BOTANICAL IMPROVEMENT OF VARIETIES—GENERAL CHARACTERS OF INDIAN VARIETIES AND THE APPLICATION OF GENETICS TO RICE IMPROVEMENT

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ABSTRACT

Indian rices belong to the *indica* group of *Oryza sativa* Linn. They are characterised by wide diversity in their morphological and physiological characters. They vary in duration from 85–200 days, in their adaptability to different climatic conditions from cultivation at sea-level to that, at an altitude of 4,000–5,000 feet. They vary in their adaptability to growing in different seasons of the year, and in growing under upland and deep water conditions. They also vary in their resistance to diseases, insect pests and drought. They exhibit wide variation in plant height, tillering, stiffness of straw, grain shedding habit, panicle length, size of grains as well as distribution of pigment on plant parts.

The main problem in rice is the production of high yielding varieties and about 445 improved varieties giving 12–20 per cent. enchanced yield have been evolved in different States by introduction, selection in natural populations and hybridization. Other problems which have received attention at the hands of rice breeders are the evolution of early maturing varieties; varieties responsive to heavy manuring; non-lodging and non-shedding varieties; varieties resistant to floods, salinity, drought, diseases and insect pests, as well as varieties with profuse tillering habit and higher milling out-turn. In all the above breeding projects the principles of heridity, variation and genetic recombination as well as the principle of differential response of genotypes under different environmental conditions, have been fully utilised for the improvement of the rice crop, and several varieties have been evolved or are in the process of evolution, to meet the different requirements.

INTRODUCTION

THE Indian rices belong to the *indica* group of *Oryza sativa* Linn. In India rice has been intensively cultivated over a long period under conditions favourable for development of local types, with the result that the crop is now a vast complex of different forms and thousands of varieties are found showing wide variation in morphological and physiological characters.

From the botanical survey of the Jeypore tract of Koraput District in Orissa, which is supposed to be a secondary centre of origin of rice, in a period of two years over 1000 distinct varieties have been collected and only a part of the area has so far been covered. Among the physiological characters, two important ones are duration and adaptation to particular seasons. In duration the varieties vary from 85–200 days. Varieties adapted to different seasons are prevalent, and rice is grown throughout the year, in some part or other of India. As regards water requirements, at one extreme there are varieties which are grown under upland conditions, while at the other extreme there are the deep-water rices of Assam and West Bengal, which grow in 15–20 feet of water. Varieties resistant to salinity are found in different States. The cultivation of rice crop extends from sea-level to high altitudes of 4,000–5,000 feet as in Kashmir and different varieties are grown for different altitudes and temperatures. In morphological characters the occurrence and distribution of anthocyanin pigmentation in the plant organs is very variable. The plants range from fully green in all parts to pigmentation present in only one, two or more parts to fully pigmented in all parts. In height, the plant (excluding dwarfs) varies from $2\frac{1}{2}$ feet to 20 feet. In the number of fertile tillers, the variation may be from 2–3 to 25–30 tillers per plant. The panicle size ranges from 13–42 cm. In grain dimensions, length varies from 5·3–11·8 mm. and the breadth from 1·9–3·1 mm. Exceptional panicle types like "cluster" where the spikelets occur in whorls, are cultivated in several regions. In kernel types, red rices are grown in almost all the States and are preferred in Malabar and Kerala. Fine, scented rices are grown all over India and are preferred by a richer section of the population for preparation of special dishes. Glutinous types are grown on a small-scale in all the rice areas for special purposes.

Almost all Indian rices are weak strawed and susceptible to lodging, which brings about considerable loss in yield, ranging from 12–33 per cent. depending upon the stage at which lodging occurs. They are unable to stand heavy manuring and are comparatively low yielders. Most of them are susceptible to diseases like blast (caused by *Piricularia oryzæ*) and insect pests like stem borer (*Schœnobius incertulus* Wlk.), gall-fly (*Pachydiplosis oryzæ*), etc. There is considerable variation in the amount of shattering or shedding in the varieties. A certain amount of shedding is present in most of the varieties; while some are highly shattering others are practically non-shattering. Almost all Indian rices are photo-sensitive and changes in day length cause changes in their growth pattern which ultimately reflects in their yielding ability.

