Potential Productivity of Rice in the Low-Country Wet Zone of Sri Lanka

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Based on mean annual rainfall, Sri Lanka is divided into three climatic zones: wet, dry, and intermediate. The wet zone, which receives on average about 2,500 mm of rainfall per annum, is demarcated further by ground elevation into low-country (below 300 m), mid-country (between 300 and 1,000 m) and up-country (above 1,000 m). Rice cultivation in the low-country wet zone (LW), consisting of Colombo, Gampaha, Kalutara, Galle, Matara and Ratnapura districts, is mainly rain-fed; and it is this rain-fed component of Sri Lankan paddy that has recorded no increase in yield per unit area during the last two decades despite the significant increase achieved in the country as a whole. The increase in yield per unit area during the recent past has mainly been due to successful introduction of high-yielding varieties into the irrigated areas in the dry zone.

Despite the availability of many high-yielding varieties it has not been possible to increase yields in the LW zone. In Kalutara and Galle in particular, the districts of the LW zone where high-yielding varieties have been least disseminated, the production level remains the lowest in the country, due to following soil and agronomic constraints: 1) the high risk involved in crop establishment due to flash floods, poor drainage and subsequent submergence, 2) soil constraints such as iron toxicity, salinity and chemically reduced state, 3) pest and disease problems, 4) inefficient control of weeds under rain-fed conditions, 5) high sterility during the *Yala* season, and 6) lack of appropriate varieties. Until very recently no efforts had been made to improve the rain-fed lowland rice cultivation in the LW zone. The major research activities were directed towards the testing of improved varieties at high management levels, mainly in the research stations, without due consideration of the diversity of problems in farmers' fields.

The objectives of our study are, therefore, to evolve techniques to identify varieties tolerant to submergence and iron toxicity and to evaluate the production potential of these varieties under the management of farmers. All the experiments outlined here were carried out in Kalutara and Galle districts.

Constraints of submergence and iron toxicity in the LW zone

The most common agronomic constraint faced in the LW zone is the excess of water during crop establishment. Submergence of seedlings due to flash floods and impeded drainage during the initial stages of crop establishment cause high mortality of seedlings. The second most serious constraint is the incidence of iron toxicity, which can occur at any growth stage. Therefore, tolerances to these constraints are vital characteristics for the adaptation of varieties to the LW zone.

1) *Screening of tolerant varieties to submergence*

Since the degree of tolerance to submergence is affected by age of seedlings, depth and duration of submergence and turbidity of water,[5] the best way to assess tolerance is probably to screen rice varieties under field conditions. Although a method of screening under greenhouse conditions has been reported,[6] it is not suitable for screening a large number of varieties because of its requirement of sophisticated water tanks and temperature regulation. Therefore, screening for tolerance to submergence was conducted in tanks constructed in brick in the field. A total of 36 tanks measuring 6 m×3 m was used. Soil conditions in the tanks were not disturbed in the process of bunding because the turbidity of water depended on the surface deposit of silt. Water for submergence was diverted from a neighboring canal. Seeds were sprouted by soaking in water for 24 hr and subsequent incubation for 48 hr, under which conditions seedling mortality was minimized. Two hundred pre-germinated seeds of each variety were row-sown, and care was taken not to place seeds too deep. Under farming conditions, flash floods usually occur immediately after sowing. Therefore, water was impounded immediately after sowing and its depth was maintained at 30 cm for ten days. Water turbidity was maintained by constant stirring of the irrigation channel. To maintain the normal temperature turbid water was continuously supplied. Water was gradually removed after ten days of submergence. The first assessment of germination and seedling survival was made immediately after water had been drained off; the second assessment of seedling survival and recovery was made ten days later.

Tolerance to submergence depends on two factors. The most important is germination and survival under submergence; the other is the rate of seedling recovery after submergence. All the semi-dwarf improved varieties tested had very poor submergence tolerance in terms of both survival and recovery. Measurements on the growth of seedlings indicated that tolerant varieties had longer root growth and shorter shoot growth during submergence. Under submergence plants usually tend to grow faster in search of sunlight. However, such behavior reduces ability to survive as weak leggy plants tend to lodge when the floodwater recedes.[2] And under normal flood conditions the settling of suspended clay on seedlings enhances their mortality. It is evident, therefore, that the growth behavior of the tolerant varieties, namely, less shoot growth and more root growth, was advantageous to survival of submergence.

