries.

Figure 4 shows flowering response. The increase in water depth from 5 to 50 cm did not significantly delay the flowering time of the entries, except BKN 6987-128-2-3. The increase in water depths from 50 to 100 cm generally delayed flowering except for BKN 6986-108-13. BKN 6987-128-2-3 deserves special mention since it was the shortest of the



4. Days to 50% flowering of six varieties and experimental lines grown at three water depths Huntra Rice Experiment Station, Thailand, 1976 dry season.

deep-water lines used and also the most delayed in flowering. Although originally short and delayed in maturity like RD7, BKN 6987-128-2-3 did not give statistically reduced yields at the 100-cm depth as did RD7.

The entries used were relatively insensitive to photoperiod. Their delayed flowering at the 100-cm water depth shows competition between the elongation process and the leaf and panicle formation processes. This delay may also apply to the photoperiod-sensitive varieties so that flowering dates, although controlled by day length and therefore relatively fixed, may vary depending on the water regime.

SUMMARY

Increases in water depths generally decreased the grain yields of the entries with elongation ability; however, most decreases are not statistically significant. The almost-zero yield of the nonelongating entry at the 100-cm water depth suggests the advantage of the new semidwarf lines with elongation ability in areas where flooding for long periods of time is a problem.

Except for T442-57, entries with elongation ability showed no significant yield increases with added nitrogen. That may result partly from high soil fertility as evidenced by the high yields without added nitrogen. The results obtained with T442-57 suggest that nitrogen fertilizer can increase grain yields even under medium deep-water conditions.

Plant height was generally increased while flowering was generally delayed with increase in water depth.

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DISCUSSION

DE DATTA: It looks like at any water depth fertilizer response is greatest with T442-57. It means that we have a long way to go to develop a variety with good elongating capacity and fertilizer responsiveness.

Kupkanchanakul: It looks that way because the area of sampling was too small.

DE DATTA: Height response to different water depths is similar for entry 1 (BKN 6986-108) and entry 5 (T442-57), but the grain yields are higher for T442-57. How do you explain this difference?

Kupkanchanakul: Also small sample.

DE DATTA: Why were there no differences in the yields of BKN 6986-108 (No. 1) at three water depths?

Kupkanchanakul: I think it is a good line—we have other evidence also. It is a good variety with wide adaptability.

CHOUDHURY: Do you have any observation on the nutrient status of the water?

Kupkanchanakul: No. But at Huntra Station the water that we use in our experimental work is pumped from the canal. That means that the condition of the water in our field is the same as that in the farmer's field.

MANEEPHONG: Do you have any information about the response from foliar application of fertilizer?

Kupkanchanakul: No. But this season we have one experiment on this at Huntra Station with R. Vichai in charge.

VERGARA: Figure 1 shows that in your present experiment, T442 is still the best, but not because of greater plant height or correct maturity. What possible reasons can you give to this superior performance of T442?

Kupkanchanakul: This may be due simply to small yield sampling. If the experiment were repeated, T442 might not be better than the other lines. Breeders need multilocation trials for yield, but in Wiengpet's paper some lines were as good as T442. Also, T442 produced better yields than usual this year.

VERGARA: Are the differences in grain yields statistically significant?

Kupkanchanakul: Yes, they are significant.

Multilocation yield trial of new, photoperiod-insensitive deep-water rice under shallow-water conditions

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C. Boonwite, K. Kupkanchanakul,
S. Somboonpong, W. Wotong, and K. Sirivong

Over the past several years, work on semidwarf rice material with deep-water tolerance and possessing good plant type, stiff straw, and other desirable features has produced a set of true breeding F_7 lines from two hybrid populations of Thai floating varieties. Early studies tested elongation ability and sensitivity to photoperiod, in addition to the usual plant type traits of high yielding varieties (HYV). However, yielding ability and grain quality under shallow-water conditions were not evaluated. Consequently, a multilocation yield trial of the most promising photoperiod-insensitive deep-water selections was initiated in the 1976 dry season. The experiment determined whether selection for elongation ability had adverse effects on yield potential under shallow water, and whether any of the lines should be included in future advanced yield tests for shallow-water areas.

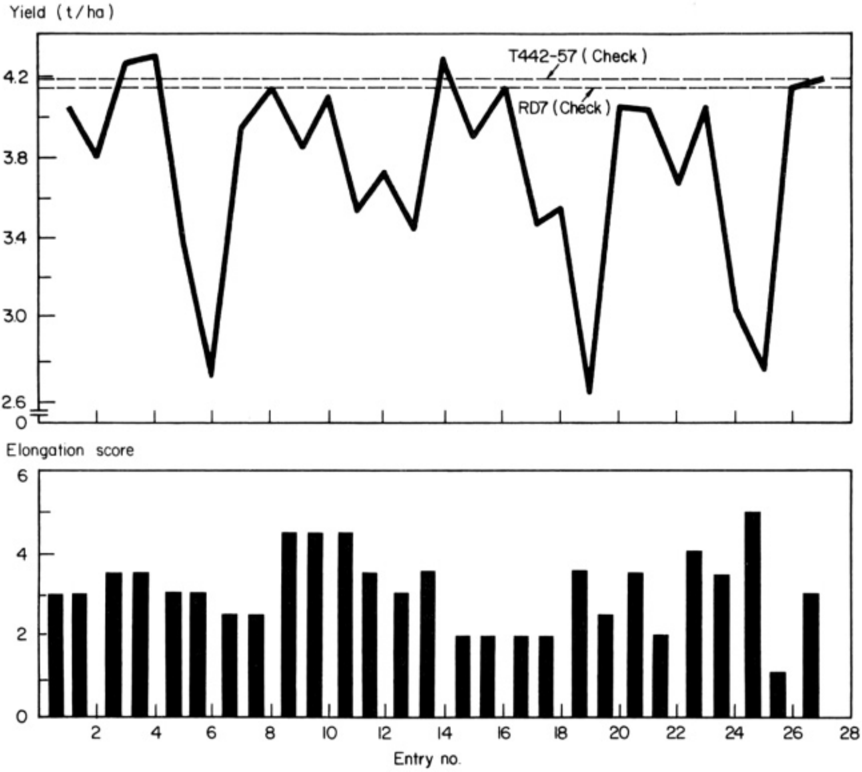
MATERIALS AND METHODS

The experiment used 25 deep water-tolerant lines and two check varieties, namely, RD7 (the newly released, non-elongating, semidwarf HYV), and T442-57 (the deep-water semidwarf prototype). Identical experiments were started at six locations in the Central Plain of Thailand early in February 1976. Seedlings were transplanted at approximately

W. Sirikant, A. Wiengweera, S. Amonsilpa, C. Boonwite, K. Kupkanchanakul, S. Somboonpong, W. Wotong, K. Sirivong. Rice Researchers, Ministry of Agriculture and Cooperatives, G.P.O. Box 2453, Bangkok, Thailand.

22 days of age. Fertilizer was applied at the rate of 75 kg/ha of elemental N and 37 kg/ha of P_2O_5 and K_2O. The experimental design consisted of four replications in a randomized complete block design using 5.0-m-long 5-row plots, with spacing of 25 × 25 cm. Observations were made on flowering date, height, disease incidence, and, where applicable, tolerance of acid sulfate soils. Three locations tended to have low natural fertility and possessed relatively low soil pH values because of the acid sulfate conditions. The other locations had good soil characteristics.

Shallow-water levels were maintained throughout the growing season since the experiment was primarily designed to assess yielding ability. At harvest time, the three center rows of each plot were harvested; grain was dried and corrected to 14% moisture before conversion to kilograms per hectare. Statistical analysis was performed by the Statistics Section, Planning Division.



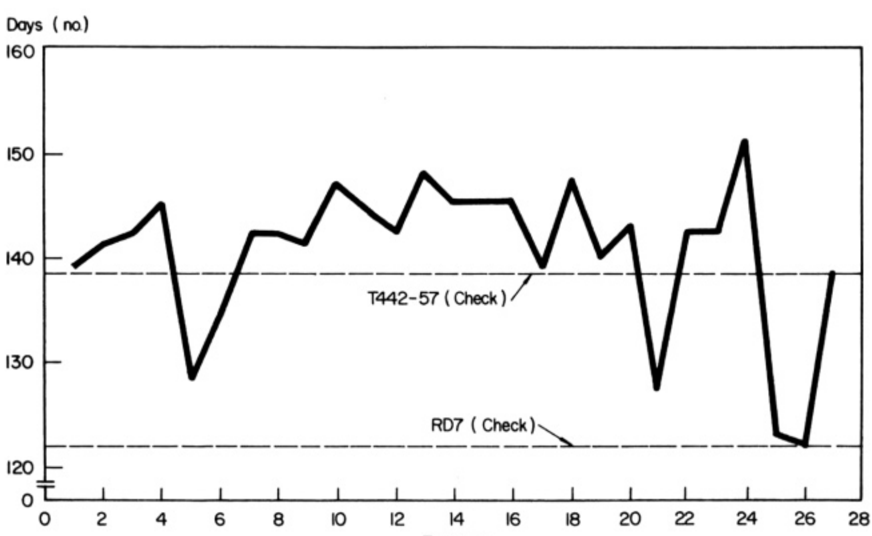
1. Average yield and elongation scores of experimental deep-water lines grown in shallow water at 6 stations, Central Plain, Thailand, 1976 dry season.

RESULTS

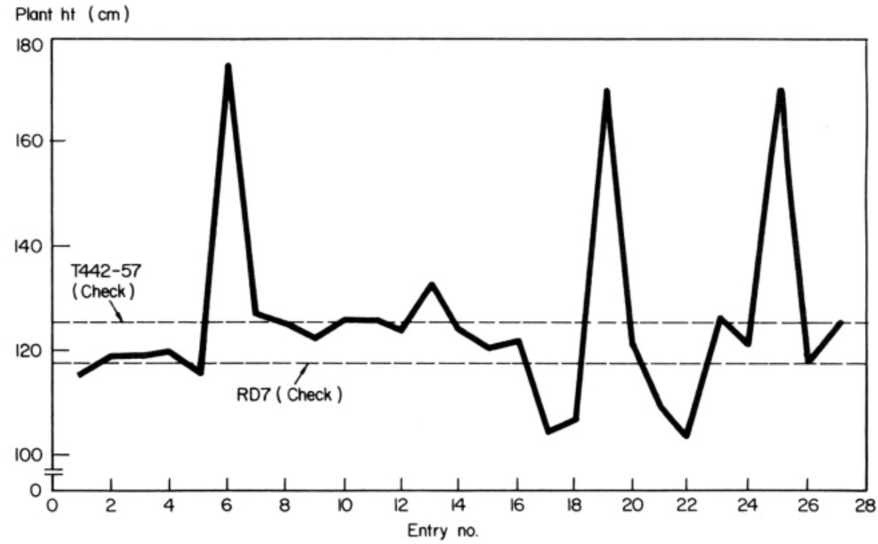
Yielding ability was extremely variable and ranged from about 2.7 to 4.3 t/ha (Fig. 1). Approximately one-half of the lines yielded as much as did the check varieties; the others yielded way below them. The lowest yields were recorded for the taller entries, which in many cases lodged heavily. A comparison of Figures 1 and 3 shows a close relationship between low yields and most tall varieties subjected to heavy fertilization. Some lines with relatively good elongation ability produced low yields; others were as good as the check varieties.