Systematic rice breeding work in India was started about 46 years ago with the appointment of a full time Botanist in the old province of Bengal in 1911. Madras followed suit almost immediately afterwards and since then rice breeding has gradually been taken up in all rice growing States. The Indian Council of Agricultural Research, since its inception in 1929, has encouraged and assisted rice breeding work in the country.

The main problem in India, as in all rice growing countries of the world, is the production of high yielding varieties. Among other problems may be mentioned breeding for earliness, resistance to diseases and pests, resistance to floods, drought, salinity, lodging and shedding of grain, breeding for higher milling, profuse tillering, etc. and the principles of heredity and variation, the principle of genetic recombination of characters from the parents into the offspring, the principle of selection within a heterozygous population and the knowledge of the variable response of a genotype under different sets of environmental conditions, have been utilized in the botanical improvement of the rice crop.

Breeding for Bigger Yield

Yield is the prime consideration in any breeding programme and in the early stages of rice breeding, attention was mainly directed towards improvement in yield of the existing varieties. Spectacular results have been achieved in this direction and a large number (445) of high yielding varieties have been isolated, out of which 394 have been evolved by selection from naturally variable populations, the remaining being evolved by hybridization (Table I). All these varieties are reported to give 12–20 per cent. enhanced yield and many of them possess other valuable characters like earliness, stiff straw, etc.

The improvement so far achieved has been among the most widely cultivated varieties growing in large concentrated tracts, while there are still extensive areas in different States, where the variability in the natural population has not been sufficiently exploited. This enormous variability, resulting in thousands of varieties, each suited to particular conditions of soil, season, rainfall, etc., has led to the low adaptability of rice varieties. Breeding has therefore to be localized and a large number of improved varieties have to be evolved.

Alongside of exploitation of natural population for increasing production, intensive hybridization projects are in progress all over India, for breeding high yielding varieties with improved ancillary characters,

TABLE I

Number of improved varieties evolved by selection and hybridization in each State

State	Improved varieties evolved by		Total	Yield of unhusked rice in lb. per acre
	Selection	Hybridization		
1. Assam	23	6	29	1640–3690
2. Andhra	69	7	76	1500–4300
3. Bihar	12	2	14	1830–2050
4. Bombay	44	1	45	1250–3140
5. Kerala	14	..	14	2000–2800
6. Madhya Pradesh ..	9	9	18	1240–2552
7. Madras	103	10	113	1800–5000
8. Mysore	17	8	25	..
9. Orissa	31	3	34	1000–4000
10. Punjab	8	..	8	2000–4000
11. Uttar Pradesh ..	22	2	24	2000–3000
12. West Bengal ..	42	3	45	2000–3690

BREEDING FOR EARLINESS

Indian varieties, as already stated, vary in their total duration from 80–200 days. There are a good number of early varieties grown in different States, *e.g.*, *aus* or *ahu* of Bengal, Bihar and Assam, *beali* or *laghu* of Orissa, *kaurs* and *kuruvais* of Madras, *sathi* of Uttar Pradesh, etc. The early maturing varieties are of special significance for tracts with low and uncertain rainfall such as parts of Bihar, Orissa, Bombay, Madras or tracts where the growing season is short due to early setting in of low temperatures as in Kashmir and Kulu valley, as well as for tracts where double cropping of rice is practiced. Early maturing varieties in general are lower yielding but early maturity can be combined with high yield and several such synthesized varieties, such as ASC. 313–11 of Assam, MTU. 15, of Andhra, Chin. 4 and Bankura 4 of West Bengal, Zinya 31 and Patni 6 of Bombay, CO. 20 of Madras, T. 136 of Uttar Pradesh, etc., are available in India.