2) Screening of tolerant varieties to iron toxicity

Tolerance to iron toxicity is complex, involving many physiological and biochemical features. In Kalutara and Galle districts most of inland valleys are associated with neighboring lateritic highlands. Soils in inland valleys are in a reduced state due to poor drainage and fluxial hydrology. Encouraged by interflow from the highlands, these conditions can cause iron toxicity at any stage of growth.[3,4]

In selecting varieties tolerant to iron toxicity, field screening is considered the best method, because rapid oxidation and precipitation of iron makes solution culture impracticable. It is important, however, to select screening sites carefully on the basis of highland characteristics, rainfall seasonality and presence of canals which could disturb interflow. The highland must be lateritic. Rice fields should not be boggy and soils should preferably be alluvial to clayey. To obtain uniform conditions of iron toxicity, the interflow should not be diagonal but could come from both sides of the valley. Such fields could be located in moderately broad valleys with very gentle gradient. An assured supply of water is also important as it is essential to maintain submergence.

Having selected a site according to the above criteria, specific varieties such as BG 11-11, which is highly susceptible to iron toxicity, were grown on the whole screening site to check whether conditions of iron toxicity were uniform. Field screening was carried out afterwards. To eliminate the possibility of deficiency in other minerals, a fertilizer mixture of 50–20–50 kg/ha of N, P and K was applied at planting. Three-week-old seedlings raised in upland nurseries were planted in three-row plots, and each variety was replicated three times. Symptoms of iron toxicity were observed visually and graded on a scale from one to ten. Assessments were made four and eight weeks after transplanting in the case of four-month to four-and-a-half-month varieties and three and six weeks after transplanting in the case of three-month to three-and-a-half-month varieties.

Evaluation of varieties in farmers' fields

1) Yield gap between research stations and farmers

Under farmer management conditions most of the recommended varieties fail to deliver the same yield as in research stations, very often by a wide gap.[1] Since farmers cannot provide optimum conditions to obtain high yields, it is imperative to ascertain the real yield potential of varieties under farmer management. In seeking suitable varieties for different environmental conditions it is important to look for those which show the smallest difference in yield between research and farmer levels.

Table 1 gives the yield levels of some popularly grown varieties under different management conditions. Several basic differences in management by the research station and the farmers account for the yield gap. It is often impracticable for farmers to prepare well-levelled fields, and poor land preparation led to a very sparse seeding stand. However, it is striking that the smallest yield gap was observed with the indigenous variety, Herath banda. The fact that Herath banda gave a yield of 2.0 t/ha under research-station management and 1.5 t/ha under farmer management indicates that varieties with a low response to a high management level suffer less due to low management, and therefore that certain varieties could give reasonably high yields without depending on high management inputs. Although it is impossible to seek varieties with potentially high yields which at the same time depend on low inputs, the indications are that some varieties show less variation than others under adverse conditions and at the same time give reasonably high yields at low management levels.

2) Varietal potential in farmers' fields

Having screened tolerant varieties by the

Table 1. Yield gap under different management conditions

Variety	Growth duration (month)	Yield (t/ha)					
		Experiments managed by research station in its own fields[1] (I)	Experiments managed by research personnel in farmers' fields[2] (II)	Experiments managed by farmers in their own fields[2] (III)	Average yield in farmers' fields[3] (IV)	Yield gap[4] (A)	Yield gap[4] (B)
BG 400-1	4 1/2	5.0	4.0	3.0	2.6	1.0	2.4
BG 90-2	4	4.5	3.0	2.5	2.5	1.5	2.0
BW 100	4 1/2	4.0	3.0	2.0	1.75	1.0	2.25
BG 94-1	3 1/2	6.0	5.0	3.5	3.0	1.0	3.0
BG 34-6	3 1/2	5.0	4.0	2.5	2.5	1.0	2.5
BG 276-5	3	6.5	4.75	3.0	3.0	1.75	3.5
Herath banda	3 1/2	2.0	1.75	1.5	1.5	0.25	0.5

Notes: 1) Average of yield evaluation experiments over five seasons.
2) Average of six regional varietal evaluation experiments over three seasons.
3) Average yield of 200 farmers in Kalutara and Galle districts.
4) A: Yield gap between (I) and (II), B: Yield gap between (I) and (IV).

procedure described above and evaluated them under research-station management, their yield potential under farmer management was evaluated. Two medium-height varieties, BW 272-6B and BW 267-3, which showed to possess desirable characteristics and the potential to increase the production under research-station management in the LW zone, were evaluated in the farmers' fields, and their performance was compared with that of two popularly grown semi-dwarf varieties, BG 276-5 and BG 94-1. BW 272-6B and BG 276-5 are three-month varieties, and the others are three-and-a-half-month varieties.

Experimental sites were selected on the basis of information on land system classification (personal communication from Dr. Panabokke). Care was also taken to select tracts where mostly indigenous varieties were cultivated by farmers who worked their fields alone or with family members. In each site varieties were replicated twice. All the field operations from land preparation to harvesting were done by the farmers following written instructions. To ensure that proper amounts of fertilizer were applied, measured quantities of fertilizer were supplied to the farmers. Measures to control pests, disease and weeds were adopted by the farmers according to their economic capacity, and these operations were monitored and recorded by research personnel who made regular visits.