Relative rankings in different locations remained reasonably similar. For example, entry 4 ranked below ten at only one of the six stations; entry 23, which is a semidwarf type, was near the bottom at all locations. Analysis of variance showed highly significant differences among entries, locations, and entries × locations. The coefficients of variability averaged about 12%, which was acceptable under the experimental conditions.

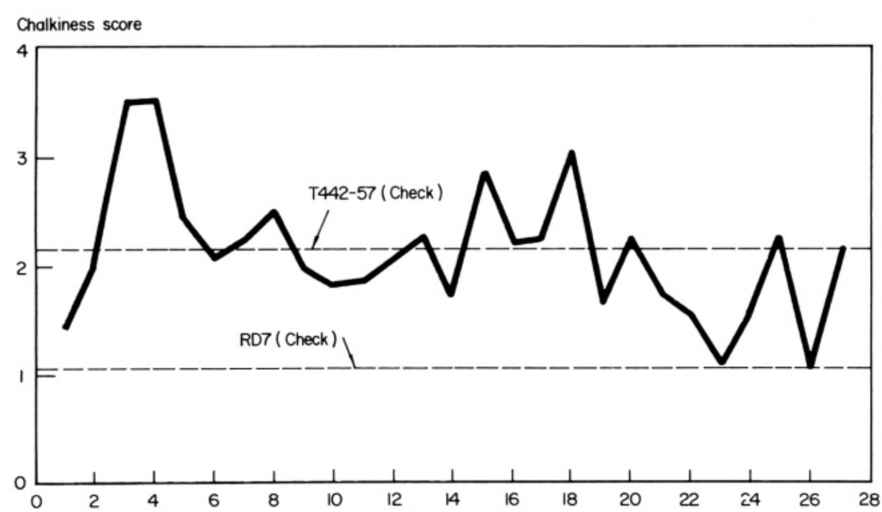
None of the experimental entries flowered as early as RD7. Many flowered later than the T442-57 deep-water check, but one flowered ahead of it by more than 10 days (Fig. 2).



2. Average days to maturity (days from seeding to flowering) of experimental deep-water lines grown in shallow water at 6 stations, Central Plain, Thailand, 1976 dry season.



3. Average height of experimental deep-water lines grown in shallow water at 6 stations, Central Plain, Thailand, 1976 dry season.



4. Average chalkiness of experimental deep-water lines grown in shallow water at 6 stations, Central Plain, Thailand, 1976 dry season.

Plant heights at maturity (Fig. 3) show that except for the three tall entries (no. 6, 19, and 25), the deep-water lines behaved like either T442-57 or RD7. Elongation ability was not necessarily dependent on height; some semidwarfs had proved superior to the taller entries in this respect.

We are concerned that all entries exhibited higher degrees of chalkiness than did RD7 (Fig. 4). Two of the highest yielding entries were also the most chalky, but another high yielder (no. 14) was less chalky than T442-57.

DISCUSSION

The testing of 25 experimentally produced lines with ability to elongate and with only two floating varieties in the parentage admittedly gives a small sample for generalization purposes. Nevertheless, the yield results are encouraging and suggest that the incorporation of elongation ability into dwarf types does not reduce their yield potential per se. If deep-water lines are to be developed for predominantly shallow-water conditions, the yield tests should be done in earlier generations, since several of these lines gave low yields under shallow-water conditions.

The major purpose of this experiment was to assess productivity of deep-water lines in shallow water. The choice becomes important in the wet season when the rice fields are subject to sudden flooding and the risk in planting ordinary HYV is great. A monsoon-season test utilizing the best lines from this experiment is under way to assess performance under such conditions.

In the wet season Thai farmers generally prefer late maturity in the form of photoperiod sensitivity, but a late maturing, photoperiod-insensitive variety might be acceptable in some areas. Plants that are slightly taller than RD7 could also be an advantage when sudden flooding occurs.

Varieties must produce clear grains over a range of environments before the Government of Thailand recommends them. Although both floating-rice parents possessed acceptable grain characteristics, the dwarf donor parent—IR262 (Peta 3/TNl)—tends to be chalky, like IR8. A number of entries had chalkiness ratings that were the same as or lower than those of T442-57. We hope that selection among the better lines will result in reduced chalkiness, even if the character may not have high priority in other countries. Experience has shown that more chalkiness develops in the dry than in the wet season. Since the breeding material presented here is generally too late for use in the dry season, its greatest utilization should be during the monsoon.

The results of the study are sufficiently encouraging to justify continued efforts to breed HYV tolerant of water depths of 100 cm or slightly more. Several lines compared favorably with T442-57, not only in yield but also in disease resistance. Studies on both photoperiod-sensitive and photoperiod-insensitive lines are being continued.

SUMMARY

Twenty-five experimental, deep water-tolerant rice lines were planted in shallow water at six locations in the Central Plain in the 1976 dry season to compare their yield potential with that of the most recently released HYV RD7 and that of the standard, prototype deep water-tolerant check T442-57.

Results showed that approximately 50% of the entries were similar to the two check varieties in productivity. The lines tended to be slightly later maturing than the deep-water check, and all exhibited more chalkiness than did RD7. Yield per se was not lowered by incorporation of the elongation character, but late maturity appeared strongly associated with elongation.

Further research is required to provide better answers to the problems of chalkiness and late maturity. The overall performance of the lines makes us highly optimistic of the possibility of developing improved deep-water types.

DISCUSSION

CHOUDHURY: This trial was conducted at 6 locations and varieties were fixed at each location, so it would be very good to analyze varietal stability. Some very interesting information can be expected from this trial.

Sirikant: We can do that quite easily by determining the magnitude of genotype × location interaction. We may do the analysis and include it in the final version of the paper.

PARK: How did the stability of yield of deep-water lines compare with that of the lowland checks? I guess I am asking for genotype × environment interaction of the two rice types.

Sirikant: Stability of deep-water lines was as good as that of the lowland checks, but we will soon perform statistical analysis to assess genotype × environment variance.

CHOUDHURY: Have you conducted any experiment to determine the maximum yielding ability of any of these varieties under shallow-water or deep-water conditions?

Sirikant: No, we have not attempted to assess absolute maximum yields.

SINANUWONG: What are the symptoms you found in the acid sulfate soil at Bangkhen station? Do you find any Fe-toxicity symptom? What is the pH of the soil?

Sirikant: The symptoms are leaf bronzing and yellowing. We are not sure that the cause is iron toxicity, but we are checking it. The pH of the soil under flooding is about 5.5.

JACKSON: In the future, all new high yielding varieties should have some deep-water tolerance.

Results of the 1975 deep-water rice flowering date survey

D.H. HilleRisLambers

This limited survey of flowering dates of deepwater rice varieties was a follow-up of discussions at the 1975 International Rice Conference at IRRI.

Flowering date studies at six locations provided the data for the survey. Collaborators and their locations were: H. Noorsyamsi and Rusmini Humairi, Kalimantan, Indonesia; P.R. Jennings, Palmira, Colombia; Siriporn Karin and Chalit Setabutara, Bangkhen, Thailand; D.K. Mukherji and S.K. Bardhan Roy, West Bengal, India; M.A. Chowdhury and M. Nasiruddin, Dacca, Bangladesh; and R.P. Sharma, Uttar Pradesh, India.

OBJECTIVES

The study aimed to give interested plant breeders in various deep-water areas an idea of flowering dates of deep-water varieties from other places, and what to expect, in this respect, of their own varieties planted elsewhere.

While adaptation to high water levels is the most important requirement for varieties in deep-water areas, certainly the next most important requirement is days to flowering, or flowering date. A variety that flowers too early or too late will not be successful in deep-water areas, and varieties that are perfectly adapted to the flooding patterns prevailing in one region may be totally out of step with the weather patterns in another area.

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Information on flowering dates is especially important with the increased international cooperation in deep-water rice breeding. Plant breeders could select both the materials they request from their colleagues, and those that they send out to other programs.

MATERIALS AND METHODS

Deep-water varieties were nominated for the survey. The following varieties were selected; all but two are floating rices:

Khao Med Lek, Leb Mue Nahng 111, Sai Bua, and Po Ngern from Thailand; Habiganj A 1, Habiganj A 2, and Habiganj A 8 from Bangladesh; DM 53 (nonfloating), Kekoa Bao, Kalar Harsall, Laki 192, Gowai 84, and ARC 5955 (nonfloating) from India; Nang Tay C and Tau Binh C from Vietnam; Baisbish from Bangladesh and India; and Saran Kraham from Cambodia.

The following instructions were given to cooperators:

1. Plant each variety in May, four plants in a pot with a diameter of 20 cm or more. Use 3 pots per variety, and a total of 12 plants per variety.
2. Record planting date and flowering date of each of the 12 plants in the provided forms. Flowering date is defined as the date when the first panicle becomes visible above the leaf sheath.
3. Send the results to Bangkok, Thailand.

The locations and their latitudes are Kalimantan, 3°20'S; Colombia, 4°00'N; Thailand, 14°00'N; West Bengal, 22°52'N; Bangladesh, 24°00'N; and Uttar Pradesh, 27°00'N.

Definition of terms. The study used the following definitions:

Basic vegetative period—the juvenile growth stage of the plant, not *affected by photoperiod.*

First flowering date—the date on which the first of the 12 plants of a given variety flowered.

50% *flowering*—a median value. Plants were ranked for flowering date; for an even number of surviving plants, the two central ranking values were averaged; for an uneven number of plants, the central ranking value was obtained.

Time to flowering—the difference in days between the date of sowing and the date of 50% flowering.

Floral initiation date—the date obtained after 35 days are subtracted from the flowering date (50% flowering).

Photoperiod-sensitive rice variety—a rice variety whose number of days to flowering is influenced by the photoperiod, or sequence of photoperiods, to which it has been exposed before flowering.

Photoperiod-insensitive rice variety—a rice variety whose number of days to flowering is independent of the photoperiods to which it has been exposed before flowering.

Strongly photoperiod-sensitive variety—a photoperiod-sensitive variety that will not flower at photoperiods longer than a certain threshold value.

Critical photoperiod—the threshold photoperiod, or the longest photoperiod at which a strongly photoperiod-sensitive variety can still be induced to flower.

Optimal photoperiod—the photoperiod, out of a range of varying lengths, at which a photoperiod-sensitive variety shows the shortest duration to flowering.

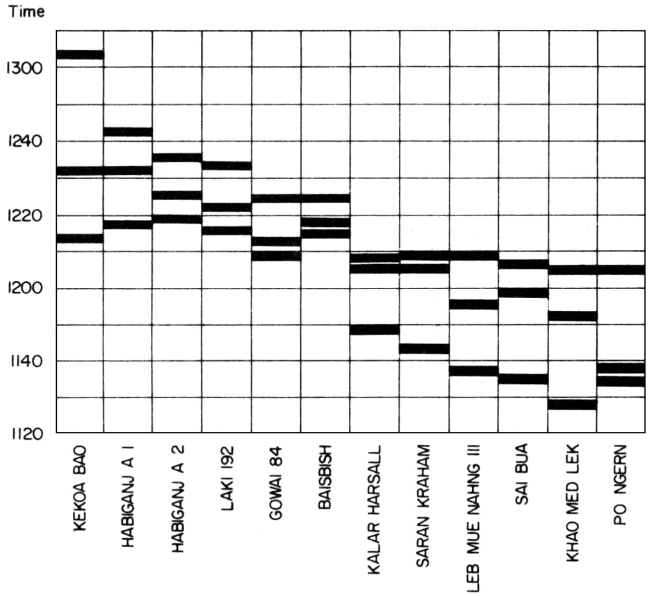
Problems in data collections. Some significant problems were met in the collection of data.

