INDIA'S RICE DEVELOPMENT MOVES FROM UNSTEADY INFANCY TO VIGOROUS ADOLESCENCE

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India is the world's second largest producer of rice and has the world's largest national acreage devoted to rice production -- approximately one-third of the world acreage. Rice is the most important foodgrain in India accounting for approximately 40% of total production. Progress in Indian agriculture and success in meeting the goal of food abundance rests with heaviest weight on the successful development of Indian rice production.

I - Unsteady Infancy

In assessing the progress in India's agriculture in the last few years, it is evident that a major transformation has taken place in the production of wheat. From a cursory view of aggregate data it would appear that a similar transformation has not occurred in rice production despite the fact that new dwarf rice varieties, physiologically similar to the exotic varieties that sparked the growth in wheat output, are available to rice growers. The logical question is: Why? There have been many explanations.

Some observers have focussed on the biological aspects of the new plant material. They point out that some farmers have tried the new dwarf varieties and have returned to their older rice types. They point to disease incidence, difficulties of assuring grain maturity, and poor grain quality as the causes of cultivator dissatisfaction.

The other observers centre their explanations on the rural institutions serving rice farmers -- inadequate markets, a lack of mechanical dryers, and antiquated milling facilities, insufficient credit, land tenure circumstances that discourage adoption, poor administration of extension services, lack of experience among researchers and extension personnel with rice, etc.

Still others concentrate their explanation on the farmer and his technical competence as a cultivator. Stagnation in rice output is laid to the low aspirations of the rice cultivator, or to the oppressive effects of the social milieu of village India, or to the low level of farming skills the cultivator brings to his agriculture.

(a) Plant Type and Sunlight

This article seeks to sort through the past and present state of India's rice development programme in an effort to bring a balanced view to the issues and trends that set the stage for the future.

We begin by exploding the myth that Indian yields per rice acre are among the lowest in the world. They are; but they do not differ significantly from the yields realized in any tropical country. The comparison that slights the Indian cultivator is one that pits his output against his contemporary farming in the temperate zones under conditions of strong sunlight; when he is compared to his tropical neighbour, he does just about as well. The failure to interpret properly the tables of international yield comparisons obscured for almost fifteen years the critical element needed for tropical rice development -- biological materials that would be responsive to fertilizer and yield well under the heavy cloud cover that reduces the sunlight energy available for plant development during the tropical monsoon rainy season.

The sub-species *indica* is the traditional type of rice grown in tropical areas. It is characterized by a non-sticky long grain, a tall growth habit with a profuse number of narrow, droopy, light-green leaves, delayed flowering and long duration to maturity. The sub-species obviously evolved under tropical rainy season conditions where heavy rain and flood gave a competitive advantage to the tall plant type; early, rapid vegetative growth assured the rice plant of an edge in competing for nutrients and space with weeds; and, most important to yield stability, delayed flowering and long maturity meant that grain formation would take place after the monsoon retreat when strong sunlight would be available for the period of reproduction requiring the greatest photosynthetic activity in the plant.

But the same characteristics that gave tropical *indicas* a superior ability to survive under severe monsoonal conditions act to suppress grain yield under modern high fertility farming regimens. The addition of fertilizer causes more vigorous plant and leaf growth and results in pre-harvest lodging with a consequent reduction in grain output. Indeed, there is now evidence that the rapid vegetative growth and profuse leafing, so useful for competition with other plant species, mutually shades the rice plant itself and its neighbours, leading to a decreased photosynthetic efficiency in fixing plant carbohydrate.

The plant type bottleneck to higher yields was first broken by plant breeders in Taiwan with the development of Taichung (Native) 1, a true *indica*, dwarf in stature, with wide, erect, dark green leaves, a high capacity for tillering, and a sturdy straw -- attributes that reduced mutual shading, allowed a large number of productive tillers per unit area of land, and gave the plant a non-lodging habit that enabled it to use applications of heavy fertilizer effectively and efficiently to produce a dramatic increase in yield under tropical conditions.