Since a large part of the rice area in this country is dependent upon rainfall, the work on the breeding of early maturing, high yielding varieties has been intensified in West Bengal, Uttar Pradesh and other States. At the Central Rice Research Institute, two early and high yielding strains, *i.e.*, CR. 1 and CR. 2 have been evolved from crosses between T. 1145 (a high yielding, medium duration variety) and Ch. 2 (a low yielding, early maturing Chinese variety) and also between T. 90 (a high yielding, fine grained, late maturing variety) and T. 1031 (an early maturing and low yielding Chinese variety). CR. 1 (medium coarse) and CR. 2 (superfine) have yielded about 3,200 and 2,300 lb. of grain per acre respectively in a large-scale trial this year. These strains are reported to have done well in West Bengal as well. The performance of some promising cultures (obtained in this project) during 1956–57 is given in Table II.

TABLE II

Performance of some hybrid strains from the early × high yield project at the Central Rice Research Institute in 1956–57

Cross combination	Culture No.	Total duration days	Calculated yield/ acre lb.	% over T. 1145 (control)	% over T. 141 (control)	Grain size
T. 141	.. Control	144	2444	124·2	100·0	Medium
T. 1145 × Ch. 2	.. 42–76–95–2–1	122	2343	119·1	95·9	do.
T. 1145 × Sathika	.. 7–13–43–95	122	2315	117·6	94·7	do.
T. 1145 × Sathika	.. 7–6–30–58	125	2283	116·0	93·4	Medium
T. 1242 × Sathika	.. 112–241–2–57	130	2210	112·3	90·4	do.
T. 1242 × Sathika	.. 112–241–2–68	130	2121	107·8	86·8	do.
T. 1145 × Ch. 2	.. 42–76–92–17	124	2121	107·8	86·8	do.
B. 76	.. Control	123	2113	107·4	86·5	Coarse, rice red
T. 1145	.. Control	135	1968	100·0	60·5	Coarse

C.D. at 5% level = 339·2 lb./acre.

Some of the early maturing introductions, especially those from China have shown great promise. They have given outstanding performances under upland conditions in several States, *e.g.*, Ch. 4 in Uttar Pradesh, Ch. 45 in Andhra, Ch. 10, 41, 42, 43, 45, 62, 1007, 1039 and 1040 in Bihar, Ch. 41, 43, 62 and 63 in Bombay, Ch. 45, 47 and 988 in the Punjab. Some of the Chinese introductions from the Central Rice Research Institute appear to be especially suited for high altitudes, *e.g.*, Kashmir and Almora (Uttar Pradesh), where yields of over 3,000 lb. per acre have been recorded. The performance of some of these varieties is given in Tables III and IV.

TABLE III

Performance of Chinese varieties (sent from the Central Rice Research Institute) over a three-year period, in replicated trials at Vivekananda Laboratory in Almora (U.P.)

Name of the variety	Source	Cal. yield/acre (in lb.)			Mean yield/ acre over 3-year period	Percentage over *Thapachini* (control)
		1955–56	1956–57	1957–58		
1. *Kaohsiung* 22 ..	China	2016	3544†	5672†	3744	174·4
2. *Taichung* 65 ..	Formosa	1984	3064†	4600*	3216	149·8
3. *Sinchu* 50 ..	China	1904	3120†	4152*	3059	142·5
4. *Chainan* 8 ..	China	1840	3560†	5032*	3477	161·7
5. *Chainan* 2 ..	China	1296	3264†	4560*	3040	141·6
6. *Thapachini* (control)	U.P.	..	1912	4528*	2147	100·0
7. *China* 4 (control)	Acclimatised Chinese type commonly cultivated in U.P.	..	..	3128	..	..
C.D. at 5% level (lb./acre.)			574	547		

* Indicates significantly superior over variety Ch. 4 (Control).
† Indicates significantly superior over variety *Thapachini* (Control).

TABLE IV

Yield data of Chinese varieties from the Central Rice Research Institute tested in Kashmir during 1954–55

Variety	Source	Calculated yield per acre (lb.)	Percentage over Ch. 1039 (standard)
1. AC. 1325 ..	China	4485	128·3
2. AC. 1344 ..	China	3900	111·8
3. AC. 2992 ..	Taiwan	3900	111·8
4. AC. 79 ..	Taiwan	3900	111·8
5. AC. 3 ..	China	3770	108·0
6. Ch. 1039 ..	Chinese type acclimatised in Kashmir	3490	100·0

