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RICE IMPROVEMENT BY WIDE HYBRIDIZATION AND ~~BY THE~~ INTERNATIONAL COORDINATION OF RICE GENETICS

Context--Wide Hybridization

Rice is the major food for more than half of the world's population. In 1982, it was planted on 146 million hectares and 435 million tons of grain were produced. More than 95% of the rice crop is grown and consumed in the developing countries of Asia, Africa and Latin America. The average yields in the developing countries were extremely low. However, substantial increases in rice yields were made following the development and wide scale adoption of short statured, nitrogen responsive and high yielding varieties at the International Rice Research Institute in collaboration with national research programs in numbers of developing countries. The result of the initiative of the Rockefeller Foundation and the Ford Foundation which led to the creation of IRRI has contributed to an increase of 50% in the average yields of rice in several countries.

The improvement of rice by breeding continues to be one of the principal purposes of IRRI. However, its core program is wholely committed to the assemblage, from within the main cultivated species, Oryza sativa, of the many beneficial genetic characteristics that are now needed by developing country rice growers. This requires the full-time commitment of the geneticists and breeders already on the staff of IRRI and they should not be distracted from this work which is vital to the continuing contemporary improvement of rice cultivation.

However, towards the middle of the decade of the 1990's it is quite possible that useful genetic variability for many characters will either have been exhausted or will have greatly diminished. Almost all of the agriculturally beneficial genes will have already been exploited by rice breeders. Consequently the means must be developed by which useful alien genes can be brought into rice from related wild species by cytogenetic manipulation or by which useful DNA sequences can be incorporated from more distant plant species by the techniques of molecular biology. This proposal from IRRI is concerned only with the first of these two opportunities.

Some wild species of rice are highly resistant to major diseases and insects. Several accessions of Oryza australiensis and O. officinalis, for example, are resistant to brown planthopper. Some accessions of O. barthii are resistant to bacterial blight (Table 1). Genes for resistance from wild species if transferred to O. sativa, would help broaden the genetic base for disease and insect resistance and enhance the yield stability of improved varieties.

Wild species of rice thrive under poor environments and must have the genetic make-up to tolerate adverse conditions such as drought, stagnant floods, and problem soils. O. australiensis thrives under droughty conditions. O. coarctata grows in salty marshes. O. perennis strains are known to thrive in acid sulphate soils (Table 1). These wild species are thus potential reservoirs of germplasm for improving the rices for unfavorable environments.

O. perennis has been successfully used for developing cytoplasmic male sterile lines which are now widely used in hybrid rice breeding programs. However, only one source of cytoplasmic male sterility is

used for producing the hybrids which were planted on 7 million hectares of rice land in 1983. This narrow base is a potential source of vulnerability of rice crop to diseases and insect epidemics. Alternate sources of cytoplasmic male sterility must therefore be located. Wild species are the most logical sources to investigate for this purpose.

Basic information about crossability, genome relationships and amount of intergenomic recombination will be important in the exploration of wide hybridization. Unlike wheat where genomic relationships of many wild species with those of cultivated wheat have been thoroughly investigated, the genomic relationships of species of Oryza are imperfectly understood. The present status of our understanding of genomic relationships of various species of Oryza is shown in Table 2. It is evident that there are many gaps in our knowledge of species relationships in Oryza.

Context--International Coordination of Rice Genetics

The second part of this proposal concerns the creation of an international network to coordinate and collate the results obtained by the many hundreds of rice geneticists and breeders throughout the world. Hitherto they have worked independently and described their results in the literature in ways which were often incompatible using different information systems. This led to confusion in our understanding of rice genetics and to difficulties in the practical application by breeders of knowledge generated by research workers who happened to use a different information system from the one to which they were accustomed. An International Rice Genetics Symposium was held at IRRI in May 1985 and

it was agreed that rationalisation of this confusion was necessary, and it was further agreed to create a Rice Genetics Cooperative which would have the responsibility of unifying the information systems and the nomenclature used in rice genetics, and of creating the genetic linkage maps without which high quality genetics will not be possible and the genetic improvement of rice will be impeded.

Proposal

The proposal is to create a team of workers at IRRI who will be mainly concerned with research on the means by which the useful genetic variation in wild and weedy species of rice can be incorporated in the rice crop. Another responsibility of the team will be to take the first steps in the coordination of information on the genetics of rice by taking active leadership in the development of the Rice Genetics Cooperative.

The team will be headed by the Rockelfeller Foundation Field Staff Senior Cytogeneticist and will work under the overall leadership of the Head of the Plant Breeding Department. The Rockefeller Senior Cytogeneticist would principally be involved in the creation of a cytogenetics research program on wide hybridization at IRRI and in Southeast Asia, but it would also be expected that from time to time he would assist the Rockefeller Foundation with other responsibilities.