(b) Exotic Varieties and Development Strategies

Taichung (Native) 1 (TN-1) arrived in India in 1963. By 1965 it was accepted by Indian rice scientists as having the physio-genetic qualitites on which to base exciting new programmes of plant breeding. But it was not until 1966 that the decision was made to use TN-1 as the major element in the Government's new High Yielding Varieties Programme (HYVP) for expanded rice output. This decision was not supported unanimously by the scientific community. The exotic plant material had been bred and selected under environmental conditions very different from those in India and its susceptibility to local plant pests and pathogens had not been extensively tested on the sub-continent. It was argued that if the new dwarf variety proved highly susceptible to diseases or insects indigenous to India, the whole HYVP would suffer and later extension work based on improved dwarf varieties would prove difficult; and that even if it did not prove susceptible in the early stages of the programme, and if, because of higher yields, there were a widespread adoption, this could be followed by a disaster of major magnitude in some future year when weather or other conditions were propitious for the sudden spread of a previously dormant local parasite.

These arguments were carefully weighed in the formulation of the HYVP strategy. By 1966 some experience had been accumulated with TN-1 under Indian conditions, not as much as many would have liked, but enough so that what were large uncertainties in 1964 were now tolerable risks. This experience and these risks were placed against the national need to do something quickly about rice production following the calamitous drop in output in 1965-66. It was literally a case of the Government having no alternative; it had to move to introduce the new plant type to the nation's rice producers. The decision has been called a gamble. In a sense it was a gamble, but a gamble between acting and doing nothing. Previous strategies of "community development" and "intensive agricultural" programmes had demonstrated the futility of trying to increase national rice output through changes in rural institutions, farmer education, or extension programmes that had very little to extend.

There was some solace for those concerned about the adaptability of TN-1 to Indian conditions in news from the International Rice Research Institute in the Philippines of a new dwarf variety that had very high yield potential -- IR 8, and in the establishment by the Indian Council of Agricultural Research of a rice development programme through an All India Coordinated Rice Improvement Project (AICRIP). Seed of IR 8 was available in India in 1966, and was grown in experimental trials at several different locations that year. The results were uniformly good. Seed multiplication of IR 8 was undertaken on a large scale in rabi 1967, and it was confidently predicted that IR 8 would soon replace TN-1 as the major variety of the HYVP.

(c) Shortcomings for Indian Conditions

Both TN-1 and IR 8 had drawbacks in their adaptation to the widely diverse environmental circumstances of India's many rice production areas.

Some of these were predicted. For example, the susceptibility of TN-1 to bacterial leaf blight was well known in Taiwan where this variety is grown almost exclusively during the dry season when the weather does not favour blight.

Others became apparent only from farmer experience. For example, IR 8 had been developed under the hot humid conditions of the Philippines and it proved to be sensitive to cool night temperatures when grown in Northern India and at higher elevations of the Deccan where delayed maturity upset the timing of farm rotations. (TN-1 is just as temperature sensitive but because of its normally shorter growing duration the delay in ripening does not affect preparation for succeeding crops, as a result it has become an important _boro_ season variety in North India.) Both varieties proved to be susceptible to the gall midge, an insect not present in the Philippines or Taiwan but which reaches epidemic proportions in some restricted areas of India and Southeast Asia.

(d) Adoption Record

These shortcomings did not overshadow the merits of the new exotics as a dynamic force contributing to Indian rice production. Instances of yields of 8,000 pounds and more obtained in the 1965-66 _rabi_ season by a number of farmers kindled a wide interest in the dwarf varieties. In _kharif_ 1966 it is estimated that roughly 1.5 million acres were planted to TN-1, a ten thousand fold expansion from the 150 acres in this variety during _kharif_ 1965 --

surely an achievement in two seasons that has few equals in the annals of crop production. The release of IR 8 in December 1966 brought about a similar story -- from 1966 to kharif 1968 this variety spread to over 3.5 million acres. In all, it is estimated that kharif plantings of dwarf material in 1968 were over 5.0 million acres, a doubling of area from 1967 and more than three times the area in 1966.