Breeding for Response to Heavy Manuring

With the present drive for intensive cultivation to increase production, there is urgent need to produce varieties which would respond to heavy manuring. Indian varieties, as already stated, belong to the *indica* group of *O. sativa* and are in general not responsive to heavy fertilization of the soil. Application of heavy doses of fertilizers induces in them rank vegetative growth resulting in lodging at early stages of plant growth, without significantly increasing grain yield; in many cases yield has been found to be depressed due to heavy doses of fertilizer application. The other group of *O. sativa*, *viz.*, the *japonica* to which belong the rices grown in the sub-tropical and warm temperate regions beyond 30° North and South Latitudes, *e.g.*, Japan, Korea, North China and other sub-tropical countries, is on the other hand composed of varieties which are high yielding and highly responsive to heavy manuring. The *japonica* rices, however, when introduced in the *indica* zone, have in general proved a failure, as the plants are very poor in growth, tillering with very small panicles. This is mainly due to the shorter day-lengths and higher temperatures that prevail under tropical conditions, which cause the *japonica* rices (adapted to longer day-length and lower temperatures) to flower prematurely without putting up sufficient vegetative growth, thus resulting in low yields. Though the *japonicas* were not found suitable for direct introduction, it was thought to utilize them as parents for evolving rice strains combining the *japonica* characteristics of high yield and good response to heavy manuring with adaptation to tropical conditions characteristic of the *indicas*. With this object, two parallel hybridization projects between *japonica* and *indica* rices—sponsored by the F.A.O. of the United Nations and the Indian Council of Agricultural Research for the benefit of South and South-East Asian countries and Indian states respectively—were started at the Central Rice Research Institute in 1950.

In these two projects 192 *indica* varieties selected by the Indian States and the various participating Asian countries were crossed to several *japonica* varieties obtained from Japan and in all 710 *japonica-indica* cross combinations were made. The seed from the hybrids of the various cross combinations was distributed to the States in India and the participating Asian countries, for growing the F_2 and the subsequent generations for further breeding work, under the environmental conditions prevailing in the tracts, where the improved strains were scheduled to be ultimately grown.

The F_1 generation hybrids besides showing marked heterosis particularly in tillering number, showed varying degrees of spikelet sterility ranging from 10 per cent. to almost 90 per cent. This high sterility appeared to be a bottle-neck in the breeding project, but later studies of this sterility in the F_2 generation showed that the variance and mean sterility percentage of the F_2 generation was of the same order in low (25%), medium (50%) and high (80%) sterility F_1 cross combinations and that equally fertile selections could be obtained from high sterility hybrids as from the more fertile hybrids. This view was confirmed from the study of F_3 and F_4 generations and it was found that by continuous selection for high fertility, good fertile lines could be isolated in later generations.

At the Central Rice Research Institute, selections made in several cross combinations involving Indian *indica* parents are in various stages of breeding. These selections were based on earliness, panicle character, spikelet sterility and yield. All the selections yielded 40–80 gm., per plant and were significantly better than the *indica* parents. In the progeny row trial, the F_4 generation cross combinations *Ginbozzu*×*Indrasail* and *Norin* 8×*Nangquot*, yielded over 100 per cent. more than the *indica* parents and further the same combinations yielded significantly more under high fertility (80 lb. N + 54 lb. P_2O_5) than under normal fertility (40 lb. N + 18 lb. P_2O_5), the increase being 40 per cent. and 20 per cent. respectively. Good results have been achieved in Andhra, West Bengal, Bombay, Madras, Orissa and other States where selections combining good yield, stiff straw and other desirable characters have been isolated.