Results of evaluations made in Kalutara and Galle districts mainly in the seasons of *Yala* 1980 and *Maha* 1980/1981 are presented in Table 2. Although the high-yielding semi-dwarf BG varieties were evaluated to possess the higher potential when management was not a limiting factor, BW varieties were slightly superior to BG ones under farmer management. Yield gaps between research and farmer management were wider with BG varieties than BW ones. Since the main objective of this evaluation was to find suitable replacements for indigenous varieties, the BW varieties were judged superior to the BG varieties because of their ability to perform well under a wide range of management conditions. This adaptability is closely related to their growth characters, such as weed competitive ability and low management requirements, which resemble those of indigenous varieties.

3) Nitrogen requirements of the BW varieties

Environmental conditions ideal for the maximum utilization of fertilizer do not exist in regions like the LW zone, where water management conditions are unsatisfactory. Therefore, farmers tend to use minimum quantities of fertilizer and varieties which require low levels of nutrients. Under these circumstances, it is imperative to ascertain the nitrogen requirements of BW varieties.

Experimental sites representing mineral soils, half-bog soils and bog soils were identified. A randomized block design was used with three or four replicates. The main treatment consisted of five nitrogen levels, including the zero level, as shown in Table 3. All treatments included 42 kg of P_2O_5 and 60 kg of K_2O per ha. Nitrogen levels, times and rates of application are also given in Table 3.

Table 2. Rice yield in the farmers' fields under different management conditions

Variety	Managed by research personnel	Managed by farmers	Yield gap
BW 272-6B	3.49 (4)	3.50 (19)	—
BG 276-5	4.89 (10)	3.19 (20)	1.70
BW 267-3	4.41 (4)	3.63 (19)	0.78
BG 94-1	4.95 (8)	3.54 (8)	1.41

Note: Figures in parentheses indicate the number of experimental sites.

Table 3. Nitrogen response of BW 272–6B and BW 267–3 grown in Kalutara and Galle districts in the *Yala* season 1980

Nitrogen level[1]	BW 272–6B			BW 267–3		
	Bog soil	Half-bog soil	Mineral soil	Bog soil	Half-bog soil	Mineral soil
N_0	2.75[2]	3.97	2.48	4.11	4.15	3.52
N_1	3.08	4.15	3.50	4.95	4.21	4.21
N_2	3.14	4.56	3.75	5.94	4.57	4.78
N_3	3.20	4.27	3.86	5.48	4.32	4.57
N_4	3.05	4.23	3.37	5.33	4.26	4.03

Notes: 1) Nitrogen application in kg/ha (total amount: basal, 2 weeks, 5 weeks, 7 weeks after sowing): N_0 (no application), N_1 (25: 5,5,5,10), N_2 (45: 9,9,9,18) N_3 (65: 12,13,14,26), N_4 (85: 17,17,17,34).

2) rice yield in t/ha.

Table 3 gives the data of nitrogen response of BW 272-6B grown in Kalutara district and BW 267-3 in Galle district in the *Yala* season 1980. The maximum response to nitrogen of BW 267-3 was observed at N_2 level under all soil conditions, while that of BW 272-6B was at N_2 level in half-bog soil and N_3 level in bog and mineral soils. The increase in yield over the N_2 level in these cases was not, however, sufficient to justify the cost of applying the additional 20 kg of nitrogen to raise input to the N_3 level. It was concluded, therefore, that the N_2 level, representing a total of 45 kg of nitrogen per ha, is appropriate for the medium-height BW varieties, since this gives a substantial saving in nitrogen fertilizer with an increase in yield.

Summary and conclusion

Since rice production in the LW zone can be increased only by increasing the yield per unit area, emphasis should be placed on the identification of varieties to replace indigenous rice varieties. The poor dissemination of high-yielding varieties in the LW zone of Sri Lanka is mainly due to the failure of the new varieties to show field stability over a wide range of soil and climatic conditions. In the LW zone, submergence and iron toxicity are the most serious constraints. It is, therefore, essential to incorporate characters tolerant to these constraints into new varieties. And the screening and selection techniques presented here promise to be useful in breeding and selecting varieties tolerant to these constraints.

The production potential of the varieties screened was evaluated in cultivation under farmer management, and varieties with desirable agronomic traits for low management conditions were selected. BW 272-6B and BW 267-3 were identified as the most suitable replacements for indigenous rice varieties in Kalutara and Galle districts. These two varieties exhibited a wide adaptability to many locations and proved to be similar to indigenous varieties in their adaptability and low management requirements.

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