Greater sunlight intensity of the rabi season adds 20% to 50% to rice yields and the popularity of the dwarfs for dry season production under irrigation is reflected in the fact that winter acreage under dwarfs estimated in 1967 at about 0.6 million has risen to close to 2.0 million acres in 1969.

Dwarf yields have repaid the decision to gamble. Top yields have been between 8,000 and 10,000 pounds of paddy per acre. According to crop cutting estimates in some of the IADP Districts, TN-1 and IR 8 yields are more than double the yields of indigenous varieties. There are reports that some farmers have tried the new varieties and have returned to planting their older types. Some critics of the HYVP have played on these reports to cast doubt on the whole programme. But behaviour of this kind should have been expected. The new plants require changes in, and greater care with crop management practices. Indeed, the production of the new exotics involves a cost of learning that the farmer must be willing to pay if he is to benefit fully from their yield potential. Some farmers are unwilling to invest in gaining experience preferring to leave it to others, better able to bear the risks and costs, whose findings can be imitated cheaply. New innovations in agriculture always pass through a period of trial and test; that farmers can be found who have tried and rejected an innovation does not prove by itself the innovation unproductive or unsuited to their farming conditions. The fact is: many farmers have mastered the skills needed to exploit to a considerable extent the yield capacities of the new dwarf materials, and many more will do so in the future.

II - A Prelude to Adolescence

In retrospect it is obvious that the intensive agricultural programmes of the early sixties met with very limited success mainly because they concentrated on increasing fertilizer consumption without providing the biological base required for its efficient and profitable use. The startling expansion in fertilizer offtake in the past three or four years has been fuelled by an increase in the farm price of grain relative to nutrient prices and the advent of varieties whose yields are very responsive to heavy applications of added plant food. In the future, grain prices can be expected to ease, leaving the growth in farm output and fertilizer consumption dependent on the diffusion of new responsive varieties among cultivators. The pace of this diffusion will rest on the extent to which cereal improvement research generates a sequence of new varietal materials possessing continuously better efficiencies of, and profit opportunities fo for increased fertilizer use.

Rice has been a staple food crop in India for millenia. In its long history preceptive cultivators made unceasing selections from among the plants in their fields, those which offered the best adaptation to the physical environment of their farming and which had the most evident power to withstand the attacks of hosts of perpetually evolving pests and pathogens. The dynamic balance between locally chosen varieties and the ecology of their production as a cultivated crop resulted in plant types that were at least partially resistant to attack from most indigenous parasites and which had built-in growth controls that suited them to traditional farming practices. The variety ecology equilibrium struck in India's immemorial rice agriculture was not matched perfectly by the new exotic dwarf materials. Disease and insect susceptibilities posed one set of handicaps to their use in traditional farming; temperature sensitivity was another; non-photo period sensitivity and low grain quality were two additional elements.

(a) Photo Period Sensitivity

Rice cultivation in India is paced by the Southwest monsoon. In most areas of the country the onset and retreat of the monsoon rains can be normally predicted to within a couple of weeks. But variations in the arrival and departure of the rains results in rice production seasons that can change in length from year to year by as much as six to eight weeks. Because strong sunlight for photosynthesis of grain carbohydrate at the end of the plant's life cycle adds to yield, most of the traditional rice varieties grown during the main rice season were photo period sensitive so that regardless of when planted, they flowered and went into their reproductive phase of growth when day length reached a certain critical number of minutes. After flowering there was a fixed time to maturity, a time interval sufficient for the monsoon to retreat and the rice to ripen ready for harvest under sunny skies.