Poor germination. Some entries either failed to germinate or germinated poorly. Incomplete but acceptable germination (1 to 6 failures only) was shown by Saran Kraham in Colombia, Habiganj A 8 in Thailand, and Tau Binh C and Baisbish in West Bengal.

Failure to flower. The Thai and Cambodian varieties often failed to flower, especially at the more northern locations. That may be explained as a complex interaction of genotype (low critical photoperiod), latitude (short photoperiods are reached only late in the season at northern latitudes), and growth conditions (low nutritional status, low temperatures). Entries that failed to flower before the experiment was stopped were marked LF (late flowering). In three cases—Po Ngern and Saran Kraham in Colombia, and Po Ngern in Thailand—six or more plants failed to flower, making it impossible to deduct a 50% flowering date, even though the first flowering date could be determined.

Irregular flowering. The first flowering date has been used prominently in summarizing the results. In some cases, the difference between the first flowering date and the date on which the second plant flowered was unacceptably high. If the difference was 13 days or more, the date the second plant flowered was used instead.

Incomplete data. As a result of the problems encountered, some locations (Kalimantan, West Bengal, and Uttar Pradesh) and some varieties (Nang Tay C, Tau Binh C, and Habiganj A 8) gave rather incomplete data. A comprehensive set of three locations in different latitudes with complete data on 14 varieties was obtained. Figure 1 is based on this set, which excludes the two nonfloating, photoperiod-insensitive varieties DM 53 and ARC 5955.



1. Estimated photoperiods at floral initiation for 12 varieties and for three locations (Colombia, Thailand, and Bangladesh).

RESULTS

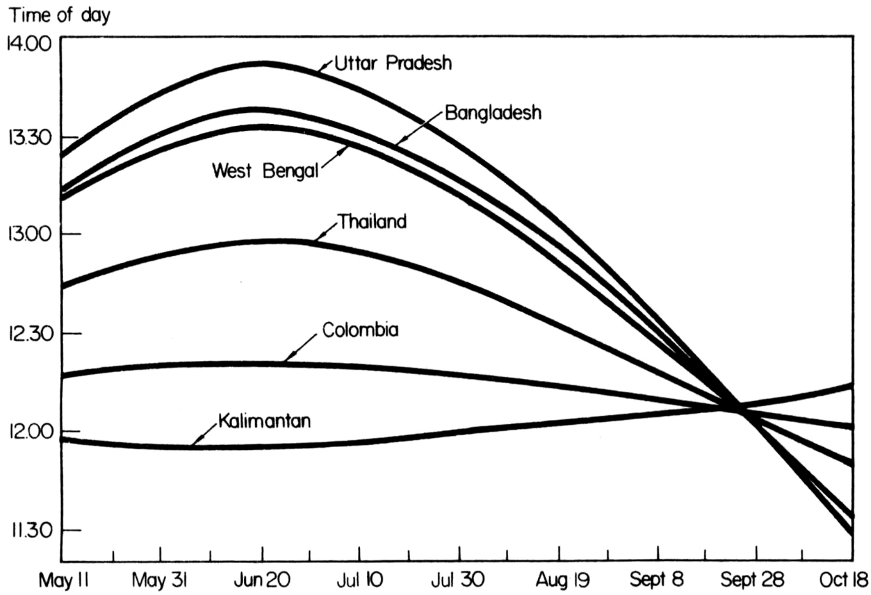
The following observations are especially worth making:

Kalimantan is the only location where the photoperiod started low and increased progressively (Fig. 2). The five other locations started with a long photoperiod which decreased throughout the growth period.

In Kalimantan, some Bangladesh varieties and some Indian entries flowered very early. Other varieties, including most Thai entries, failed to flower 121 days after seeding. The latter group probably represents varieties with either a long basic vegetative period, or a short critical photoperiod, or both (Table 1, 2). The resulting photoperiod was too long by the time the variety had completed the basic vegetative period.

Habiganj A 1 had floral initiation on June 9, at the age of 9 days, in Kalimantan (Table 3). This observation is remarkable, but not new. Vergara (*personalcommunication*) has found this variety to have a basic vegetative period of 6 days.

The time to flowering and the flowering dates in Kalimantan show little correlation with those in any of the five other locations. Among those five sites the ranking changed very little. However, with higher northern latitudes, the difference between the earliest and the latest



2. Duration-of-daylight curves for six locations: Kalimantan, Colombia, Thailand, West Bengal, Bangladesh, and Uttar Pradesh.

groups increased, and date of 50% flowering and time to flowering occurred later.

On the basis of data in Tables 1 to 4 and in Figure 1, the varieties can be grouped according to earliness of flowering and photoperiod sensitivity (Table 5):

1. Photoperiod insensitive: DM 53, ARC 5955, Kekoa Bao
2. Photoperiod sensitive: Habiganj A 1, Habiganj A 2, Laki 192
3. Photoperiod sensitive: Habiganj A 8, Gowai 84
4. Photoperiod sensitive: Tau Binh C, Baisbish
5. Photoperiod sensitive: Kalar Harsall, Saran Kraham
6. Photoperiod sensitive: Nang Tay C, Leb Mue Nahng 111, Sai Bua
7. Strongly photoperiod sensitive: Khao Med Lek, Po Ngern

Flowering dates based on five plants or less often deviated markedly in neighboring sites, especially for Habiganj A 8 and Nang Tay C (Table 1). Ignoring such data on an *a priori* basis as was done in Figure 1 would be good practice in the future.

In the above grouping, the first mentioned group was the earliest, and the first mentioned variety was the earliest within the group. The distinction between insensitivity and sensitivity to day length was made on the basis of both the longest photoperiod at which flowering was

Table 1. Flowering dates[a] for 17 deep-water rice varieties planted at six locations, 1975 Deep-Water Rice Flowering Date Survey.

Variety	Flowering date					
	Kalimantan (Banjar-masin)	Colombia (Palmira)	Thailand (Bang-khen)	West Bengal (Chinsurah)	Bangla-desh (Dacca)	U. Pradesh (Ghogra-ghat)
Khao Med Lek	LF	3 Nov 6 Nov	15 Nov 15 Nov	LF	25 Nov 27 Nov	LF
Leb Mue Nahng 111	24 Jul 24 Jul	18 Oct 20 Oct	12 Nov 13 Nov	LF	19 Nov 20 Nov	26 Nov 28 Nov
Sai Bua	LF	27 Oct 27 Oct	7 Nov 12 Nov	LF	20 Nov 22 Nov	30 Nov 2 Dec
Po Ngern	LF	3 Nov 12 Nov	3 Dec LF	LF	20 Nov 23 Nov	LF
Habiganj A 1	14 Jul 15 Jul	8 Sep 15 Sep	25 Sep 25 Sep	8 Oct 12 Oct	2 Oct 2 Oct	17 Oct 20 Oct
Habiganj A 2	24 Jul 27 Jul	25 Aug 23 Sep	4 Oct 4 Oct	21 Oct 22 Oct	7 Oct 8 Oct	20 Oct 21 Oct
Habiganj A 8	LF		12 Oct 13 Oct		24 Oct 25 Oct	22 Oct 23 Oct
DM 53	24 Jul 27 Jul	22 Aug 23 Aug	4 Jul 4 Jul	16 Aug 18 Aug	8 Jul 9 Jul	5 Sep 7 Sep
Kekoa Bao	LF	25 Sep 7 Oct	25 Sep 3 Oct	26 Sep 24 Oct	16 Sep 20 Sep	20 Oct 22 Oct
Kalar Harsall	LF	27 Oct 31 Oct	28 Oct 2 Nov	9 Nov 10 Nov	10 Nov 11 Nov	14 Nov 16 Nov
Laki 192	21 Jul 25 Jul	15 Sep 26 Sep	23 Sep 26 Sep	10 Oct 17 Oct	17 Oct 18 Oct	26 Oct 28 Oct
Gowai 84	27 Aug 27 Aug	20 Oct 28 Oct	6 Oct 12 Oct	27 Oct 28 Oct	24 Oct 25 Oct	28 Oct 30 Oct
ARC 5955	5 Aug 20 Aug	3 Sep 3 Sep	29 Jul 30 Jul	5 Sep 5 Sep	28 Jul 29 Jul	12 Sep 14 Sep
Nang Tay C					14 Nov 15 Nov	3 Dec 6 Dec
Tau Binh C			16 Oct 23 Oct	30 Oct 30 Oct	1 Nov 1 Nov	28 Oct 30 Oct
Baisbish	13 Aug 13 Aug	15 Sep 15 Sep	6 Oct 6 Oct	28 Oct 7 Nov	20 Oct 21 Oct	28 Nov 29 Nov
Saran Kraham	LF	20 Oct 27 Oct	29 Oct 6 Nov		14 Nov 14 Nov	17 Nov 18 Nov

[a] Upper date = first flowering date; lower date = 50% flowering; LF = did not flower before 8 Sep (Kalimantan), 6 Dec (Thailand), 20 Nov (West Bengal), and 3 Dec (Uttar Pradesh); blanks indicate no information. Planting dates were 1 June for Kalimantan, 9 June for Colombia, 12 May for Thailand (transplanted 19 May), 26 May for West Bengal, 9 May for Bangladesh, and 22 May for Uttar Pradesh (transplanted 3 July).

Table 2. Days from seeding to flowering[a] for 17 deep-water rice varieties planted in six locations, 1975 Deep-Water Rice Flowering Date Survey.

Variety	Days from seeding to flowering					
	Kalimantan (Banjar-masin)	Colombia (Palmira)	Thailand (Bang-khen)	West Bengal (Chinsurah)	Bangla-desh (Dacca)	U. Pradesh (Ghogra-ghat)
Khao Med Lek	LF	150	187	LF	202	LF
Leb Mue Nahng 111	53	133	185	LF	195	190
Sai Bua	LF	140	184	LF	197	194
Po Ngern	LF	156	LF	LF	198	LF
Habiganj A 1	44	98	136	139	146	151
Habiganj A 2	56	106	145	149	152	152
Habiganj A 8	LF		154		169	154
DM 53	56	75	53	84	61	108
Kekoa Bao	LF	120	144	151	134	153
Kalar Harsall	LF	144	174	168	186	178
Laki 192	54	109	137	144	162	159
Gowai 84	87	141	153	155	169	161
ARC 5955	80	86	79	102	81	115
Nang Tay C					190	198
Tau Binh C			164	157	176	161
Baisbish	73	98	147	165	165	191
Saran Kraham	LF	140	178		189	180

[a]Based on median flowering dates. LF = did not flower before 100 days (Kalimantan), 208 days (Thailand), 178 days (West Bengal), 195 days (Uttar Pradesh).

induced, and the degree of variation in the estimates of photoperiod at floral initiation, measured at different locations. The comparison between Habiganj A 1 and Kekoa Bao illustrates the method of classification: although Kekoa Bao on the average flowered later than Habiganj A 1 the estimated photoperiod at floral induction was much more variable for it than for Habiganj A 1.