The team would also have a Senior Research Associate who would be expected to be a cytogeneticist, to conduct research on wide hybridization with the Rockefeller cytogeneticist. He would also work on the collation of genetic nomenclature, and on linkage studies and assist Dr. Khush to bring into effective operation the newly formed Rice Genetics Cooperative.

These two leaders of the team (the Senior Cytogeneticist and Senior Research Associate) will be supported by four research assistants and by appropriate support staff, the expenses for whom have been included in the proposed budget (attached).

An important element of this work will be the opportunity that it offers for training in cytogenetics and genetics. If, as can be expected, the exploitation of alien genetic variation expands markedly in rice--whether introduced by cytogenetics or by molecular technology--much of the manipulations will be in hands of cytogeneticists. Competence in this field must therefore be disseminated among the developing countries. For this purpose it is planned that up to five post-doctoral trainees should be associated with the program. Although presented in the budget as though the number will be constant throughout, it is anticipated that these trainees will be less numerous in the early years and more numerous in the later years of the work.

The objectives of this work are initially to create a raft of knowledge upon which subsequent exploitations can be built. Consequently the work is long term and this request is for support in the first instance for 5 years but with notification that the research will probably extend beyond this period. It is understood that the Rockefeller Foundation may wish to undertake a mid-term review of the program in its third year.

IRRI will be very willing to participate in the Annual Review of the Rockefeller-Supported Rice Program.

A budget for 1986 is attached. It is understood that in subsequent years until 1991 the budget will be increased to match inflation.

Objectives of the project

(1) To develop methods for the transfer of useful genes of wild species into improved rice cultivars.

(2) To transfer alien genes for resistance to major diseases and insects from wild species into cultivated rice.

(3) To incorporate genes for stress tolerance (drought, submergence, stagnant flooding, problem soils) from wild species in improved cultivars.

(4) To develop alternate sources of cytoplasmic male sterility for diversification of the basis of hybrid rice production.

(5) To explore the possibility of increasing the biomass and yield potential of rice through introgression of genes from wild into cultivated species.

(6) To accumulate basic information about the species relationships in *Oryza* such as crossabilities, genome homologies, genetic control of chromosome pairing and nucleo-cytoplasmic relationships. This knowledge will constitute the basis for further improvement of rice germ plasm by wide crossing and by molecular biology.

(7) During the recently concluded International Rice Genetics Symposium, the Rice Genetics Cooperative (RGC) was established for coordinating the work on rice genes, structural changes and linkage maps. To commence this work, this proposal requests support to:

(a) Assemble all the available marker genes of rice at IRRI.

(b) Settle gene nomenclature problems.

(c) Determine the chromosomal location and map position of the unmapped markers through trisomic inheritance and through standard linkage tests.

(d) Provide seeds of stocks with marker genes to collaborators in linkage mapping as well as to scientists working on various aspects of rice biotechnology.

Plan of work

Year 1

Wide hybridization

(1) Survey wild and weedy species of rice for useful characters including disease and insect-resistance and physiological attributes.

(2) Test crossabilities and initiate hybridization program for cytogenetic studies.

Rice Genetics Cooperative

(1) Accumulate information from collaborators.

(2) Assemble genotypes from laboratories in other countries.

Year 2

Wide hybridization

(1) Continue as in Year 1.

(2) Examine the initial hybrids cytologically and in terms of phenotypes particularly of agriculturally significant attributes.

(3) Commence backcrossing program to cultivated rice.

Rice Genetics Cooperative

(1) Continue the accumulation of genetic stocks internationally.

(2) Commence testing for allelism.

(3) With international collaborators, agree on terminologies.

Year 3

Wide hybridization

(1) Continue as in Years 1 and 2.

(2) Study meiotic behavior of wide crosses to assess feasibility of introducing genes by recombination.

(3) Make classical genome analyses.

(4) Commence separation out of alien addition lines.

Rice Genetics Cooperative

(1) Continue as in Years 1 and 2.

(2) Make backcrosses for gene mapping.

(3) Commence chromosomal location studies by trisomic methodology.

Year 4

Wide hybridization

(1) Continue work commenced in earlier years as necessary.

(2) Screen backcross derivatives including any alien chromosome addition lines for the presence of agriculturally useful and rare genes.

(3) Isolate *Oryza sativa* genome in alien cytoplasm to detect potentially new sources of cytoplasmic male sterility for hybrid rice breeding.

Rice Genetics Cooperative

(1) Continue work commenced in earlier years as necessary.

(2) Analyse first results on the chromosomal location of genes.

(3) Start planning 2nd International Rice Genetics Symposium at which time there will be a meeting of the Rice Genetics Cooperative.