Some indigenous varieties, particularly those grown in the aus and boro seasons in Northeastern India, are non-photo period sensitive in that they flower and are ready for harvest at a definite time interval after planting. Both TN-1 and IR 8 are non-photo period sensitive. There is no question that some farmers have found this an impediment to adoption. Early planting resulte resulted in early flowering, early maturity and early harvest, all of which may have had to take place under heavy rain. In some parts of the country, most notably in Tanjore, large investments have been made to establish mechanical drying facilities to process early harvests. More drying facilities are critically needed in other rice areas if farmers are to find it profitable to adopt dwarf plant materials. Until rice farmers have access to dryers there will be a continuing demand for photo sensitive and long duration varieties to match the rainy season.

But there are opportunity costs in developing and using photo period sensitive, long duration materials; a cost in the opportunity lost to grow more than one crop, and the research investment needed to produce a variety with a relatively limited range of geographic adaptability. The route to multiple rice cropping and to rice breeding programmes that will have a national impact on farmers at all latitudes (the locational factor determining day length) lies with the development of short duration non-photo period varieties, and an infra-structure investment in dryers, thereby reducing risk of loss, at the same time providing the farmer a higher yielding variety and more time for another crop to succeed the short duration one. The farmer cannot master the seasons but now can be provided the means whereby the season need not dictate to or master him.

In the wheat growing areas of India the decision to adopt a new variety and to feed it with plant nutrients, is a decision the farmer can make in isolation from the decisions of his neighbours. In most high productivity canal irrigated rice areas of India the decision to use a dwarf variety and fertilizer is not as easy because few cultivators control the flow of water to and from their individual fields. The common practice of rice irrigation is to flow water from field to field, down and across a terraced area from the supply channel at the top to a drain at the terrace base. It may take as much as a month for water to flow across the terrace and cover all the fields from top to bottom. When all the cultivators farming land commanded by a channel were using photo period sensitive varieties, the difference in planting times between the upper and lower fields had little impact on production, the varieties on the terraces would all flower and be ready for harvest about the same time. In the case of non-photo period sensitive materials, however, the absence of individual field water control constrains the decision-making capacity of the cultivator -- if he grows the dwarf materials and his neighbours do not, how is he to be assured of the water he needs for his crop, and how can he arrange for the draining of his field as his crop matures when those on the terraces above and below him still need the flow of water across his field for their longer duration varieties? The ultimate answer lies in infra-structure investments for terminal water spreading and drainage networks to provide full water control at the individual fields in the canal areas. Investments that have been ignored in the past, but without which India's rice development, indeed India's agricultural development cannot reach full maturity.

(b) Grain quality

Good grain quality is one of the imponderables of consumer preferences. It is either there or it isn't. In TN-1 and IR 8 it isn't. The fact that it isn't was not important when the decision was made to include these varieties in the HYVP. What was needed in 1966 was rice for hungry people and the medium-coarse to coarse quality of the dwarf grain type, not dissimilar to the quality of the majority of Indian rices, was a secondary consideration to its yield potential. As the immediate pressure of population against food eases, however, quality and the spread of market prices reflecting quality will become a paramount concern of the cultivator. To obtain the best output from the dwarf materials he must fertilize heavily and rely on the sales of his surplus production to cover his input costs. The present system of controlled procurement prices for coarser rices and virtually free prices for finer quality grain not only discourages the volume production potentially available from exploiting the dwarfs by lowering their profitability, it also diverts acreage to growing fine grain varieties to supply the demands of the economic elite leaving the poorer consumers dependent on rationed rice supplies and low quality wheats.