The variety Baisbish flowered more than a month later in Uttar Pradesh than in Bangladesh and West Bengal. That was the only puzzling aspect of an otherwise quite consistent behavior, it only slightly influenced the above grouping.

Several Thai varieties that flowered in Bangladesh failed to do so in West Bengal, although the Bangladesh site is farther north than the site in West Bengal. Possibly temperature or nutritional differences between

Table 3. Estimated dates of floral initiation[a] for 17 deep-water rice varieties planted in six locations, 1975 Deep-Water Rice Flowering Date Survey.

Variety	Date of floral initiation					
	Kalimantan (Banjar-masin)	Colombia (Palmira)	Thailand (Bang-khen)	West Bengal (Chinsurah)	Bangla-desh (Dacca)	U. Pradesh (Ghogra-ghat)
Khao Med Lek	LF	29 Sep 2 Oct	11 Oct 11 Oct	LF	21 Oct 23 Oct	LF
Leb Mue Nahng 111	19 Jun 19 Jun	13 Sep 15 Sep	8 Oct 9 Oct	LF	15 Oct 16 Oct	22 Oct 24 Oct
Sai Bua	LF	22 Sep 22 Sep	3 Oct 8 Oct	LF	16 Oct 18 Oct	26 Oct 28 Oct
Po Ngern	LF	29 Sep 8 Oct	29 Oct LF	LF	16 Oct 19 Oct	LF
Habiganj A 1	9 Jun 10 Jun	4 Aug 11 Aug	21 Aug 21 Aug	3 Sep 7 Sep	28 Aug 28 Aug	12 Sep 15 Sep
Habiganj A 2	19 Jun 22 Jun	21 Jul 19 Aug	30 Aug 30 Aug	16 Sep 17 Sep	2 Sep 3 Sep	15 Sep 16 Sep
Habiganj A 8	LF		7 Sep 8 Sep		19 Sep 20 Sep	17 Sep 18 Sep
DM 53	19 Jun 22 Jun	18 Jul 19 Jul	30 May 30 May	12 Jul 14 Jul	3 Jun 4 Jun	1 Aug 3 Aug
Kekoa Bao	LF	21 Aug 2 Sep	21 Aug 29 Aug	22 Aug 19 Sep	12 Aug 16 Aug	15 Sep 17 Sep
Kalar Harsall	LF	22 Sep 26 Sep	23 Sep 28 Sep	4 Oct 5 Oct	6 Oct 7 Oct	10 Oct 12 Oct
Laki 192	16 Jun 20 Jun	11 Aug 22 Aug	19 Aug 22 Aug	5 Sep 12 Sep	12 Sep 13 Sep	21 Sep 23 Sep
Gowai 84	23 Jul 23 Jul	15 Sep 23 Sep	1 Sep 7 Sep	22 Sep 23 Sep	19 Sep 20 Sep	23 Sep 25 Sep
ARC 5955	11 Jul 16 Jul	30 Jul 30 Jul	24 Jun 25 Jun	1 Aug 1 Aug	23 Jun 24 Jun	8 Aug 10 Aug
Nang Tay C					10 Oct 11 Oct	29 Oct 1 Nov
Tau Binh C			11 Sep 18 Sep	25 Sep 25 Sep	27 Sep 27 Sep	23 Sep 25 Sep
Baisbish	9 Jul 9 Jul	11 Aug 11 Aug	1 Sep 1 Sep	23 Sep 3 Oct	15 Sep 16 Sep	24 Oct 25 Oct
Saran Kraham	LF	15 Sep 22 Sep	24 Sep 2 Oct		10 Oct 10 Oct	12 Oct 14 Oct

[a] Upper date = first flowering date; lower date = median flowering date. LF = did not flower before experiment was terminated.

Table 4. Estimated day lengths [a] at dates of floral initiation for 17 deep-water rice varieties planted in six locations, 1975 Deep-Water Rice Flowering Date Survey.

	Day length (h, min) at floral initiation					
Variety	Kalimantan (Banjarmasin)	Colombia (Palmira)	Thailand (Bangkhen)	West Bengal (Chinsurah)	Bangladesh (Dacca)	U. Pradesh (Ghograghat)
Khao Med Lek	LF	12 05 12 04	11 53 11 53	LF	11 29 11 26	LF
Leb Mue Nahng 111	11 56 11 56	12 09 12 09	11 55 11 54	LF	11 37 11 36	11 22 11 19
Sai Bua	LF	12 07 12 07	11 59 11 55	LF	11 36 11 33	11 16 11 13
Po Ngern	LF	12 05 12 03	11 40	LF	11 36 11 31	LF
Habiganj A 1	11 56 11 56	12 17 12 16	12 32 12 32	12 33 12 28	12 42 12 42	12 25 12 20
Habiganj A 2	11 56 11 56	12 19 12 14	12 25 12 25	12 16 12 14	12 36 12 34	12 20 12 18
Habiganj A 8	LF		12 19 12 18		12 12 12 11	12 16 12 15
DM 53	11 56 11 56	12 20 12 19	12 54 12 54	13 27 13 26	13 32 13 33	13 24 13 21
Kekoa Bao	LF	12 14 12 11	12 32 12 26	12 48 12 12	13 03 12 57	12 20 12 16
Kalar Harsall	LF	12 07 12 06	12 07 12 03	11 52 11 51	11 49 11 47	11 40 11 37
Laki 192	11 56 11 56	12 16 12 14	12 33 12 31	12 30 12 21	12 22 12 21	12 10 12 07
Gowai 84	11 58 11 58	12 09 12 06	12 23 12 19	12 08 12 07	12 12 12 11	12 07 12 04
ARC 5955	11 57 11 57	12 18 12 18	12 57 12 57	13 12 13 12	13 37 13 37	13 16 13 13
Nang Tay C					11 44 11 42	11 12 11 07
Tau Binh C			12 16 12 10	12 04 12 04	12 01 12 01	12 07 12 04
Baisbish	11 56 11 56	12 16 12 16	12 23 12 23	12 07 11 53	12 18 12 15	11 19 11 17
Saran Kraham	LF	12 09 12 07	12 06 12 00		11 44 11 44	11 36 11 34

[a] Upper values = first flowering date; lower values = median flowering dates. LF = did not flower before experiment was terminated.

locations were responsible for the discrepancy. It must also be noted that in Bangladesh the test was planted 17 days earlier than in West Bengal.

The variety Kalar Harsall flowered consistently around late October or early November. The date of floral initiation is around September 21, the focal point of the photoperiod curves (Table 3, Fig. 2). Theoretically one may expect strongly photoperiod-sensitive varieties having

Table 5. Grouping of 17 varieties into seven groups on the basis of flowering dates, 1975 Deep-Water Rice Flowering Date Survey.

	Flowering date [a]					
	Kalimantan	Colombia	Thailand	West Bengal	Bang-ladesh	Uttar Pradesh
DM 53, ARC 5955, Kekoa Bao	–	6 Sep	9 Aug	5 Sep	7 Aug	2 Oct
HA 1, HA 2, Laki 192	20 Jul	6 Sep	27 Sep	13 Oct	9 Oct	21 Oct
HA 8, Gowai 84	27 Aug	20 Oct	9 Oct	27 Oct	24 Oct	25 Oct
Tau Binh C, Baisbish	–	–	11 Oct	29 Oct	26 Oct	–
Kalar Harsall, Saran Kraham	LF	24 Oct	28 Oct	9 Nov	12 Nov	10 Nov
Nang Tay C, Leb Mue Nahng 111, Sai Bua	–	–	10 Nov	–	18 Nov	30 Nov
Khao Med Lek, Po Ngern	LF	3 Nov	24 Nov	LF	22 Nov	LF

[a]— = no realistic average could be calculated due to missing data. LF = did not flower before experiment was terminated.

a critical day length of 12 hours, 7 minutes or thereabouts, to flower at the same date, regardless of northern latitude when planted around May.

The grouping suggests the possibility of international exchange of material among floating-rice breeding stations: for the first three groups, exchange among the states of India should be without problems; groups 4 and 5 appear promising for farther reaching exchange all the way from southern Vietnam to northern India. For those five groups, the critical photoperiod was close to that reached at the focal point of the day length curves.

The last two groups appear to be limited in their applicability to Thailand, Cambodia, and Vietnam.

DISCUSSION OF RESULTS

This limited survey has shown that, even though the theory of photoperiod sensitivity in rice is more or less recognizable in the results, major problems still exist in the practical application of the various parameters that have been extracted. The observed variation in estimates for day length at floral initiation would not, even if translated into flowering dates of any one of the six curves (Fig. 2), be an acceptable predictor of flowering dates.

For the time being, however, plant breeders who want to compare the photoperiod reactions of one variety under several environments, or of an array of varieties under the same photoperiod, will have to do empirical studies like the one presented here.

The basic difficulty in linking theory to practice is that theoretical work on photoperiod uses results from a range of day length treatments that are held constant. In the present experiment, materials were exposed to the natural pattern of changing photoperiods, on which were superimposed climatic and other differences among locations.

Twilight, a confusing source of extra day length, is controlled in theoretical work, but the literature study of Vergara et al. (1969) mentions it as a relevant modificator of flowering time in some cases.

Photoperiods at floral initiation, obtained from the first flowering dates, were less variable among themselves in most cases than those at 50% flowering. The first flowering date of Po Ngern in Thailand gave the only realistic estimate because less than half of the plants ever flowered.

CONCLUSIONS AND IMPLICATIONS FOR FUTURE WORK

The study suggests that the only reliable guide in predicting the flowering behavior of a variety in a certain location is data obtained from actually growing that variety there.

In view of observed and supposed influence of environmental factors, future experiments should be planted in a field instead of in pots, and they should follow the farmers' growing season as closely as possible. Furthermore, the assortment of varieties from the previous test may be reduced with little loss of information by removal of DM 53, ARC 5955, Habiganj A 1, Habiganj A 8, Tau Binh C, Baisbish, Nang Tay C, Sai Bua, Khao Med Lek, and Po Ngern. Other varieties of unknown flowering behavior, preferably new hybrid lines coming from the various deep-water rice breeding programs, could then be added.

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DISCUSSION

SUBIYANTO: You mentioned that flowering is also affected by temperature, besides photoperiod. How would you separate the effects of these factors, and the practical application for breeding purposes? Would it be helpful if, beside field nurseries, a check experiment is conducted in the greenhouse under better controlled conditions?

HilleRisLambers: Separation of effects using the greenhouse would be most instructive. However, this trial was only empirical. Thus, the test varieties had to be exposed to whatever factors affect flowering.

VERGARA: What are the differences among the five types of photoperiod-sensitive varieties?

HilleRisLambers: The classification has no relevance other than that it is a grouping of 14 varieties into 5 groups with close correspondence within groups regarding flowering date in the various locations.