BREEDING FOR RESISTANCE TO BLAST DISEASE CAUSED BY *Piricularia Oryzæ*

Of the diseases prevalent on the rice crop, blast disease is the most widespread and of common occurrence. The damage is caused directly by the loss of grains due to neck infection and indirectly by leaf infection. Under conditions favourable for the development of the disease, a loss of 43 per cent. of grain yield has been recorded at Cuttack (*Annual Report, The Central Rice Research Institute*, 1952–53). A total destruction of crop by blast over large areas has been reported in recent years from Andhra, Madras, Kerala, Bombay, Orissa and Kashmir States. Cultivation of resistant varieties appears to be the most usefel way of combating the ravages by this disease. Work on breeding strains resistant to this disease was taken up in Madras as early as 1926 and has since been intensively pursued. With the collaboration of the Mycologist and Rice Breeder several new strains combining resistance to blast and other economic characters have been isolated. Among the new varieties produced are two hybrid strains CO. 25 and CO. 26 from the cross CO. 4×Adt. 10. These new strains however are very late maturing (165–180 days), coarse and not adapted for cultivation in different parts of the country. There is need for short duration blast resistant varieties and vigorous programme of hybridization has therefore been taken up in several States like Madras, Andhra and Bombay as well as some other States. In Madras one culture No. 9958/1 from the double cross (Adt. 5×CO. 15) ×(Adt. 17×CO. 15) is slightly susceptible to the disease and yields 4,110 lb. per acre as against 3,774 lb. of Adt. 17. Several other cultures yielding significantly better than the control have been isolated. In Andhra cultures 5,390, 5,392, 5,352 from crosses between improved varieties and CO. 4 (a highly resistant variety) are being tested at district level, while in Bombay resistant parents like CO. 25, CO. 26 and *Intrasal* are being crossed to the State's high yielding but susceptible varieties.

At the Central Rice Research Institute work in collaboration with the Mycologist is in progress since 1953, to evolve high yielding, early to medium duration and blast resistant varieties. High yielding early to medium duration, resistant to slightly susceptible, fairly homozygous selections from the cross between CO. 13 (high yielding, early, susceptible variety) and CO. 25 (very late and resistant variety) are being tested in bulk trials. Performance of some of these cultures in the F_5 generation tested in Progeny Row trial in 1956–57 is given in Table V.

TABLE V

Cross combination	Culture No.	Mean plot yield in oz.	Calculated yield per acre (lb.)	% over CO. 13	Total duration (days)
1. CO. 13×CO. 25 ..	556–59	35·7	4050	892	129
	610–94	31·5	3575	788	140
	569–36	27·3	3086	683	136
	559–41	26·8	3040	670	131
	562–31	24·3	2759	608	136
	569–49	24·0	2723	603	139
	562–62	23·0	2614	575	132
	545–36	22·6	2563	565	124
	558–59	22·1	2505	553	131
	558–29	22·0	2496	550	124
2. CO. 13 ..	Standard	4·0	454	100	117

Besides breeding blast resistant varieties by hybridization, over 500 varieties have been tested for their reaction to blast, both under artificial infection at the seedling stage in pots and under natural infection at the seedling and adult stages in the field and so far 14 varieties, *viz.*, BJ. 1, Sm. 6, Sm. 8, Sm. 9, CP. 6, CP. 9, AKP. 8, AKP. 9, S. 67, MTU. 5, S. 624, H. 755, Ch. 55, and PTB. 10 have been found to be resistant and moderately resistant to blast. The resistant nature of these varieties has been confirmed from trials conducted under field conditions at 46 centres in various parts of India. More varieties are being tested each year.

Another important disease of rice is the Helminthosporium, caused by the fungus *Helminthosporium oryzæ*. At the Central Rice Research Institute of the nearly 500 varieties tested, six, *viz.*, Ch. 13, Ch. 45, T. 141, BAM. 10, T. 498-2 A and CO. 20 have been found to be resistant under artificial infection and natural infection in the field, in the seedling and adult stages. A breeding programme to evolve Blast-*cum*-Helminthosporium resistant varieties by crossing BAM. 10 (resistant to Helminthosporium but susceptible to blast) and CO. 25 (resistant to Blast but susceptible to Helminthosporium) is in progress at this Institute.

BREEDING FOR RESISTANCE TO INSECT PESTS

Gall-fly is one of the major pests of rice and is prevalent throughout the monsoon period in all the Indian States. Rice varieties exhibit considerable variation in their resistance to particular insect pests. Investigations carried on at the Central Rice Research Institute on the varietal susceptibility to gall-fly show that in general green, scented or purple pigmented (leaf-sheath purple) varieties show much less incidence of this pest than the green non-scented varieties. In Andhra H.R. 35, an improved variety is reported to be fairly resistant to gall-fly. At the Central Rice Research Institute a hybridization project in co-operation with the Entomologist has been taken up to combine high yield and scented rice of T. 412 with the purple and purple wash leaf blade and leaf-sheath pigment of CP. 12 and CH. 17 respectively.

