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Rice Breeding And Associated Informations

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Introduction

Rice is one of the world's oldest known cultivated crops. The sowing of rice was an important religious ceremony in China 5000 years ago and differences among rice varieties were recognized in India as early as 1000 B.C. Rice has spread throughout the world since then and by 1970 more than 308 million tons of rice paddy was produced. Rice provides nourishment to a greater number of people than any other grains.

Oryza sativa is believed to have been introduced to West Africa by Arab traders around the 13th century. It originated in South-Eastern Asia. *Oryza glaberrima* (steudel) however, has its origin in West Africa. Most likely originated in the Central Niger Delta (Mali) and was grown there long before the Christian era. It has weak stems, easy-shattering, red grain with a long dormancy, susceptible to disease and is low yielding. It has been largely replaced by *O. sativa*, L.

The genus includes at least other 18 valid species besides the two mentioned above. Some wild species of Africa origin are *O. brachyanta*, *O. angustiflora*, *O. perennis*, *O. punctata*, *O. stapfii*, and *O. tisseranti*.

Oryza sativa, L. belongs to the tribe Oryzeae under the sub-family Pooideae in the grass family Gramineae (Poaceae). Biosystematists recently divided the genus *Oryza* into several sections and placed *O. sativa* under series Sativa in section Sativae.

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The rice plant varies in size from dwarf mutants only 30cm to 40cm tall to floating varieties more than 7 meter tall. The vegetative organs consist of roots, culms and leaves. A branch of the plant bearing the culms, leaves, roots and often a panicle is a tiller.

Rice Breeding Methods

Breeding methods in rice are those usually associated with self-pollinated crops. Five methods followed by brief discussions on each are listed below.

1. Pure line selection
2. Mass selection
3. Hybridization, with the segregating generation handled by the
    (a) Pedigree method
    (b) Bulk method
    (c) Backcross method
4. Hybrid varieties
5. Mutation breeding

Pure Line Selection

From a genetically variable original population a large number of plant selections are made. These are grown out and undesirables are discarded. The superior lines are eventually released as pure-line varieties. This method was used a lot in the past. It is not commonly used now.

Mass Selection

This is similar to pure line selection, the only difference is that the final variety is made up of a number of plants rather than just one as in pure line selection. The variety developed consists of superior lines from several hundred or two or three thousand individuals. Mass selection is used commonly in purification of existing varieties in connection with pure seed programs.

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Hybridization

In order to create new variability two or more varieties are artificially crossed. The objective is to produce desirable recombination. These crosses are allowed to self-pollinate and the segregating populations are handled either by the pedigree method or by the bulk method or by the backcross method.

Pedigree Method

This is the most popular method in treating segregating materials resulting from hybridization. The method involves a detailed record of the ancestors hence the name. Briefly, two parents are chosen because each possesses some trait lacking in the other and the intention is to obtain a new plant that by recombinations has these desirable traits from the two parents.

F_2 seeds harvested from the F_1 plants are planted. It is best to have up to 2,000 plants as a minimum. This figure is not reached in some cases especially when the characters being searched are those with high heritability and/or are dominant. Undesirable plants are discarded in the F_2 selection.

To raise F_3 from F_2 selections, an F_2 plant is planted in a row. An F_3 row becomes a family thus selection is made within superior F_3 families though still based on single plant. Usually 3-6 selections are made per row though could be as high as 10 in superior families.

The F_4 generation is handled as in F_3 generation. Plants are still selected on the single plant basis. However, differences between families are much greater than within families.

By the F_5 the emphasis in selection is almost entirely based on families. In the F_6 and F_7 generation, superior lines are bulk harvested and planted on non-replicated observational plots for evaluation. These are later tried in many places with cultural practices included and comparisons with standard varieties

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made before releasing as varieties.

Bulk Method

The bulk method differ from the pedigree method because here no record of ancestors are kept and only representative samples of the previous bulk is used for the next bulk generation. This continues until F_6 to F_8 when individual selections are made and carried as families like in the pedigree method. There is a modified bulk method in which artificial selection is made based on the individual plant performance. Another variation of bulk method is called bulk population breeding. Here a number of desirable parents are selected and crossed in all possible combinations. Equal samples of hybrid seeds from each cross are mixed to raise bulked F_1 plants. From now on progenies of successive generation are bulked harvested coming from randomly selected seed samples. Sometimes artificial selection is practiced. Yield evaluation of the unselected bulk may start after F_8 or F_{10} and continued concurrently with bulk propagation. Bulk population may be continuously grown for 30-40 generations.

The Backcross Method

The backcross method is used when it is desirable to transfer one or few genes to a good variety defficient in one or few characters that are found in an otherwise undesirable variety. It involves making of a cross between the two varieties. The F_1 is crossed again with the standard parent which is called a recurrent parent. The plants chosen for crossing are those with the desirable traits of the non-recurrent parent. Backcrossing continues until the plant breeder is satisfied that most of the recurrent parents characters are kept. After the sixth backcross 99.2% of the genes belong to the recurrent parent. Extensive yield evaluation trials are not required for varieties developed after seven or more backcrosses to a recurrent parent.