VERGARA: I think your data have shown conclusively that the critical photoperiod of a variety, as determined under field conditions, is not a good criterion for determining the date of flowering of that variety when planted at a different latitude. Therefore. the best way to find out which lines planted in Bangkok will flower more or less at the right time in Dacca is to plant a variety from Dacca together with the lines planted in Bangkok. For example, Habiganj A-1 types flower between October 2 and 22 in Dacca, and between September 25 and October 5 in Bangkok. Lines flowering between September 25 and October 5 in Bangkok would be more likely to have suitable flowering dates in Dacca. One should not send the Leb Mue Nahng 111 types, which flower on November 13, to Dacca as they will flower very late there.

ZAMAN: Are these data from 1 year's result?

HilleRisLambers: Yes, but there is a follow-up on these experiments in Kalimantan and in Bangkhen.

ZAMAN: In Bangladesh, when varieties are introduced from equatorial regions (0–5°) they flower in the first season normally when grown in the June-November growing season, but in subsequent years they gradually deteriorate and ultimately fail to flower and reproduce. It seems there are some factors other than photoperiod and temperature that control flowering and grain formation. Will you please comment on this?

HilleRisLambers: I have no experience with this effect. I would look for a seed source effect.

Preliminary observations of deep-water rice pests in Bangladesh

S. Alam and H.D. Catling

In Bangladesh, deep-water rice is planted in about 2 M ha. It is sown in March and April and harvested in November and December. Deep-water rice belongs to a complex and ancient agroecosystem with a delicate faunal balance that is relatively undisturbed by pesticides. Very little systematic work has been carried out on its pests and diseases. Conflicting conclusions have been drawn on the importance of various pest species. Apart from the data for the ear-cutting caterpillar, no reliable assessment of crop loss is available. Because deep-water rice is usually a low-value crop, the application of pesticides is warranted only in serious pest outbreaks.

During the First International Seminar on Deep-Water Rice in Bangladesh in 1974, four papers from Bangladesh were presented, and information on pests and diseases in the region was evaluated. The present paper summarizes the situation in Bangladesh from 1974.

RECENT SURVEYS

Observations at intervals of 3 to 4 weeks were made from October 1974 to November 1975 in a typical, extensive deep-water rice area around Agrakhola village (Keraniganj, Dacca District). Direct counts and observations were made and sweep-net samples occasionally taken. In 1975, seven local rice varieties were planted in March and harvested in

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Table 1. Activity of insect pests in deep-water rice fields at Agrakhola, Dacca district, Bangladesh, October 1974 to November 1975.

Period	Field crops	Pest incidence
Winter (Dec. to Mar.) dryland	Deep-water rice stubble, boro rice, pulses, gram, weeds	Ear-cutting caterpillar (diapausing in stubble) on alternate host plants: green leafhoppers, orange-headed leafhopper, brown planthopper, rice leaf folder moths, rice skipper, rice butterfly, leaf beetles—9 species, white leafhoppers, whitebacked planthopper, grasshoppers
Early summer (Mar. to early June) preflood	Deep-water rice at early tillering stage	Rice seedling fly, pink borer, leaf beetles — several species, whitebacked planthopper, green leafhopper, rats
Monsoon (June to Aug) flood	Deep-water rice at stem elongation and tillering stages	Yellow borer, dark-headed borer, pink borer, leaf beetles, grasshoppers—5 species, leaf folder, rice thrips, rice hairy caterpillar, large numbers of spiders
Later summer (Sept. to Nov.) Flood receding	Deep-water rice at reproductive stage	Yellow borer, dark-headed borer, pink borer, rats, large numbers of spiders

November. The incidence of pests and diseases was very low and no outbreaks were observed. Two of the most dangerous pests, ear-cutting caterpillar and *ufra* nematode, did not appear in the growing crop. The activity of insect pests is summarized in Table 1.

Short field trips were made in 1974 to determine the species composition of rice stem borers in deep-water rice (Alam and Catling, 1976). In Barisal district in September, the yellow borer was predominant and the dark-headed borer occasionally appeared. Yellow borer larvae were predominant, and a single dark-headed borer was recorded in 11 observations in infested fields between Daudkandi and Madhabpur in the central eastern part of the country. Nematode parasites and microorganisms were associated with those larvae. In the same month, yellow borer larvae and a single pink borer larva that cause whiteheads were recorded in a small outbreak at Habiganj.

DEEP-WATER RICE PESTS IN BANGLADESH

Alam (1974, 1975) made checklists of deep-water rice pests. Khan (1975) described the pest management of deep-water rice and Miah (1975) described major diseases. Additional insect pests recorded in deep-water

Table 2. Preliminary checklist of deep-water rice pests in Bangladesh (After S. Alam, 1974, 1975; Alam and Catling, 1976).

Common name	Scientific name	Family	Plant stage most affected
Ear-cutting caterpillar [a]	*Mythimna separata* (Walk.)	Noctuidae	Ripening
Yellow rice borer [a]	*Tryporyza incertulas* (Walk.)	Pyralidae	All stages
Dark-headed rice borer [a]	*Chilo polychrysa* (Meyr.)	Pyralidae	"
Pink borer	*Sesamia inferens* (Walk.)	Noctuidae	Not applicable
Rice leaf folder [a]	*Cnaphalocrosis medinalis* Guen.	Pyralidae	Vegetative stage
Rice hispa [a]	*Dicladispa armigera* (Oliv.)	Hispidae	Mid tillering
Rice green leafhoppers [a]	*Nephotettix virescens* (Distant)	Cicadellidae	Mid tillering to ripening
	Nephotettix nigropictus (Stål)	Cicadellidae	Vegetative
Whitebacked planthopper [a]	*Sogatella furcifera* (Horv.)	Delphacidae	”
Rice bug [a]	*Leptocorisa acuta* (Thunb.)	Coreidae	Reproductive stage
Grasshoppers [a]	*Heiroglyphus banian* F.	Acrididae	All stages
	Oxya sp.	Acrididae	”
Rice leaf butterfly	*Melanitis leda ismena* Cramer	Satyridae	Reproductive stage
Ufra nematode [a]	*Ditylenchus angustus* (Butler) Filipjev.		Vegetative stage
Swarming caterpillar	*Spodoptera mauritia* (Boisd.)	Noctuidae	” (preflood)
Mealy bug	*Ripersia oryzae* Green	Coccidae	(Dry conditions)
Mole cricket	*Gryllotalpa africana* (P. de Beauv.)	Gryllotalpidae	Seedling (preflood)
Rice seedling fly	*Atherigonia* sp.	Anthomyiidae	
Leaf eating beetles	–	–	All stages
Rice thrips	Several species	–	Early vegetative stage
Rice hairy caterpillar	*Dasychira securis* Hb.	Lymantriidae	All stages
Rats	5 species	–	
Birds	–	–	Ripening
Fish	6 species	–	
Crabs	–	–	Tillering stage
Snails	–	–	

[a] Has major pest status.

rice by Alam and Catling (1976) included the pink borer, rice mealy bug, rice swarming caterpillar, mole cricket, rice seedling fly, rice thrips, and rice hairy caterpillar. An updated checklist for Bangladesh is in Table 2.

Most insect pests move into deep-water rice from adjacent rice crops and alternate hosts. But to date, the whorl maggot (*Hydrellia* sp.) and rice gall midge (*Pachydiplosis oryzae* (Wood-Mason)) have not been recorded in deep-water rice in Bangladesh (S. Alam, 1975).

Pest species associated with plant diseases are the nematode causing *ufra* disease, and the green leafhoppers that are vectors of tungro disease. Tungro disease was recorded in deep-water rice in Bangladesh (Miah, 1975).

NOTES ON MAJOR PESTS

Ear-cutting caterpillar. The ear-cutting caterpillar is a noctuid that had been wrongly identified as *Pseudaletia unipuncta* (Haw.). It is a major pest causing serious crop loss in some areas of Bangladesh. In 1975 M.Z. Alam made detailed bioecological studies on the species, In 1975, he described outbreaks of the pest in deep-water rice. Severe outbreaks, which may cause total crop loss within a few days, occur in the ripening stage as the floodwater recedes. In October and November, the gregarious sixth-instar stage of the fourth brood cuts down rice panicles during ravenous night feeding. When environmental conditions are particularly favorable, population densities may increase 100 to 150 times between successive generations. Outbreaks are associated with hot, dry spells (in August and September) followed by periods of cloudy overcast weather. Those conditions are believed to encourage outbreaks by disturbing the natural enemies that include at least eight larval parasites and several microorganisms. It is claimed that heavier use of pesticides has brought about more regular outbreaks of the pest. Outbreaks can be predicted by assessing the larval population density earlier in the season. Control measures consist largely of aerial sprays applied in early morning or late afternoon.

Rice stem borers. Stem borers, which cause the well-known deadhearts and whiteheads, appear to be the most persistent pest group. Some workers claim that borer damage is a major yield constraint in susceptible varieties in some localities. However, that has yet to be confirmed since no crop loss assessments have been made.

The yellow borer is usually predominant throughout the deep-water rice growing season. The dark-headed borer appears less regularly although at times it may outnumber the yellow borer (Alam and

Catling, 1976). Yellow borer moths are most active in October when large numbers are seen on the leaves of deep-water rice plants (Alam, 1974, 1975). The pink borer is rare (Islam, 1976; Alam and Catling, 1976). It is believed to be less adapted to deep-water rice since its oviposition sites, the leaf sheaths, are often under water (Islam, 1976). However, another explanation is that the pink borer is usually more active in winter and spring when deep-water rice is not available. In winter the yellow borer diapauses in the larval and pupal stages in rice stubbles; the dark-headed and pink borers do not enter diapause (Alam, 1974, 1975; Islam, 1976). It is reported that borer populations are reduced after the removal of rice stubbles or after the growing of alternate crops in rabi (Islam, 1976).

Ufra. *Ufra* (Miah, 1975) is caused by a nematode that is an obligate parasite of deep-water rice. It attacks the meristem and causes total crop loss in susceptible varieties. Early infestations are the most dangerous, and symptoms appear from August onwards. The disease is spread slowly by water currents. Under dry conditions the nematode overwinters in a coiled, dormant state. About 2% of the deep-water rice in Bangladesh is affected. Sources of varietal resistance have been found.

SUMMARY

There has been little systematic research on the pests and diseases of deep-water rice in Asia, including the large areas in Bangladesh. This paper gives a provisional checklist of deep-water pests in Bangladesh, a summary of pest incidence at one observation site during the 1975 crop season, and notes on the major pests—the ear-cutting caterpillar (*Mythimna separata* (Walk.)) ; rice stem borers, especially the yellow borer (*Tryporyza incertulas* (Walk.)); and the *ufra* nematode (*Ditylenchus angustus* (Butler) Filipjev.).

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DISCUSSION

CHOUDHURY: Is the ear-cutting caterpillar different from the swarming caterpillar (armyworm)? If so, how would you rank the swarming caterpillar in importance?

Catling: Yes. The swarming caterpillar appears to be a minor pest of deep-water rice in Bangladesh in most years.

SARAN: What is the most effective method of controlling stem borers in deep-water rice?

Catling: Effective control has been claimed in Bangladesh with aerial spraying of standard insecticides.

OHTA: The nematode is a very serious problem in Vietnam. According to V.T. Xuan, in a letter dated March 29, 1976, "Surprisingly rice stem nematode *D. angustus* was widespread in the Delta this year inflicting more damage than the brown planthopper, especially in the floating-rice areas."

