

REVIEW PAPER

BREEDING PERSPECTIVES FOR FLOOD-PRONE RICE LANDS OF SOUTH AND SOUTHEAST ASIA

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ABSTRACT

Total rice extent of the world is approximately 147 million ha, about 17 million ha is confined to flood prone ecosystems and the largest extents are in Bangladesh (2.49 mn ha) and India (2.47 mn ha). Research on flood prone rice began in the first half of the 20th century in India (Habiganj) and Thailand (Huntra). Geographic location, flood water depth, duration of inundation and heterogeneity of edaphic constraints, has made the flood prone eco-system a complex one. The traditional cultivars grown in these environments have evolved through selection from land races. Some of these are popular premium grain quality types. The present emphasis on varietal improvement is confined to shallow and medium water depths below 100 cm. Erect growth habit, initial seedling vigor, tolerance to drought, submergence and complex soil problems, seed dormancy to prevent pre-harvest sprouting, water depth induced internode elongation are specific traits in the plant type designed for shallow and medium water depths. Deepwater areas (water depth > 100 cm.) have to depend on traditional floating rices with very little or no scope for further improvement through selection. The breeding efforts in floating rice should emphasize traits such as kneeing ability, nodal rooting, post-kneeing plant type features and location specific photosensitivity requirements to improve productivity.

KEY WORDS : Breeding, Flood-prone eco-system, Rice.

INTRODUCTION

Of the 147 million ha of rice grown annually, 17 million ha fall within flood prone ecosystems and includes the boro rice cultivated during the dry season. Catling (1992) reports that nearly 9 million ha of flood prone lands are located in the river basins of Asia and Africa. The Ganges – Brahmaputra – Megna basin (Nepal, India, Bangladesh) alone accounts for more than 58% of Asia's flood prone rice lands (8.33 million), while the basins of Irrawady in Myanmar, Mekong in Cambodia and Vietnam, and Chao Phraya in Thailand account for most of the remaining extents. Africa's 0.5 million ha of flood prone rice lands are primarily confined to the upper and middle basins of Niger in West Africa.

Among the rice producing countries, Bangladesh and India have the largest extents amounting to 2.49 and 2.47 million ha, respectively, and Myanmar ranks next with 1.28 million ha. Catling (1992) reports that nearly 25% in India and 6 % in Bangladesh, are flood prone. Average yields of these flood prone lands are below 2.0 t/ha. The uncontrolled floods, harsh soils, climatic stresses and the comparatively insignificant extents, have made people think that

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attempts to improve productivity of flood prone rice lands would be futile.

Research on flood prone rice may have begun in the early 20th century, but emphatically in Asia it was with the establishment of Habiganj and Huntra research stations in India (now in Bangladesh) and Thailand in 1934 and 1941 respectively. Since gaining independence in 1947, bulk of the deepwater rice research activities in India was mandated to the Chinsurah (West Bengal), Pusa (Bihar) and Ghagharaghat (UP) research stations (Swaminathan, 1979). Nearly 30 research stations/centres across flood-prone ecosystem of the world are currently involved in deep water rice varietal improvement and related research activities to increase productivity of flood-prone rice (Catling, 1992).

FLOOD-PRONE ENVIRONMENT

Geographic distribution of flood-prone lands has direct relevance to adaptability of rice cultivars. There can be restrictions imposed on varietal adaptability due to differences in day length and/or temperature regimes based on geographic location of the land. The flood-prone lands of Ganges-Brahmaputra basin are confined between the latitudes 23 and 28' N, and the Irrawadi, Chao Phraya and Mekong basins lie between the latitudes 9 to 17' N of equator. The tidal and inland swamps of Kalimantan, Sumatra, are in the southern hemisphere.

Soil heterogeneity associated with edaphic constraints is expected across the flood plains of these major river basins. The soils may range from alluvial to peaty tidal swamps of high organic content resulting from poor or impeded drainage. Acidity, salinity, alkalinity, nutrient deficiencies (P, Zn) or toxicities (Fe, Al, and soil reduction products) are some of the edaphic stresses common to these lands.

The factors discussed above have contributed to the complexity of the flood-prone ecosystem making it difficult, if not impossible, to develop universally adapted cultivars across the environment.