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Hybrid Varieties

F_1 populations used for commercial plantings are referred to as hybrid varieties. These make better use of heterosis which is expressed in more vigour and yield. This method is not commonly used in rice breeding due to two main reasons. The yield advantage due to F_1 heterosis is only moderate and pollen production and dispersal are poor.

Mutation Breeding

The objective of mutation breeding is to create new variability by the use of X-rays, fast neutrons, gamma-rays and chemical mutagens. Evaluations of mutagen treated populations are made for yield and rejection of those showing deleterious changes is done. This method is useful in changing simply inherited characteristics in highly developed genic systems. Nevertheless this apparent advantage make many breeders to be reluctant to use it as it might disrupt a superior combination of genes.

Releasing Of A Variety

After a line or a newly introduced variety has been tried in sufficient number of sites where it would be used, the line or variety is named and/or released. By the time a variety is released there should have been many data on its yield in many locations and years. Similarly, the cultural practices and pests and disease resistance should have been determined over some seasons and locations. Grain quality, cooking quality and acceptability tests should preceed a release. Researchers and extension workers concerned should meet to discuss the general performance of the variety and plan on seed distributions. Above all, the breeder must have sufficient quantity of both breeder's seed and sometimes foundation seed for distribution to ministries, registered and certified

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seed growers.

The time it takes to release a variety depends on many factors such as

1. The starting plant population - F_2 or F_4 lines or an improved promising introduced variety.

2. Method of breeding as discussed above.

3. The amount and type of testing required. If the variety is just better than existing one it may have to be tested more. Also if it is to serve large areas many locations are required.

4. The pressure for a new variety. If a country is desperate little or no trial is done to meet a certain demand a variety is released as soon as it is introduced. This is risky and in some cases a program of research is initiated to replace the variety as soon as possible.

5. Availability of fund. This determines whether or not a variety is released early or later. It may be that there is also a need for justification of funds given. Thus a variety may be released earlier than otherwise to stimulate interest of the donors.

The above and many others in various combinations may determine whether a variety is released after 3 or 10 years of its research initiation.

Most of the released varieties have been bred by using the pedigree method. Some popular West African varieties are OS6, BG79, SML lines, Moroberekan, BD2, CP4 and Iguape cateto.

Techniques Of Rice Hybridization

Detailed accounts can be found in several books, that of Chandraratna is recommended.

The two most commonly used methods of emasculation are the clipping and hot water methods. The clipping method involves the excision of glume spices; up to one half of the glumes may be clipped off with fine scissors. The six stamens are then extracted without damaging the stigma and lodicles.

The hot water or hot air method is used in some stations. Water at 43°C is kept in a vacuum flask. A little of the warm water is poured into an empty vacuum flask, shaken up and emptied out. The flask is then inverted over the panicle already selected and prepared as the female parent. A special clamp or fingers are used to hold and close the flask across the mouth. The flask is kept in position for from one to three minutes. Stamens of opened spikelets are removed and the unopened spikelets are cut off.

After emasculation pollens are obtained from the male parents and dusted over the receptive stigmas of the emasculated female parent. The pollinated panicles are covered for at least a week.

Rice Breeding Objectives Using IITA Objectives as an example

Rice which used to be food for special occasion in Nigeria is becoming a regular food item in many homes. The production and cultivation of rice have increased considerably the past six years. This trend is true in many other African countries. Thus rice is a crop in which a consolidated research effort is worth while. With this in mind rice improvement is one of the main research in IITA.

The main objectives can be broadly listed under five headings as follows:

Grain yield improvement

Plant type improvement

Resistance to African pests and diseases

Maintenance of high grain quality

Emphasis on upland improvement

In explaining these main objectives it is necessary to discuss factors contributing to each of these. Under yield related factors we consider in our

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selection.

1. Medium to high panicle number
2. Medium to high grains/panicle
3. Medium to high grain weight
4. Non-shattering but easy threshing.

The number of panicles per plant is very important in determining the yield of rice crop. Where soil moisture is adequate a high panicle number which is related to a high productive or effective tillers per plant is desirable. Under some moisture stress a medium number will be satisfactory as filled grain per panicle will be less. Panicles per plant could range from 4-28. Similarly, a medium to high grain panicle is desirable depending on the water regime. Grain number per panicle can vary from 80-170. The 1000 grain weight is an important factor that determines the grain weight of a variety. The 1000 grain weight ranges from 16- 47gm, 25-35gm being the usual.

Shattering or grain shedding before harvest is due to the anatomy of the pedicel apex and the spikelet base. When these fit horizontally there is shedding but when there is an oblique joining with an enlarged pedicel apex there is no shedding. In our selection we look for a balance between these two extremes.