III - A Vigorous Adolescence

Before Taichung (Native) 1 was adopted as a core element in the HYVP, Indian rice scientists recognized that if the production potential of its plant type could be exploited through new varieties adapted to Indian conditions, a powerful new weapon would be forged for the pursuit of national abundance. To create such a weapon the Indian Council of Agricultural Research organized and financed the All India Coordinated Rice Improvement Project (AICRIP) to undertake a broad programme of plant breeding, testing, selection and production experimentation at centres located throughout India. Assistance in this new programme was provided by the Rockefeller Foundation and US-AID in cooperation with the International Rice Research Institute. AICRIP headquarters are at Rajendranagar, the site of the Andhra Pradesh Agricultural University near Hyderabad. AICRIP scientists coordinate trials at the State rice research centres, the Indian Agricultural Research Institute at New Delhi, and the Central Rice Research Institute at Cuttack. The Project operates through seven zonal centres, 12 regional centres, and three special testing centres where adaptive research trials are conducted on new varieties and various agronomic practices. To assure a productive balance betweenAICRIP varietal work and at the same time effectively combat the rice parasites of the country, selections from genetic crosses made at the major research stations and material from the large collections of world rice varieties now being built in India are screened for resistance to local pests and pathogens at specialized research stations: 13 centres are working on rice blast disease, four on blight, two on rice viruses, two on rice stem borer, and two on gall midge.

Coordinated research and new research findings are the common objective of all the centres under the Project. The burden of leadership for work on new research findings rests with both the AICRIP staff and the senior rice research scientists at the Central Rice Research Institute, Cuttack.

(a) New Indian Dwarf Varieties

Plant materials selected at the AICRIP centres from the crosses made by the Project geneticists that successfully pass a screening for resistance to insects and diseases are sent for production testing to over 50 different locations throughout India. The results of all the experimental work conducted at AICRIP research centres and testing stations are reported to semi-annual national conferences of rice workers. These conferences review past results and develop the experimental programme for next season's trials. Each conference also undertakes a careful study of the data on those selections from breeder lines that show promise of having the many qualities required of a successful new rice variety and, if performance is accepted in comparison with the check varieties, can recommend to the ICAR the release to farmers of promising types. The last AICRIP conference, held at the Central Rice Research Institute in November 1968, voted to recomment the release of two new lines, CR 28-25 developed at the CRRI, and IET 723 developed at Rajendranagar. Both lines came from selections made by crossing TN-1 and the Indian tall variety Type 141, a variety that has good grain quality and a wide adaptability to Indian conditions. These two breeder lines were released by the ICAR in December under the names Padma and Jaya respectively.

Jaya and Padma are the first products of the all-India resea research effort to exploit the higher yield potential of the dwarf plant type. They are the first of what will be a long list of truly improved plant materials adapted to Indian conditions that will become available to Indian rice cultivators over the next decade. Under the AICRIP varietal development programme there is sufficient breed seed to plant 100 acres of Jaya and 2,000 acres of Padma for seed multiplication by the National Seeds Corporation during _rabi_ 1969. This should translate into enough seed for the cultivation of 15-20,000 acres of Jaya and roughly 400,000 acres of Padma for this year's _kharif_ crop. The major contribution of these varieties will be in 1970, but the experience this year will provide a reading on the potential of these new releases to underpin the nation's rice development.

It is likely that farmer experience with these Indian developed varieties will be more satisfactory than with the earlier imports. Experimental data on Jaya indicates a yield potential that is 10% superior to the yield of IR 8, and it has a 10 day earlier maturity; it is somewhat more resistant than IR 8 to the major diseases of blight and blast; and it has a fairly wide adaptability to the geographic diversity of the nation's rice areas and to the annual cycle of heavy monsoonal cloud cover and bright _rabi_ sunshine. Padma has a grain quality superior to the earlier dwarfs, and it can be expected to find its greatest usefulness in seasons requiring a short duration variety such as the _boro_ plantings in Northeastern India and in multi-crop rotations. However, these new varieties, like the two before them, do require good management and close attention to husbandry if their yield potential is to be properly exploited.

It was anticipated in 1966 that TN-1 would quickly be replaced on Indian rice fields by the superior IR 8. It is likely, in turn, that IR 8 will be replaced by Jaya as soon as seed supplies permit (the acreage of IR 8 will however continue to grow for the next few years, however, while seed of Jaya diffuses through the rice growing regions).