The type of flooding differs in different regions of the river basins ranging from inland flash floods to long duration stagnant floods with maximum sustained water depth varying from shallow (50 cm) to very deep (2 to 3 m). In coastal regions, floods may have tidal influence, sometimes associated with intrusion of salt water. The flood situations are, therefore, described as temporary submergence, tidal submergence and stagnant flooding of different depths persistent for long durations. Water depth of stagnant floods is loosely classified by different scientists using different yardsticks employing the same terminology viz. shallow, intermediate, semi-deep, deep, and very deep. Catling (1992) identified three water regimes and described the plant stature suitable for each regime. Accordingly, water depths below 50 cm (shallow) were suitable for the non-lodging modern plant type of intermediate stature; improved types with need based elongation ability (facultative floating types) that could adjust plant height under submergence or traditional tall types with lodging resistance being suitable for water depths ranging from 50

to 100 cm (deep); and the floating types for water depths above 100 cm (very deep).

Obviously the plant breeding interventions are more effective and impact oriented when focused at shallow (<50 cm) and deep (50-100 cm) stagnant flood situations. As a result, the extreme marginal areas of water depths beyond 100 cm, the very natural habitats of floating rices, are not considered seriously in varietal improvement. This is probably due to low returns to investments, as any tangible improvement in floating rices is doubtful. Yet, the fact remains that many lives are sustained by rice in those marginal lands, the only crop adaptable under the given circumstances.

TRADITIONAL CULTIVARS OF FLOOD-PRONE ENVIRONMENT

Evolution of flood-prone rice cultivars must have taken place in isolation along the flood plains of different river basins in Asia and West Africa. The floating rices of Barogar and Desaria groups in Bihar (Thakur and Mishra, 1997) or Rayada group in southern Bangladesh (Catling, 1992) exemplify regionalization of cultivars due to such isolated evolution. The floating rices do not offer much genetic variability/diversity for any tangible improvements but are considered valuable sources for specific traits that helped them to thrive under those undesirable environments (Sarma, 1997).

In contrast, the traditional quality rices such as Khao Dawkmali (Thailand), Wag wag (Philippines), Pawsanhmwe, Ngakywe and Medon (Myanmar), will continue to be grown in the deepwater lands (50-100 cm) due to their premium quality which could easily compensate for the inherent low productivity of these lands.

SPECIFIC MORPHO-PHYSIOLOGICAL TRAITS IN FLOOD-PRONE RICES

Catling (1992) summarized the essential as well as other important traits identified for the improvement of flood-prone rices. Among them are some characteristics vitally important for thriving under prolonged submergence, deep (50-100 cm) and very deep (>100 cm) conditions. Few of such important traits in developing specific ideotypes for flood-prone environments are discussed below. Though the scope for improvements is limited, floating rices cannot be totally ignored.

Seedling vigor is cited as an important trait for early crop establishment, particularly in direct seeded crops (Broadcast Aman), to compete weeds. Intensive weed management practices are not expected in flood-prone rice lands. Therefore, initial seedling vigor in cultivars is important for smothering weeds at the beginning of crop establishment. Prostrate growth habit of seedlings in floating rices has to be changed to erect habit to compete with weeds more efficiently at initial crop establishment.

As the flood-prone lands are exclusively rainfed, drought tolerance at early vegetative phase of the plant is beneficial for good stand establishment. Post-planting spells of drought can

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be expected prior to inundation, coinciding with initial growth phases of the crop. This situation can be overcome by introducing drought tolerance at seedling phase.

Submergence tolerance is an essential character throughout the life cycle of the plant due to the unpredictable time and degree of flooding. Ability to withstand submergence is apparently a function of the plant's capacity to release energy through anaerobic degradation depending on the level of stored carbohydrates. Submergence tolerance is negatively related with internodal elongation. Both processes are induced simultaneously demanding energy from anaerobic degradation to function as survival mechanisms under submerged conditions (Setter *et al.*, 1997). Submergence tolerance is reported to be governed by both qualitative as well as quantitative genes (Suprihatno and Coffman, 1981; Mohanty *et al.*, 1982; Haque *et al.*, 1989; Ray *et al.*, 1990; Dwivedi, 1992; Mishra and Senadhira, 1994, unpublished). As a result, the degree of submergence tolerance can be improved through hybridization within tolerant varieties of different origin and subsequent selection to pin down transgressive segregants of improved submergence tolerance.