CHOUDHURY: In West Africa *Aphelenchoides* causes some damage on deep-water rice, but the extent is not known.

JACKSON: Most farmers do not put fertilizer on deep-water rice. Is it necessary to do so in your proposal?

Catling: We want to see the effect of higher fertility on the incidence of pests and diseases since improved varieties may one day be fertilized.

Some workers believe that blue-green algae may be important in feeding nitrogen to the deep-water rice plant. If this is so, then they will obviously have considerable impact on many aspects of improvement, and we must be careful not to disturb the algae, or their environment, with plant protection measures.

New research project on pest management of deep-water rice in Bangladesh

H.D. Catling

The need for more study of diseases and insect pests of deep-water rice was recognized at the first International Seminar on Deep-Water Rice at Joydebpur, Bangladesh, in August 1974. At the 1975 International Rice Research Conference in the Philippines, the Deep-Water Rice Group requested the assistance of the International Rice Research Institute (IRRI) in securing

> "funds for conducting a systematic survey of pest and disease problems of deep-water rice in affected areas of Asia. This would be accompanied by crop loss assessment studies of injurious organisms. Where possible, plant resistance to significant pests would be identified for incorporation of resistance."

The group developed a detailed proposal for donor agencies to consider. It suggested that the new project be attached to the existing IRRI-Thai Deep Water Rice Project in Bangkok. Earlier this year, the Bangladesh Rice Research Institute (BRRI) and IRRI approached the Ministry of Overseas Development of the United Kingdom (UK) for assistance. Because the large deep-water areas in Bangladesh exhibit great diversity of plant type and deep-water habitats, and because BRRI and IRRI have strong cooperative arrangements, it was decided that the pest management study be based in Bangladesh as part of the BRRI-IRRI cooperative program.

There has been no systematic study of pests and diseases of deep water rice, and no plant protection specialists work full-time on this

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rice type. Conflicting reports abound on the significance of pests, but stem borers, the ear-cutting caterpillar, and *ufra* disease caused by a nematode are clearly important and warrant immediate investigation in Bangladesh. Although pesticide use is low, large pest outbreaks in Bangladesh are often controlled by aerial spraying. The method is costly, hazardous, and probably disturbs the ancient agroecosystem. New high yielding varieties may prove more susceptible to pests than the numerous local varieties that have gradually evolved over hundreds of years.

ORGANIZATION AND FUNDING

The proposed investigation will be a component of the ongoing BRRI-IRRI cooperative program. It will ensure close cooperation with the IRRI deep-water rice breeder and other rice scientists at BRRI, as well as with IRRI's deep-water rice program in Thailand. It is proposed that an expatriate entomologist to lead the project be added to the IRRI team in Bangladesh.

The project will be funded for an initial period of 3 years by a bilateral grant to the Government of Bangladesh from the UK Ministry of Overseas Development. This follows the Memorandum of Understanding for scientific and technical cooperation in rice research between BRRI and IRRI.

Funds will be provided for salary, benefits, and international travel of the entomologists, junior researchers, and BRRI field assistants assigned full-time to the project. Funds for a field vehicle, several small insectaries, and other equipment and supplies will be required. BRRI will provide office, laboratory, and work space and accommodations for the junior staff.

RESEARCH OBJECTIVES

The overall objective is to assess the significance of pests and diseases in reducing the yield of deep-water rice and to start developing reliable, economic control measures to prevent crop loss without seriously disturbing the faunal balance in the agroecosystem.

RESEARCH PROGRAM

The project work will be performed mostly by BRRI's plant pathology division. Most work will be done in farmers' fields. The program will consist of:

1. Review of literature on pests and diseases of deep-water rice and collation of past outbreaks in Bangladesh.

a. Description of the main zones or habitats in deep-water areas. Features will include :

- the nature of the water and alluvium of flood plains,
- the flooding pattern (time of inundation, receding, and maximum depth reached),
- timing of first rains, and
- cropping systems.

b. Selection of several study sites for regular sampling. designation of areas to be visited less frequently and selection of sites for field experiments. Locations under consideration are Habiganj, Faridpur south, Tangail, Matlab/Hajiganj, Dacca south, Santia/Bera, and Utpara.

c. Development of methods. In some cases completely new sampling methods will have to be devised and tested.

d. Selection and training of research assistants.

2. Survey of pests and diseases and, where possible, follow-up reports on serious outbreaks. The survey will be extended to deep-water areas in other countries, from the second year onward. Alternate host plants for pests and diseases and the complex of natural enemies will be noted. A collection of insects attacking deep-water rice and a visual record of diseases will be built up. At first, the identity of these organisms will be confirmed by overseas taxonomists. At an early date, arrangements will be made for more rapid identification.

3. Simple field experiments to determine the extent of yield loss from the activity of key insects and diseases. Two or three field sites, including the Habiganj substation, will be used.

4. Study of bioecological aspects of important pest species. To start with, the pests will be the complex of stem borers, the ear-cutting caterpillar, and *ufra* nematode. As the study progresses, other significant organisms will probably be included—pests such as the leaf roller, green leafhoppers, whiteback planthopper, hispa, swarming caterpillar, stem maggot and crickets; and diseases such as bacterial leaf blight, bacterial leaf streak, and false smut. The role of natural enemies is likely to be very important in a complex agroecosystem. For example, most deep-water rice fields in Bangladesh are heavily populated with spiders. The organism will be studied in winter when deep-water rice fields are either fallow or planted to alternate crops. The growth habit of the plant, its successive phases of tillering, and their effect on the feeding of insect pests, particularly stem borers must be understood.

5. Assistance to plant breeders in identifying the most injurious

species, finding sources of resistance, and screening new plant material. For instance, some improved Bangladesh varieties have a slight resistance to stem borers.

6. Simple agronomic field experiments, in collaboration with agronomists, to investigate the effects of heavy fertilization and varying plant density on yield and incidence of pests and diseases. We will keep simple records of yields in farmers' fields, most successfully grown varieties, and cultural practices and inputs typical of areas in which we work.

7. Studies on the nature of the faunal balance between phytophagous insects and the associated complex of natural enemies by comparing activity in untreated plots with that in plots receiving heavy insecticide applications. We predict that regular application of insecticide will disturb this balance. Fish mortality following the use of insecticides has been reported several times.

8. Determination of suitable, nonpersistent pesticides or biological agents for controlling disease outbreaks where varietal resistance is inadequate. Cultural methods may also be considered. In the past, nonselective materials such as endrin, DDT, parathion, malathion, dimecron, penitrothion, and sevin have been used.

The first International Rice Deep-Water Observational Nursery

B.S. Vergara, B.R. Jackson, W.R. Coffman, and H.E. Kauffman

The International Rice Testing Program (IRTP) is a cooperative effort by scientists of the rice-producing countries to develop improved rice varieties suited to different environmental conditions. The International Rice Deep Water Observational Nursery (IRDWON) is a part of the IRTP and is one of the many nurseries it coordinates. IRDWON is designed to provide a convenient medium for the exchange and evaluation of breeding lines and varieties among scientists engaged in developing deep-water rice varieties. The first IRDWON was started in 1976 with the participation of 10 countries.

Burma	Indonesia	Philippines
Thailand	Vietnam	Bangladesh
India	Sri Lanka	Colombia
Ecuador		

The list does not include the countries cooperating with the West Africa Rice Development Association (WARDA).

The nursery had 50 entries, mostly improved breeding lines from Thailand that are crosses between high yielding and floating rice varieties. The 50 entries included several check varieties: C4-63, Pelita I/l, RD1, IR442-2-58, Habiganj DW 2, ARC 5955, and DM 53.

Photoperiod-sensitive varieties or long growth duration varieties are needed in most deep-water rice areas. High yielding varieties do not

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have the ability to elongate. They generally have short growth durations so that they mature when the water level in the field is still too high. Observations of the IRDWON at Huntra, Thailand; Chinsurah, West Bengal, India; and Los Baños, Philippines, showed the following lines to have long growth durations:

BKN 6985-60-38	BKN 6986-80	BKN 6988-21
SPT 6738-25	BKN 6986-38-1	BKN 6986-147-2
BKN 6986-173-5	BKN 6986-81	BKN 6987-161-6
BKN 6987-108	BKN 6986-81-5	BKN 6986-167

The 50 entries in the IRDWON had been tested for rooting and kneeing ability at the International Rice Research Institute (IRRI). Most showed poor ability to produce roots at the nodes. The following showed the best rooting ability:

BKN 6986-29	BKN 6987-108	Pelita I/1
Habiganj DW 2	ARC 5955	

When internode elongation occurs at high floodwater depths, the long stems are lowered to the mud as the floodwater recedes. The ability to knee or bend upwards to keep the panicles from touching mud is an essential plant character needed in deep-water areas. In screenings at IRRI, the following showed good kneeing ability (1 = good kneeing ability; 9 = no kneeing):

Entry	Kneeing score
BKN 6986-29	3
BKN 6986-59-12	3
BKN 6986-58-1	3
BKN 6986-71	3
BKN 6987-225	3
ARC 5955	1

The IRDWON entries exhibited plant heights that ranged from semidwarf through intermediate to tall. Many late maturing lines have intermediate height, a plant character that, combined with stiff straw or the nonlodging ability, is useful in deep-water (stagnant water and 50 to 150 cm water depth) areas.

The phenotypic acceptability scores under shallow-water conditions at the three planting sites show the following lines as promising:

Entry	*Plant height*	*Growth duration*	*Rooting ability*	*Kneeing ability*
BKN 6987-128-2-4	Semidwarf	Early	–	4
BKN 6987-68-14	”	”	7	5
BKN 6986-45-1	”	”	7	7
RD1	”	”	6	7
BKN 6986-108-2	”	Late	5	6

BKN 6986-105-P	Intermediate	Early	7	5
Pelita I/l	”	”	5	5
BKN 6986-147-2	”	Late	7	6
BKN 6986-38-1	”	”	7	7
BKN 6986-167	”	”	7	6

BKN 6987-128-2-4, BKN 6986-45-1, and BKN 6986-108-2 also had high phenotypic acceptability in Indonesia.

All observations were from shallow-water plantings. Deep-water plantings in Bangladesh; Philippines; and Chinsurah, India, were destroyed by early floods. Few lines in the IRDWON planted in deep water at Huntra, Thailand, showed good tillering; plant density was generally poor.

Several promising advanced lines observed at the Rice Experiment Station at Chinsurah, India, will be included in the next IRDWON. Nominations will also be accepted from participants of this Deep-Water Rice Workshop. Several scientists working on deep-water rice visited Bangladesh and India before coming here. Several of you conducted the IRDWON at your location. Your observations and suggestions are needed.

IRDWON needs at least 2 kg of seeds per line, and the seeds must be at IRRI before February 1977.