Improvement of the rice plant type is a concern not only of the IITA scientists but also the Federal Agricultural scientists. We are aware of limitations of the present unimproved plant types. Their height and leafiness make them prone to lodging, non-nitrogen fertiliser responsive and poor yields. Selection criteria for morphology improvement include short to medium height stiff strawed plants; tough, slowly senescent and moderate length and fairly upright leaves; good tillering, superior root development and seedling vigour; lastly well exserted panicles.

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In most cases shorter plants with stiff stem will lodge much less than tall ones if harvesting is not delayed. A height of not more than a meter is our goal. Slow senescent leaves and good basal wrapping has two advantages. It is able to photosynthesize for a longer period and the chances of lodging are reduced. Moderate length and fairly upright leaves afford maximum exposure to sunlight by reducing mutual shading.

There are many physiological factors considered to achieve our objectives. These are directly or indirectly related to yields, growth period and ability of the crop to withstand some adverse conditions. The criteria include medium to early maturity, nitrogen responsive, tolerant of moisture stress, tolerant of deep water, high iron absorptive capacity, tolerant of iron and magnesium toxicity and satisfactory embryo dormancy. In many areas for upland crops medium to early maturing (135-100 days) is highly desirable as crop will be able to complete its life cycle under favourable soil moisture content. Tolerance to moisture stress or drought is an essential trait for a good upland variety. It is important that an upland crop be able to withstand five to seven days of no rain.

For a farmer to obtain his money-worth from fertilizer application it is essential that the crop will respond to this in form of increased grain production. Lack of dormancy is selected against as this will cause sprouting of grains before harvest if the moisture condition is right. This is an undesirable situation because the grain quality is spoilt and such grains will be useless for planting in the following season.

Physical grain quality factors are related to attractiveness of the grains and total milled rice recovery. In our selection we choose medium to long grain varieties with clear, translucent grain appearance which produces a high total milled rice. A clear, translucent grain will possess neither white belly nor

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white core which are responsible for grain breakages during milling. Too long a grain (over 8mm milled grain) also produces much breakages during milling unless special precautions are taken.

In determination of chemical grain qualities factors considered are inter mediate to high (20-30%) amylose content, medium gelatinisation temperature, high protein content (12%) and favourable amino acid balance. An intermediate to high amylose content produces a well separated fluffy and dry rice on cooking. Amylose starch is the straight chained starch residues in contrast to amylopectin which produces sticky rice on cooking. Most West African rice consumers prefer the non-sticky rice except when the rice is used in making a special food preparation known as tuwo. A low gelatinization temperature means shorter time in cooking. Protein is an essential chemical item in our food and the good balance of its amino acids improves the dietary quality of the protein. Therefore these are considered important in our program.

On the question of pests and diseases main emphasis is placed on resistance to *Pyricularia oryzae* (blast), resistance to leaf scald and brown leaf spot and resistance to stem borer and diopsid fly. On average good soil and water conditions the most devastating rice diseases in West Africa is blast. Therefore we are looking at this problem very closely. Neck rot, grain blast, sheath blast etc. are the other forms of expression of the fungus.

In West Africa more than 70% of the rice is grown under upland conditions therefore we are pursuing more vigorously improvement of upland varieties. This is being done in a multi-disciplinary way involving the pathology, entomology, physiology, agronomy, etc. of upland varieties in addition to breeding and selections. This we feel is the best way to achieve our objectives in rice improvement program.

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The Institute general programme for West Africa on rice is not laid down as such but our outreach and cooperational programs develop as more cooperators and materials are identified. We are ready to make our facilities, results, expert's advice, seeds availalbe to any desirable groups, Institutes, Universities and ministries that request for them. Our program outside the Institute premises will depend on the response or request from the various bodies in and out of the country. In carrying out most of our objectives above we shall depend on the cooperations of other researchers and extension workers in West Africa. We have sent out seeds of many promising varieties for nurseries or trials to many parts of West Africa for on site evaluations. These will help determine among other things their adaptability and acceptability in these areas. W.A.R.D.A. is going to co-ordinate most of these nurseries and trials from 1973.

Suggested Reading Materials

Allard R.W. 1960. Principles of Plant Breeding. John Wiley & Sons Inc.

Briggs F.N. & P.F. Knowles. 1967. Introduction to Plant Breeding. Reinhold Publishing Corporation.

Chandraratna M.F. 1964. Genetics and Breeding of Rice. Longmans.

Chang T.T. 1964. Present Knowledge of Rice Genetics and Cytogenetics. Tech. Tull. No. 1. Int. Rice Res. Inst., Los Banos, Philippines.

Chang T.T. & E. Bardenas 1965. The Morphology and Varietal Characteristics of the Rice Plant. Tech. Bull. No. 4. Int. Rice Res. Inst., Los Banos, Philippines.

Grist D.H. 1968. RICE. Longmans, Green and Co. Ltd., London.

International Rice Research Institute 1972. Rice Breeding. Int. Rice Res. Inst., Los Banos, Philippines.

Poehlman J.M. 1966. Breeding Field Crops. Holt Rinehart & Winston, Inc. New York. pp 175-190.

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