In Madras State, variety CO. 1 evolved from a natural cross in GEB. 24, is reported to be resistant to the stem-borer (*Schœnobius incertulas*), while from Bombay State, *Patni* 6, an improved variety, has been found to be resistant to store moth. More work is needed to test all the available varieties in the country for their susceptibility to various insect pests. Work in this connection is in progress at the Central Rice Research Institute where a number of Genetic stocks are being tested every year for their varietal susceptibility to important pests.

Breeding for Resistance to Lodging

Lodging of rice is a very serious problem affecting rice production in India. Most of the Indian varieties including the improved ones, are weak strawed and susceptible to lodging, more so when heavily manured. With the present drive for intensive cultivation, lodging has assumed increased significance. It has already been pointed out that Indian varieties are generally non-responsive to heavy fertilizer application, which induces in them rank vegetative growth resulting in premature lodging. Preliminary studies made at the Central Rice Research Institute on the extent of loss in yield due to lodging show, that losses upto 34% occur when lodging occurs at preflowering stage, while it is reduced to about 12% when lodging occurs during dough and ripening stages. Thus the problem of lodging in rice is a very serious obstacle in the way of increasing production. Breeding projects are under way in many States to evolve non-lodging high yielding strains. The hybrid *Luchai*×*Gurmatia*×Burma No. 2 evolved in Madhya Pradesh is a non-lodging non-shedding and heavy yielding strain capable of responding to heavy doses of manure.

At the Central Rice Research Institute, work is in progress on the evolution of high yielding, early to medium maturing and non-lodging strains. A large number of genetic stocks are being tested under low-lying and high fertility conditions, for their yield and non-lodging habit. In the preliminary trial conducted last year three non-lodging types, *viz.*, AC. 1951 and W. 113 and W. 130 from Indonesia yielded 2,463, 2,255 and 1,754 lb. per acre respectively which was significantly more than that of T. 141 standard, which yielded 1,182 lb./per acre, the increase being 108·5, 90·5 and 48·5 per cent. respectively over the standard. These varieties are somewhat later than T. 141 by 1–15 days. Hybridization between the non-lodging types and the improved Orissa types has been carried out and promising selections from F_2 and F_3 generations yielding 39·5–51·0 gm. of grain per plant with flowering duration varying between 91–119 days, have been isolated and are under study. Some very promising selections have been obtained from crosses between T. 90 (local) and AC. 517 (a highly non-lodging, poor yielding and early variety from U.P.).

Breeding for Resistance to Drought

Of the 75 million acres under rice, only 20 per cent are under irrigation, while the remaining 60 million acres are dependent upon rainfall. Due to irregular and often scanty rains as in the current year, vast areas are subjected to drought conditions resulting in enormous damage to the crop. The problem of evolving drought-resistant varieties or varieties which are economical in their use of water, has been receiving the attention of the Rice Breeders in different States.

It has been observed that certain varieties grown under restricted conditions of water-supply thrive better than others and this would show the capacity to resist drought is genotypic and governed by specific genes in the varieties concerned. Most of the drought tolerant varieties however are low yielding and there is therefore strong need to produce medium to high yielding, drought-resistant varieties. As the varieties suitable for drought affected areas have to be of short duration, this factor of early maturity is kept in mind in the breeding programmes. In Madras State, one project on the breeding of varieties resistant to drought has been in operation for a number of years and promising homozygous cultures have been isolated from the cross BAM. 3 × TKM. 2, and are being tested. From the crosses between cultivated types like CO. 13, GEB. 24, CO. 1, CO. 2, CO. 5 and the wild varieties belonging to *O. sativa* var. *fatua*, five hybrid cultures have been found to be most promising under Coimbatore conditions. Of the several improved strains evolved by different States, a few of them are reported to be drought-resistant as well.