The following entries were suggested for the 1977 IRDWON:

Entries	*Location*	*Person who made the suggestion*
One entry from :		
B922C-ML-21	Indonesia	S. Subiyanto
B922C-ML-69		
B922C-ML-91		
B922C-ML-118		
B1050C-ML-7-3		
Pelita		
Cu La	WARDA	M.A. Choudhury
Malobadian		
FRRS 43/3		
CNL 312	Chinsurah	S.K. Datta
CNL 244	West Bengal, India	
CNL 231		
CNL 180		
CNL 31		

Habiganj A 2 Habiganj A 4 Habiganj A 8	BRRI Bangladesh	M.S. Ahmed
Two lines from Thailand	Thailand	D.H. HilleRisLambers
Two lines from Burma	Burma	Ohn Kyaw
Five lines from Bihar	Bihar, India	S. Saran
IR442-2-59	IRRI	S.K. De Datta
IR lines with elongation ability	IRRI	B.S. Vergara
Bangladesh lines with elongation ability	IRRI	B.S. Vergara
RD1 Pelita I/1 C4-63 BKN 6987-128-2-4 BKN 6987-68-14 BKN 6986-45-1 BKN 6986-105-P BKN 6986-147-2 BKN 6986-38-1 BKN 6986-167 BKN 6986-108-2 And other lines subsequently identified	IRDWON	International Rice Testing Program
Varieties that will indicate the ideal flowering date		D.H. HilleRisLambers

DISCUSSION

PRECHACHART: Many lines in the International Rice Deep Water Observational Nursery seem very early. In what place will this kind of materials be suitable for planting?

Vergara: Those early lines will be useful in areas where farmers plant early and harvest when the water level is increasing. The practice is common among farmers in certain parts of Vietnam. If water is available, they plant high yielding varieties early in the season and harvest when the water is around 50 cm. They get better yields than when they plant deep-water rice.

The method, however, involves harvesting when the water is deep, and at certain times the water may rise very early and damage the plant. If the variety has some elongation capacity besides earliness in flowering, it will have a built-in safety in case water comes in early or is too high.

CHOUDHURY: We received the seeds of the IRDWON in August 1976, which was too late for the season. The amount was enough for only one location. We planted them for seed increase; next year we will conduct the trial in two or three locations in the WARDA region.

Vergara: We will try to send the seeds as early as possible. Next year we hope to send the seeds by March.

SOPHONSAKULKAEW: Did you test the IRDWON entries for elongation ability?

Vergara: No. We hope to test the 1977 IRDWON, not only for elongation ability but also for kneeing ability. Dr. De Datta will also test the entries for drought tolerance.

Promising lines and future plans

B.R. Jackson

Most of you are familiar with or have heard of the IRRI cross IR442 or T442, which provided the original basis for developing new semidwarf deep water-tolerant forms through incorporation of elongation genes from floating rice. In India the lines 442-2-50-1-3-2 and 442-2-58-2—as well as Pankaj, a selection from IR5—were released for medium deep water areas. In Thailand, the breeders selected several lines from the bulk F_4 population of IR442 and identified one particular line (T442-57) that has undergone extensive testing for areas where maximum water depths do not exceed 150 cm.

All IR442 material that has either been released or been seriously considered for naming has two outstanding weaknesses-lack of photoperiod sensitivity and susceptibility to diseases, especially bacterial leaf blight and blast. With these things in mind, we in Thailand have accelerated the deep-water research program by selecting from new crosses lines that are a decided improvement over IR442. The most advanced materials are F_8 lines from the crosses IR262/Pin Gaew 56 (BKN 6986) and IR262/Khao Nahng Nuey 11 (BKN 6987).

The purpose of this paper is to call attention to some of the more promising new lines that have evolved from our deep-water breeding program. The lines can serve as examples of what to expect as the deep-water rice breeders pursue their respective work.

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BKN 6986-108

The line BKN 6986-108 is a photoperiod-insensitive semidwarf that tends to be slightly taller than such varieties as IR8. Aside from having good deep-water tolerance, it has exhibited very good ability to withstand submergence in three consecutive tests at the Klong Luang Rice Experiment Station (Table 1, p. 106 of Boonwite et al., 1977). Tests have shown it to have medium resistance (MR) to bacterial leaf blight (BLB) and fast seedling growth. Another interesting feature is its drought tolerance (Table 1, p. 85, Fig. 3, p. 90, De Datta and O'Toole, 1977)

Under both shallow-water and direct tidal-effect conditions in Banjarmasin, Kalimantan, Indonesia, BKN 6986-108, was one of the more promising lines. It showed no adverse effects from submergence under tidal swamp conditions for several hours each day during the seedling stage. Its performance supports the Thailand submergence data discussed earlier and opens up new areas of research interest.

BKN 6986-147-2

The strongly photoperiod-sensitive semidwarf line BKN 6986-147-2 can withstand water depths of about 120 cm. Under flood conditions it has shown excellent kneeing and rooting ability. It has long slender grain. De Datta and O'Toole report that it has reasonably good drought tolerance (Table 1, p. 85, Fig. 3, p. 90). Under Thai conditions, it exhibits MR to BLB. Its strong photoperiod sensitivity is a major advantage for some areas of Thailand and West Bengal. It should be especially good for stagnant-water areas of intermediate depth where, with its heavy tillering capacity, it could be better than traditional tall and semifloating varieties. Recent observations in shallow water at the Chinsurah Station support our optimism that such a type has good prospects for success.

BKN 6986-141

For areas requiring intermediate height, stiff straw, and photoperiod insensitivity, line 6986-141 appears promising. In crosses of floating rice with semidwarf forms, stiff-strawed segregates with intermediate height are usually difficult to recover. This line has, in addition to stiff straw, excellent plant type; it withstands water depths of up to 150 cm and takes about 115 days from seeding to harvest.

BKN 6986-81-5

The line BKN 6986-81-5 has intermediate to tall plant height, high tillering ability, strong photoperiod sensitivity, MR to BLB, relatively stiff straw, fast seedling growth, and excellent elongation ability in water up to 200 cm. Its greatest potential appears to be for areas of semideep water.

BKN 6986-167

The line 6986-167 is similar to 6986-81-5 in elongation ability, photoperiod sensitivity, straw strength, and seedling growth. Its plant type appears to be slightly better than that of line 6886-81-5. The lines 6986-147-2, 6986-81-5, and 6986-167 are included in the fertilizer-water depth study at Huntra.

Several other lines also show promise but are not presented here since the purpose of this paper is to point out some identified superior characteristics. We hope that the delegates to this Workshop will provide information on the performance of these lines and others in their respective countries. All are now included in the International Rice Deep Water Observational Nursery. It is exciting that important rice characteristics, such as deep-water tolerance, drought resistance, fast seedling growth, and strong photoperiod sensitivity, can be obtained from floating varieties that, by themselves, are considered undesirable except for areas of extremely deep water, and then transferred to improved-plant types. These characters appear to offer the best opportunity to score another breakthrough for large areas of Asia where the present high yielding varieties can not be successfully grown due to unfavorable conditions. I am optimistic that we will succeed!

FUTURE WORK

More work is needed on the following research areas.

1. Rooting ability
2. Elongation rate
3. Drought resistance
4. Seedling height
5. Kneeing ability
6. Inheritance of the above characteristics in association with elongation

7. Response to fertilizer at varying water depths
8. Types of submergence tolerance and methods of screening
9. Morphology and anatomy of stems and roots
10. Role of phytohormones in elongation
11. Relation of plant height to elongation ability

In the future, all new varieties with high yield potential should have some deep-water tolerance. What is needed now is a commitment that each person will conduct research on one or more of these areas so that at the next Workshop we will have many new important subjects to report and discuss.

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DISCUSSION

CHOUDHURY: What are the parents of BKN 6986?

Jackson: IR262 (Peta^3/TN1)/Pin Gaew 56. Pin Gaew 56 is a traditional floating variety with long slender grain which is on the Thai Government's recommended variety list. It grows in at least 300 cm of water and is one of our most popular floating varieties.

SARAN: What is the duration (seed to seed) of BKN 6986-147-2, BKN 6986-81-5, and BKN 6986-167?

Jackson: In Bangkok they usually flower in late November, which means on the 11-hour 45-minute day. Because they are photoperiod sensitive, their flowering depends more on day length than on number of days as is the case with nonsensitive forms. In Thailand, late November flowering means that the farmers will harvest after deep water has receded from their fields.

MAZAREDO: Are you not going to consider seed dormancy as one of the character traits needed in breeding for deep-water rice?

Jackson: Yes, we think that is very important and expect to test freshly harvested seed for postharvest dormancy.

DE DATTA: The BKN 6986-108 type (deep-water semidwarf which is photoperiod insensitive) may have relevance not just to deep-water rice but also to rainfed lowland and upland rice. Those who have interest in rainfed rice should look into it.

DE DATTA: What do you know of its tungro resistance?

Jackson: I don't recall its tungro reaction at this time, but we should have information at Bangkhen or from IRRI. We have not had enough heavy tungro infection at Bangkhen for several years to obtain a natural reading.

SUBIYANTO: What is the tolerance of BKN 6986-141 for acid sulfate soil?

Jackson: As I recall, its reaction is quite good at the Bangkhen Rice Station.

OHN KYAW: I think that the present facility for testing flood tolerance in Huntra uses still, clear water. Will the varieties be all right submerged in rushing muddy water?

Jackson: When we first apply the water it is muddy, not clear. Therefore, elongation takes place in muddy water. We have found a few lines, such as BKN 6986-108, that can also stand complete submergence in muddy water.

APPENDIX A Tour of deepwater areas

Workshop participants toured the deep-water rice areas of Thailand's central plains to observe research at the Huntra Rice Experiment Station and in farmers' fields (see map). The main stop was at the Huntra Station, operated by the Rice Division of the Ministry of Agriculture and Cooperatives. The following researches were in progress:

1. International Rice Deep Water Observational Nursery
2. Comparison of varieties in deep-water and shallow-water treatments
3. Effects of water depth and fertilizer application on yield
4. Screening for elongation ability
5. Yield trials of new lines in 100 to 130 cm of water
6. Demonstration of kneeing ability
7. Yield trials of deep-water lines growing in shallow water

The Rice Division has 22 experiment stations. Deep-water rice research has been conducted at Huntra, Klong Luang, Bangkhen, Suphanburi, Rangsit, and Chainat Stations.

Klong Luang and Huntra are the main stations where deep-water rice yield trials are conducted in shallow-water conditions. Klong Luang has two deep-water ponds for testing submergence tolerance. The station is often used, in alternate years, to test hybrid materials for traits that can best be observed in shallow, controlled water conditions. Several deep-water rice crosses have been made at Bangkhen and at Suphanburi. A new station is being established at Prajinburi for screening deep-water rice in water several meters deep.

HUNTRA RICE EXPERIMENT STATION

The Huntra Rice Experiment Station is used primarily for deep-water rice research. It is located 80 km north of Bangkok.

Work at the Huntra Station is allocated to three major activities—seed multiplication, agronomy, and plant breeding.

Seed multiplication. Huntra station is responsible for the production of foundation seed of the deep-water rice varieties Pin Gaew 56, Leb Mue Nahng 111, Tapow Gaew 161, and Nahng Chalawng. Fifteen hectares of land are planted to these varieties every year.

Agronomy. Several yield trials are planted annually. Specialized trials assess the yield potential of deep-water rice in ponds up to 150 cm deep. Observational trials of previously untested promising lines are conducted at other stations. Yield trials of materials that performed acceptably in previous trials are planted at Huntra and at other stations. Early maturing lines are tested separately from the late and photoperiod-sensitive lines.

Plant breeding. The main objective of the breeding program is to develop a range of varieties that combine several traits from floating rice and from modern semidwarf rice varieties. Three main plant types are needed:

1. A variety of intermediate height with elongation ability, sensitivity to photoperiod, and flowering date around early November. It could give an alternative to farmers who now grow photoperiod-sensitive tall varieties.