Floating ability is a mechanism of an aquatic escape from shoot anoxia by elongating rapidly with increased water depth that ensures survival of floating rices in their natural habitats of very deepwater (>100 cm). This is also a character to be inbuilt in improved plant type in the development of ideotypes with need based elongation ability (facultative improved cultivars) for deepwater (50-100 cm). A non-destructive approach to identify elongation ability, without submerging plants, suggested that foliar application of 500 ppm GA3 at seedling stage, horizontal orientation of plants in shallow water and assessing elongation based on developmental, morphological differences could be used to test plants for their elongation potential (Dwivedi *et al.*, 1994). Both quantitative and qualitative genes have been reported to control elongation ability (Hamamura and Kupkanchanakul, 1979; Thakur and HilleRisLambers, 1989; Dwivedi and Senadhira, 1993). Accordingly, improvement of this trait can be effected through cross breeding as explained for submergence tolerance above. Productivity of large extents of deepwater rices can be improved by introducing need based internode elongation to the improved plant type of appropriate stature to develop facultative floating cultivars specific to the localities. IR442 and RD19 are few examples of strategic attempts of this nature.

Nodal tillering, nodal rooting and kneeing ability are traits exceptionally important in floating rices. Nodal tillers are those tillers emerging from aerial nodes of the shoots. They develop into panicles above the water level in floating rices. Capacity of a floating rice cultivar to produce nodal tillers to compensate yield losses due to inhibition of basal tillering by floods could be considered a yield determinant of paramount importance in varietal improvement. In floating rices, the expected maximum panicle number per square m is around 200 (Catling, 1992). There could be room to improve tiller number by genetic adjustment of canopy structure of nodal tillers to resemble that of improved plant type. Whether floating rices should be panicle weight type or panicle number type, is a debatable issue, but the best option is to compromise both yield components to maximize productivity by increased number of heavy panicles per unit area.

In floating rices, nodal roots will keep the plant anchored to the soil for nutrients particularly when lodged due to floodwater receding. Ability to produce nodal roots will therefore eventually contribute to the productivity through sustenance of lodged plant.

Kneeing ability could be defined as strong phototropic or negative geotropic response of the lodged plant by upward growth of the shoots to keep canopy and panicles above water level. This, along with nodal tillering and nodal shooting, should be taken into consideration in conceptualizing canopy structure of the ideotype to improve productivity of floating rices.

Photoperiod sensitivity is considered important in flood prone rice as the deep water and floating rices are grown in the floods during Kharif season as a broadcast sown (B. Aman) or transplanted (T. Aman) crop. The crop should remain vegetatively active until the flood level reaches its peak irrespective of the time of sowing/planting. If the rice plant flowers prior to peak flooding, no further elongation of stems could be expected (Mishra, 1994, unpublished). The critical day length for flood prone rices should therefore lie within the period of peak flooding. This makes deep water and floating rices date fixed, in contrast to period fixed, photoperiod insensitive cultivars. The critical day length thus dictated by the time of peak flood depth differs from country to country depending on the latitude. Bangladesh and India (23-28° N), critical day length varies from 13-14 hrs. For Thai and Cambodian cultivars, the critical day length will be 12-12.5 hrs due to their proximity to the equator. The differences in critical day length requirements and latitude cause the Thai and Cambodian varieties to flower late in November when planted in India and Bangladesh. Conversely, the Indian and Bangladeshi varieties flower in September in Thailand and Cambodia. Neither late November flowering in India/Bangladesh nor September flowering in Thailand/Cambodia is desirable. This imposes restrictions in the flow of genetic material from one region to another.

Grain dormancy to prevent inundation induced pre-harvest sprouting is also considered an essential trait in deepwater and floating rices. Besides the specific traits discussed above, the cultivars developed for flood-prone ecosystem should possess all other traits concerned with yield and grain quality of other rice varietal improvement programs.

Tolerance to stress factors (biotic and abiotic) is another group of essential traits to be incorporated in varietal improvement. Among the biotic stresses, stem borer, brown plant hopper, leaf eating caterpillar and ufra (nematode) are considered important. Abiotic stresses associated with peat and acid sulfate soils in coastal swamps (alkalinity, salinity, acidity, iron toxicity, soil reduction products) and nutritional deficiencies such as P, Zn are considered major constraints to improve productivity. In flood-prone rices, varietal tolerance/resistance is the most appropriate solution for stress related constraints limiting productivity.

PROGRESS IN VARIETAL IMPROVEMENT

Early attempts on rice varietal improvement in the flood-prone ecology were confined to exploitation of genetic variability of the traditional germplasm through selection. Records as

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early as 1917, indicate, that collection, maintenance and evaluation of traditional cultivars were in progress in Dhaka, India (Saran and Sahai, 1979). A similar process had been initiated in Thailand in early 1930 and in Vietnam and Indonesia in the 1940s (Jackson and Vergara, 1979). In West Africa, selection from traditional germplasm was performed in Rokpur Rice Research Station in early 1930 (Catling, 1992).