BREEDING FOR NON-SHEDDING CHARACTER

Shedding or shattering of grain from the rice plant before its harvest, is one of the important factors contributing to loss in yield in rice. There is wide variation in this character in different varieties, but certain varieties which are otherwise desirable become unpopular with the cultivators on account of this shedding habit. The problem of shedding is of special importance at high altitudes, *e.g.*, Kashmir, where the normally non-shedding or slightly shedding rice varieties from the plains, become shedding. Shedding has been found to be a heritable character and the problem of shedding is being tackled by hybridization between appropriate parents.

In Madhya Pradesh, it is proposed to cross some of the improved but shedding varieties of the State with a triple cross hybird strain *Luchai* × *Gurmatia* × Burma No. 2 which is high yielding, non-lodging and non-shedding. In Kashmir State, besides selection in natural populations, crosses are being made between local varieties and the non-shedding Chinese and Japanese varieties to evolve high yielding and non-shedding strains.

Among the high yielding improved varieties, MTU. 7 (Andhra), S. 22 (Assam), PTB. 9, CO. 12 and GEB. 24 from Madras, are reported to be non-shedding also.

Breeding for Resistance to Floods and Submersion in Deep Water

Large areas in Assam, Bihar, Kerala, Orissa, Madras, Western India and Andhra, totalling about 3 million acres get flooded to varying depths of water during the monsoons. The depth of water varies from 2 feet to 16–20 feet (as in Assam) and the duration for which the rice plants may remain submerged, varies from a few days in certain regions, to several days as in some parts of Assam, Madras and Kerala. Besides submersion to varying depths of water, the rice plants in many regions like those of Assam and Bihar, have to contend against the mechanical force of the surging flood waters. Thus the problems of each flooded area are peculiar and these have to be studied before embarking upon breeding programmes.

Varieties differ in their capacity to withstand submersion for a particular length of time and also in their capacity to grow fast with the rise of water and thus keep above the surface. States afflicted with the problem of low-lying areas which are inundated with varying depths of water, or those subjected to heavy annual floods, have evolved by breeding, flood-resistant varieties. Notable among these are the long stemmed strains EB. 1 and EB. 2 of Assam, which can stand 8–15 feet of water and others like Ar. 1, Ar. C. 353–148 and Ar. 614–256 which can stand 2–6 feet of water. Other strains like FR. 13 A and FR. 43 B of Orissa are resistant to floods, while Hybr. 84 of West Bengal can stand submersion up to 6 feet depth. Similarly certain high yielding strains of Madras are capable of standing submersion up to 3–4 feet depth.

Breeding projects, some partly financed by the Indian Council of Agricultural Research for evolving strains suitable for cultivation in flooded areas, are in progress in Andhra, Bombay, West Bengal and Assam and soon a project is proposed to be started in Madras too. Hybridization projects to evolve flood resistant strains, are in progress in a number of States.

Breeding for Resistance to Salinity

Large areas along the sea-coast in the States of Andhra, West Bengal, Bombay and Madras are subject to salt water inundation. Several States have evolved salt tolerant strains, the most notable among these being the SR. 26 B strain of Orissa, which has been found to be doing well in the salt areas of different States. Others, include Chin. 13 of West Bengal, *Kalarata* 1–24 and *Bhurarata* of Bombay, 349 *Jhona* of the Punjab and T. 21 of Uttar Pradesh.

In Andhra State progenies from 13 cross combinations between improved Coimbatore types and four saline resistant varieties, *e.g.*, T. 892, *Kathir*, *Bairuvadlu* and SR. 26 B are under study and promising selections have been isolated. In Bombay progenies of crosses between noble sweet land varieties and saline resistant varieties are under study.

BREEDING FOR SEED DORMANCY

In general, short duration varieties in India lack seed dormancy, with the result that under wet weather conditions at the time of harvest, seeds begin to sprout while still on the panicles, causing considerable losses in yield. Seed dormancy therefore is a desirable character in the short duration varieties. In Madras State, seed dormancy has been found to be an inherited character and is being introduced in the short duration varieties by hybridization between the popular short duration varieties like CO. 10, CO. 13, CO. 18, ADT. 3 and MTU. 3 and the exotic short duration varieties from Iraq and Italy which possess seed dormancy.