2. A semidwarf variety with high yield potential and some elongation potential to adapt to incidental water depths of up to 100 cm. It would take the risk out of growing varieties with high yield potential in flood-prone areas.

3. A traditional type floating rice, selected for high yield or a wide spectrum of disease resistance, or both. Varieties of this type have not been released. Through recombination and selection for yield increase, such lines may be identified.

Crosses from Thailand and elsewhere are being screened for elongation ability in ponds, and for agronomic type in shallow-water fields. Testing for bacterial leaf blight is also done. About 200 crosses have been made in Thailand and 250 at IRRI. Some hundreds of these are currently represented in materials at Huntra Station.

Two hectares of land has been divided into 16 rectangular ponds where water depths can be controlled to subject rice to water depths of up to 200 cm. Interspersed with the ponds are two hectares divided into 11 fields where water levels are kept lower than 50 cm.

Twenty hectares of land at the Station is subject to natural flooding. In some years maximum levels are 50 cm, but in others the water may reach up to 200 cm. About six hectares of this land is normally used for yield trials and other experiments, and the rest is used to multiply seed of recommended deep-water varieties.

The station has a screenhouse for single plant and hybridization work and a cold room for seed storage.

APPENDIX B Deep-water rice terminology

Elongation —increase in plant length resulting from elongation of internode, leaf sheath, blade, or combinations. When necessary specific plant parts should be named, e.g. internode elongation.

Basal tillers, basal roots—tillers or roots produced from the basal nodes.

Nodal tillers, nodal roots—tillers or roots which arise from the nodes above the plant base. The term “nodal” is used to differentiate the tillers produced on the upper nodes from those produced at the base. The terms “aerial tiller” and “branches” should be discarded.

Kneeing—change of direction of upper plant portions from horizontal towards vertical.

Designation of internodes—In the mature plants, the first internode, the internode responsible for the exsertion of the panicle, is designated as n-0; lower internodes are designated successively as n-1, n-2, n-3, n-4.

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APPENDIX C **Standard scoring system for measuring elongation ability of deep-water rice**

Procedures for regulating water conditions in deep-water tanks, and scoring methods.

1. Direct seed 5 g pregerminated seed in each 125-cm row in a wetbed nursery.
2. From 0 to 30 days after seeding (DS), manage like lowland rice. Water depth should not exceed 10 cm.
3. 30 DS: Estimate stand percentage in each row.
4. 31 DS: Increase water depth to 25 cm.
5. 33, 35, 37, etc. DS: Increase water level by a maximum of 10 cm on alternate days until the target depth is reached. Record scores at or near the target depths of 50, 150, and 200 or more cm. As the biological check for the 50-cm depth, use a nonelongating semidwarf. For 150 cm, use T442-57; for more than 200 cm, use the best local floating variety.

Note: If leaves of the check variety are visible above water on the second day at any depth, add enough water to submerge.

6. Score the plants at the target depths. Scores should indicate water depth and elongation behavior. For example, a score of 160-5 indicates that at 160 cm depth the entry's response was similar to that of T442-57.

Score	Description	Biological check
0	No information	
1	Best elongation response	Best local floating variety
3	Response better than that of T442-57, not as good as that of the best local floating variety	
5	Response similar to that of T442-57	T442-57
7	Response better than that of the nonelongating semidwarf, not as good as that of T442-57	
9	Poorest elongation, or none	Nonelongating semidwarf

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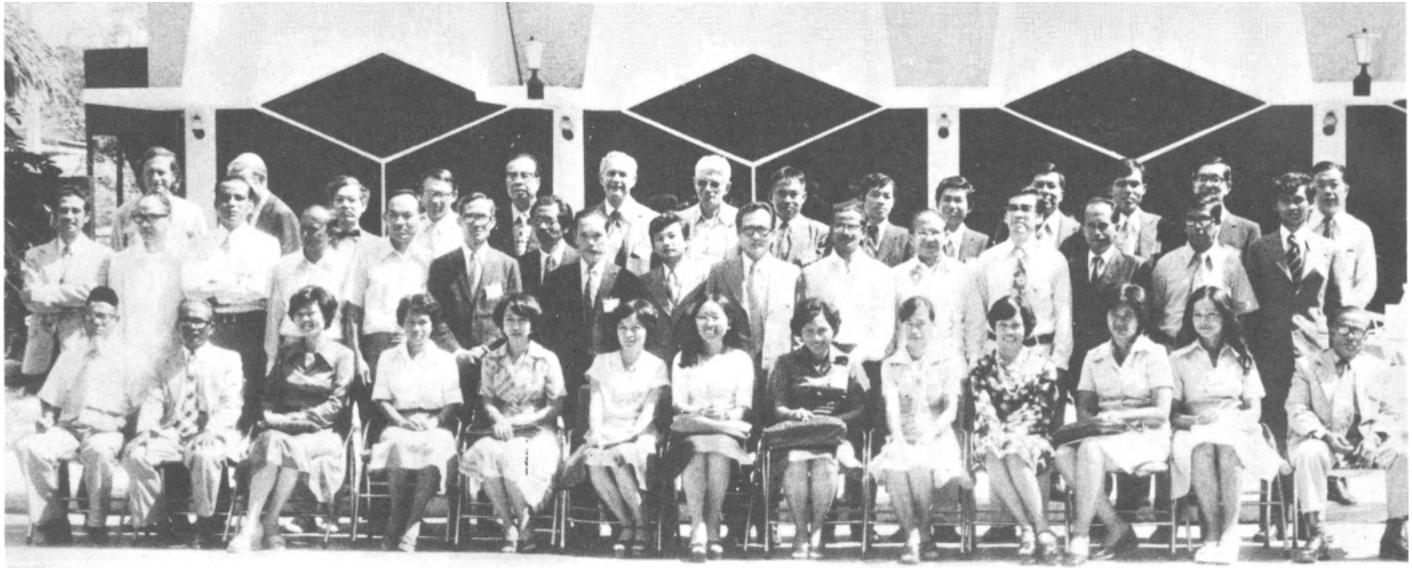

Participants of the 1976 Deep-Water Rice Workshop, 8–10 November, Bangkok, Thailand. Front row (L-R): Munshi S. Ahmed, S.M.H. Zaman, Somsri Sinanuwong, Amara Wiengweera, Asanee Sarigabutr, Wiengpet Sirikant, Samlee Sophonsakulkaew, Kalaya Kupkanchanakul, Chaluay Boonwite, Siriporn Karin, Aurora Mazaredo, Sommai Amonsilpa, and Amirul Islam. Middle row: Surajit K. De Datta, Benito S. Vergara, M.A. Choudhury, S.K. Datta, Soon Jai Park, Pedro B. Escuro, Sujadi Subiyanto, Ohn Kyaw, Nopporn Supapoj, Chai Prechachart, S. Saran, B.H. Siwi, Hiroshi Ikehashi, Soonton Naka, M. Nasiruddin, and Aroon Saenghirun. Back row: H. David Catling, Derk HilleRisLambers, Yasuo Ohta, Dwight Kanter, Kaung Zan, Ben R. Jackson, H.M. Beachell, H. Noorsyamsi, Boriboon Somrith, Tawee Kupkanchanakul, Sermsak Awakul, Sompong Nuchoy, Kunio Hamamura, and Pricha Khambanonda.

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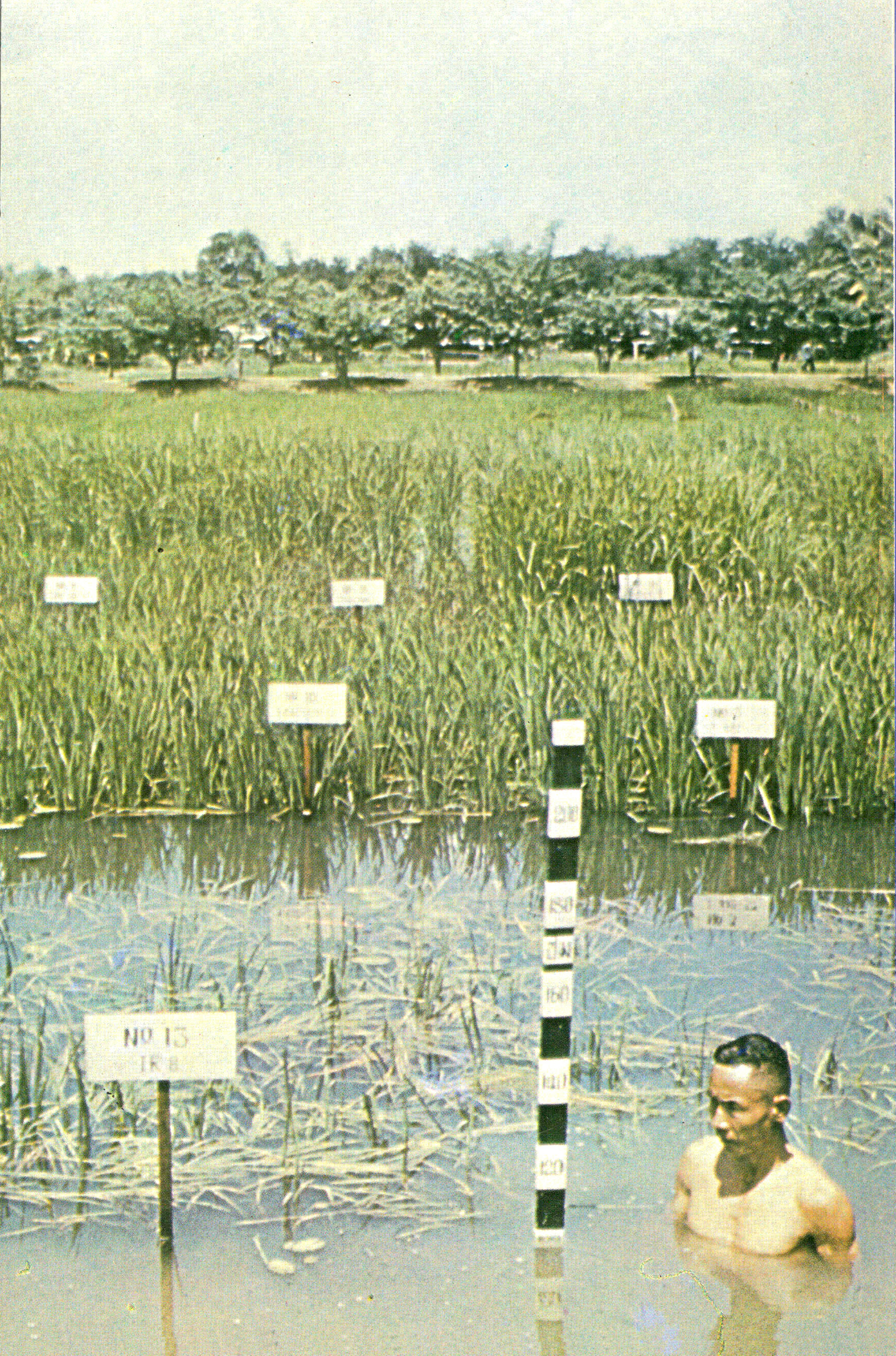
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