In flood-prone ecosystems, improving highly adapted existing varieties is the best short-term approach to increasing productivity. But in floating rices, the genetic gain in productivity by purification of land races through selection had not been significant. These cultivars may have to spend almost all the energy reserves for sustenance under extreme circumstances and have little left for grain production. Further, they resemble wild species in many respects and even under stress free conditions no appreciable yield improvement is shown (Senadhira and Palaklang, 1994, unpublished). The attainable marginal improvement in productivity by exploitation of inherent genetic variability of these cultivars has already been achieved either by inadvertent selection by farmers or by subsequent pureline selection resulting in cultivars like Rayadas, Dolamon, Matin Aman, Laki, Jaisariya, Jalmagna, Jalnidhi, etc. Though the yield increase is meager, the initial efforts in varietal improvement have resulted in identifying specific genotypes with vital attributes needed for survival in this ecosystem. This information can be used in planning future strategies in varietal improvement in floating rices.

The deepwater and tidal rices have had a better scope for improvement through pureline selection in early varietal improvement work. T 1242 and BAM 6 in Orissa, Latisail and Patnai in West Bengal, Madhukar and Chakia 59 in Uttar Pradesh, India, are few examples of purelines still being cultivated significantly in flood-prone lands. The two well known submergence tolerant cultivars, FR 13A and FR 43B, are also pureline selections from the respective land races Dhullaputtia and Bhetanasia. Many quality rices (KDML 105, Wag wag, Medon) and other types (Jaladhi I and II, Padmapani, etc.) in deepwater and saline tolerant types (Pokkali, Nona Bokra, Kuatic Putih) in coastal tidal tracts are also outcomes of selections from traditional land races in the respective ecologies. CR 1014, Jalpriya, Barh Avarodhi, Jogan, Mandira, Dinesh, Purnandu, Sudhir, Golak and Saraswati are some examples of cross-bred varieties for deepwater situations.

FUTURE STRATEGIES IN VARIETAL IMPROVEMENT

The varietal improvement techniques are not exceptional to the flood prone rices though there are specific traits concerned with adaptation of cultivars to the target environment. It is a matter of identifying appropriate breeding strategies for the objectives concerned, involving selection of suitable donors for hybridization and development of screening techniques to single out the most adapted genotypes from the segregating populations. Simulated target environments in research stations may not be much dependable for confirmatory assessments of genotypes. Hence, more emphasis should be placed on evaluations under farmer field conditions for ultimate decisions. Farmer participatory breeding programs, may have the advantage of making use of accumulated traditional knowledge and field experience in determining attributes of the

ultimate ideotypes, over typical researcher managed programs.

The best option in the flood prone environment is to avoid floods by shifting the cropping season rather than planting into the floods. A dry season irrigated crop of rice (boro), especially in local land depressions where there is sufficient residual water in the soil, would be the ideal option wherever possible. Short stature, cold tolerant, modern varieties like Gautam, developed recently have expanded the boro rice cultivation in India beyond traditional boundaries. In Bangladesh too, boro is the major rice crop in a majority of flood prone lands. Expansion of boro rice extents depends on rice varietal interventions providing early maturing, cold tolerant (seedling phase) modern cultivars to escape high temperatures during reproductive phase and/or early floods at maturity phase. Many high potential cultivars developed for irrigated ecology can be utilized this way for boro rice cultivation with little or no modifications to the existing plant type characteristics.

In Vietnam, irrigation and drainage constructions in the Mekong delta enabled conversion of traditional floating rice lands to double and triple cropping allowing option to utilize early and medium duration modern varieties to optimize productivity. Tolerance to edaphic and biotic stresses needed for a particular locality as well as other agronomic and physiological attributes pertaining to yield and quality should also be introduced with characteristics stated above.

Owing to inherent features of the environment, if rice cultivation in flood-prone lands is to be continued in Kharif, the most realistic approach is to differentiate the land mass into water depth regimes, shallow (<50 cm), deep (50-100 cm) and very deep (>100 cm), to introduce the respective hypothetical ideotypes (semi dwarfs, facultative floating types or floating types). In no way should the floating rices be given a suicidal verdict in the process of varietal improvement. Efforts should be made, though not adequately substantiated, to improve productivity of floating rice cultivars until more productive and economical alternatives are invented for such ecologies. The other characteristics needed for better adaptation to these target areas have to be introduced from suitable donor cultivars through cross breeding. Saline and non-saline tracts with tidal influence in the coastal belt should be dealt accordingly taking into consideration the region specific constraints. Cultivars for tracts with tidal influence may not always require to be tolerant to submergence or have elongating ability, but should have sturdy culms and appropriate plant stature to overcome tidal influences.

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