BREEDING FOR HIGHER MILLING OUTTURN

The ultimate value of a rice variety depends upon its milling percentage, *i.e.*, the percentage of clean rice to paddy grain. Wide variation is known to exist among varieties for this character. In general, coarse rices give a higher milling outturn than the fine ones; thus for an improved variety to be popular among the cultivators, it must possess a higher milling percentage also. No work appears to have been done in this direction; preliminary work on determining the milling percentage of the genetic stocks maintained at the Central Rice Research Institute, has been taken up to determine the extent of variability in rice for this character, with a view to its utilization in future breeding programmes.

UTILIZATION OF MUTATIONS IN BREEDING

There is a very strong positive correlation between the number of ear-bearing tillers per plant and yield. In rice improvement therefore, this character is given the first place and most of the field selections are based primarily on this character. A dwarf mutation called D. 102 with profuse tillering (80–100 ear-bearing tillers per plant) was observed at the Central Rice Research Institute in the variety T. 1222–12, in 1954. The mutant has short panicles, bearing only 15–20 grains per panicle and yields about 15·0 gm. per plant. With a view to transferring the profuse tillering habit of the mutant into some of the cultivated varieties, the mutant was crossed to the original parent as well as to the variety AC. 9. The F_3 performance of some of the selections is given in Table VI.

While none of the segregates could reach or come near to the 80–100 tiller number of the dwarf mutant, some segregates with 20–25 tiller number

TABLE VI

Cross combination	Culture No.	No. of ear-bearing tillers per plant	Single plant yield (gm.)	Percentage over the cultivated parent	
				Ear-bearing tillers per plant	Single plant yield
D. 102–4×AC. 9 ..	R2–14–6–8	25	62·0	192·3	295·2
	R2–35–3–11	24	60·5	184·6	288·1
	R4–18–4–20	23	57·0	176·9	271·4
	R2–21–4–12	25	55·0	192·3	261·9
	R2–35–2–7	22	55·0	169·2	261·9
	R4–18–4–6	25	51·5	192·3	245·2
	R5–3–2–12	20	50·0	153·8	238·1
AC. 9 ..	Normal parent	13	21·0	100·0	100·0
D. 102–4×T. 1222–12 ..	7–1–19	23	56·0	191·9	255·7
	17–4–8	21	48·5	175·0	221·5
	25–3–15	22	47·0	183·3	214·6
	15–8–30	23	46·5	191·9	212·3
	15–8–3	21	46·5	175·0	212·3
	15–3–9	26	46·5	216·7	212·3
T. 1222–12 ..	Normal parent	12	21·9	100·0	100·0

appear to be promising, in that, besides the high tiller number, they combine good yield as well.

IMPROVEMENT BY SECONDARY SELECTION

Most of the improvement in rice in India, has been achieved through primary selections in natural populations; and because rice is a self-fertilized crop, it is presumed that there would not be enough genetic variability in these primary selections to permit of profitable secondary selections. However, yield the main objective in breeding, is a complex character of a polygenic nature, dependent sometimes on a very large number of genes, which may not become homozygous even after many generations of selfing. The value of secondary selection in rice breeding has been studied at the Central Rice Research Institute. Twenty-nine established strains, each arising from an original single plant selection were studied for the purpose. Results showed that secondary selection could be profitable in the case of some varieties while not in others. In the variety T. 1222–12 yield was progressively raised by continued selection from 31·4 per cent. in the first year of selection to 40·0 per cent. in the fourth year. This is shown below.

		Yield per plot oz.	Percentage over bulk
T. 1222–12 (bulk)	..	10·94	100·0
T. 1222–12–116	..	14·37	131·4
T. 1222–12–116–30	..	14·57	134·1
T. 1222–12–116–30–58	..	15·16	138·6
T. 1222–12–116–106	..	15–32	140·0

Similar results were obtained in the case of variety T. 897, where the yield of the selections T. 897–432 and T. 897–457 significantly increased by 13·0 per cent. and 23·6 per cent. respectively over the T. 897 bulk.

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