A look to the future as seen from the AICRIP plots leaves no doubt that Padma and Jaya in their turn will become items in the history of Indian rice agriculture within a very few years. AICRIP's scientists are experimenting with several thousand new lines from which, after rigorous testing, will emerge the new varieties of the seventies. Among these are crosses based on high quality grain types -- rices such as basmati and the fine grained non-scented varieties preferred in South India -- crosses that incorporate new resistances to viruses and other major diseases, crosses that have internal resistances to insect attack, and crosses that generate varieties with specific adaptations to the particularly difficult environments of some of the nation's rice growing areas such as the cool climate of Kashmir and the heavy rains and cloud of Assam. Over the next decades the work of AICRIP will produce a continuous flow of new rices of high yielding potential on which India can build and sustain an expanding food output.

(b) Variety Potential and Output Growth

The key concept in building on the work of AICRIP is embraced in the word potential. Establishing a sound biological base for output growth is the first prerequisite for generating agricultural development. But the biological base alone does not add to supplies of consumable grain. It is through the farmer that the nation will realize the biological potential for growth. But only if the farmer is supported and able to meet the management needs of the new materials.

Foremost among these is fertilizer. Without nutrient supplies there is no possibility for the farmer to innovate, and there will be no return on the public investment in rice research. The crucial need is for supplies of adequate quantities of the correct formulations to be available when needed at a market convenient to the cultivator. A combination of circumstances that still seems to elude the power of administration to effect.

A competent extension service trained in rice production techniques can greatly reduce the cultivators' time and costs of learning. It can bring to the farmer those many small management practices which taken alone are of small consequence, but when applied in combination can add substantially to yield, things like seed bed preparation, depth of transplanting, placement and timing of fertilizer applications, proper methods of water control (where this is possible), the correct and safe use of pesticides, proper drying and storage techniques.

Good markets for inputs and to handle surplus production through efficient transportation linkages with major consuing centres are basic to the price structure that establishes farmer incentives.

Pesticide supplies to protect both invested operating capital in the crop and the crop itself from pests and diseases. Saving 15% to 20% of the low (1,000 to 2,500 pounds) yields of traditional rice farming could not buy much protection chemical, saving this percentage on yields of 5-6,000 pounds per acre is usually a highly profitable investment.

Post-harvest facilities for processing, drying and storage of rice will enable cultivators who have access to water for multi-cropping to overcome one of the most severe bottlenecks in the production chain -- saving the grain of a short duration crop that is harvested under the high moisture conditions of the rainy season.

And over it all is the need for expanded and more efficient farm credit facilities to support the cultivator in his move to a modern agriculture.

IV - From Adolescence to Early Maturity

A review of India's experience with the HYVP thrust for greater rice production suggests strongly that in spite of some drawbacks, farmers have responded and responded well to the production opportunities opened by the new dwarf plant types. The two varieties on which the HYVP was built initially do have characteristics which slowed their diffusion among rice cultivators, but the spread of TN-1 from 150 acres to close to 1.5 million acres in two seasons, and of IR 8 from 30 acres in 1966, to 250,000 acres in kharif 1967, and to over 4.0 million acres in kharif 1968 indicates clearly, if any doubt existed, that the Indian rice farmer is willing and anxious to innovate -- all he needs is an assured supply of productive inputs capable of underpinning a profitable transformation of his agriculture. What scientists found as a plant type more efficient in utilizing fertilizer and sunlight, many farmers found as a money-maker more efficient in using their land and labour.

The disadvantages inherent in TN-1 and IR 8 are already largely overcome by AICRIP research work. The demand from cultivators now is for new varieties of high yield potential without the defects of the earlier dwarfs; it is not for old varieties with an improved yield capability tacked on. This demand is being met, and will continue to be met on an ever expanding scale. AICRIP scientists will be turning their attention shortly to the needs of upland rice farmers, to developing photo period sensitive varieties for areas where drainage and water control are restricted, to work on deep water rice varieties, etc., work that will create a perpetually growing potential for abundance.