Year 5

Wide hybridization

(1) Continue to completion wherever possible work commenced in earlier years.

(2) Assess feasibility of incorporating useful alien variations into the rice crop by recombination or by induced translocation.

(3) Survey of genome analysis, species relationships and progress in rice improvement to be achieved from wild and weedy relatives.

Rice Genetics Cooperative

(1) Complete the arrangements for a unified system of gene and chromosome nomenclature and mapping.

(2) Complete the creation of the best possible gene locus and structural chromosome maps of rice on the basis of currently available knowledge.

Table 1. Chromosome number, genome symbol, and geographical distribution of Oryza species.

Section, Species	2n	Genome	Geographical distribution
Section Oryzae			
sativa L.	24	AA	Worldwide, cultivated
rupifogon Griff (=perennis Moench)	24	AA	Asia, America
barthii A. Chev.[a]	24	AA	Africa
(=longistaminata A. Chev. et Roehr)	24	AA	
glaberrima Steud.	24	AA	Africa, cultivated
breviligulata A. Chev et Roehr	24	AA	Africa
(=barthii in the sense of Clayton, 1968)			
australiensis Domin	24	EE	Australia
eichingeri A. Peter	24	CC	Africa
punctata Kotschy	24,48	BB, BBCC	Africa
officinalis Wall	24	CC	Asia
minuta J. S. Presl.	48	BBCC	Asia
latifolia Desv.	48	CCDD	America
alta Swallen	48	CCDD	America
grandiglumis Prod.	48	CCDD	America
Section Schlechterianae			
shlechteri Pilger		?	New Guinea
Section Granulatae			
meyeriana Baill. (-granulata Nees et Arn.)	24	?	Asia
Section Ridleyanae			
ridleyi Hook, f	48	?	Asia
longiglumis Jansen	48	?	New Guinea
Section Angustioliae			
brachyantha A. Chev. et Roehr.	24	FF	Africa
angustifolia Hubbard	24	?	Africa
perrieri A. Camus	24	?	Malagasy
tisseranti A. Chev.	24	?	Africa
Section Coarctatae			
coartata Roxb.	48	?	Asia

[1]From Morishima (1984)

Table 2. Some wild species of Oryza with traits of economic importance.

Wild species	Useful trait
O. nivara	Resistance to grassy stunt and blast
O. barthii	Resistance to bacterial blight
O. longistaminata	Floral characters for outcrossing
O. glaberrima	Resistance to green leafhopper
O. officinalis	Resistance to brown planthopper
O. australiensis	Resistance to brown planthopper and drought
O. coarctata	Resistance to salinity
O. perennis	Tolerance to acid sulphate soils and stagnant flooding. Source of sterile cytoplasm.

Rice Improvement by Wide Hybridization and the International Coordination of Rice Genetics

Budget for 1986 to be Indexed to Inflation in Subsequent Years

		$ US '000	Notes on budget, see below
Salaries and benefits			
(1) Rockefeller Field Staff Cytogeneticist	:	--	1
(2) Senior Research Associate on IRRI staff	:	60	--
(3) Four Research Assistants	:	20	--
(4) Ten Field Workers and Laborers	:	20	--
(5) Secretary	:	5	--
(6) Part time staff to assist Senior Research Associate with International Rice Genetics Cooperative	:	5	2
Training			
Five Post-docs	:	120	--
Equipment and supplies			
(1) Equipment-initial cost in year 1		(100)	3
-recurrent costs	:	50	--
(2) Supplies	:	50	--
(3) Expenditure on International Rice Genetics Cooperative	:	5	4
Travel			
(1) International	:	10	5
(2) Local	:	1	--
Indirect costs	:	50	--
TOTAL			
Annual recurrent	:	396	--
Annual for 1986 including initial equipment costs	:	(496)	--
Contribution from IRRI Core Budget	:	75	6

Notes on the Budget

1. Costs of the RF Field Staff Cytogeneticist to be written in by the Foundation.
2. At some times in the year the Senior Research Associate will need additional help to assist with the collation of information from the international network.
3. Start-up equipment costs have been included to cover the RF Field Staff Cytogeneticist, the Senior Research Associates and their Research Assistants and Post-docs. The equipment will include microscopes, incubators, centrifuges, scintilation counters, photomicrography equipment, isotope handling facilities, etc.
4. This covers the stationary, postage, printing, etc. necessary to run an international network.
5. Does not include expenditures on travel by the RF Field Staff Cytogeneticist.
6. IRRI will contribute from its Core Budget in the form of the work of its Genetic Evaluation and Utilization Program including the International Rice Germplasm Centre, and the input of scientists in the Departments of Pathology, Entomology, Soil Science and in the Tissue Culture Facility.