Bao Dhan of Assam: organically grown indigenous rice slated to increase farmer's income

Megha Rohilla, Priyanka Roy, Dhiren Chowdhury, Kishore Kumar Sharma, Prabal Saikia, Priyabrata Sen, Nagendra Kumar Singh and Tapan Kumar Mondal

India, including Assam, has diverse geographical regions with varied climatic conditions for rice cultivation. Thousands of hectares of land is subjected to flood every year which results in poor economic returns to the farming community. Although deep-water rice (DWR) is grown in many states of India in limited areas, the main area of DWR cultivation is the Brahmaputra valley of Assam. Although rice plays a pivotal role in the socio-cultural life of the people of Assam, DWR is God's gift to Assam, which provides food and nutrition to 30 million people in a condition where other crops cannot be cultivated due to year-round stagnation of water. The state is severely affected by floods almost every year during rainy season due to overflow of the Brahmaputra basin causing enormous damage to crops, livestock, land and properties. However, DWR rice is naturally grown in such areas, giving some economic relief to the flood-prone poor farmers.

DWR, popularly known as Bao Dhan, includes traditional rice landraces generally grown in low, swampy lands and flood-prone areas with water stagnation beyond 50 cm height that remains for periods of 2–6 months in their growing season (Figure 1 *a*). The average yield of DWR is poor, ranging from 1.5 to 2.0 t/ha, because of the fragile ecosystem that prevails right from seedling to harvesting stage of the crop. DWR displays stem elongation and/or tolerance to submergence along with kneeing ability upon receding flood waters. Due to poor economic conditions of the farmers along with little scope of applying the fertilizers due to water staganation, cultivation of Bao Dhan is by default organic in nature.

Geographical distribution

Apart from Assam, DWR is also cultivated in Bihar, West Bengal, Uttar Pradesh and Odisha, albeit in few pockets. As a conservative estimation, Assam has approximately 100,000 ha of area under DWR cultivation. Most of the areas are in Dhemaji, Lakhimpur, Sibsagar, Majuli districts of Upper Assam, but some areas are also found in certain pockets of Middle and Lower Assam district, such as Kamrup, Nalbari, Barpeta, Goalpara and Morigaon. In Dhemaji district alone, nearly 25,000 farm families spread over 25 Panchayats depend on DWR cultivation. The annual rainfall in this region is as high as 3900 mm, causing severe floods during rainy season. Over the years, these areas have been experiencing an increasing number of precipitations-driven flash floods and long-duration floods.

Botany and adaptation

DWR under flooding can grow up to a height of 2 m (Figure 1 *b*). Prolonged submergence during seed sowing leads to death of the seedlings, but at early vegetative stage (4–6 weeks after germination), height of the plants increases rapidly with gradual rise in flood-water level. Interestingly, in late vegetative stage or in advance growth stage, elongation ability become slower indicating it is developmental stage-specific[1]. Most of the DWR varieties have red kernels (Figure 1 *c*), which may be due to the accumulation of more anthocyanins in the aleurone layer and in the starchy endosperm as well. The mature seed is visible with a long awn, which is considered to be an introgressed trait from its wild progenitor (Figure 1 *d*). The maximum elongation per day per plant can be as high as 25 cm; however, it depends on genotype as well as level of submergence[2].

The culm or stem of DWR does not grow entirely erect, rather it becomes zigzag under deep-water condition[3]. When grown under such conditions, the size of air cavities in the culm increases[4], while diameter of the cells of cortex and

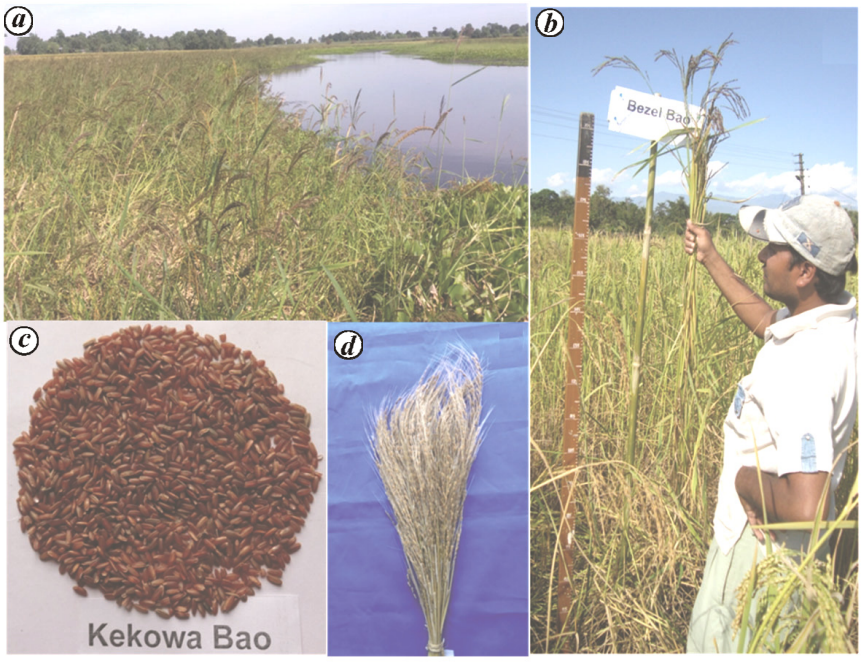

Figure 1. Deep water rice (Bao Dhan) of Assam. ***a***, DWR cultivation in a farmers' field at Dhemaji district of Assam. ***b***, Mature rice (Bezel) that grows more than 2 m. ***c***, Red-coloured grain of Bao rice (Kekowa genotype) indicating the richness of natural anthocyanin. ***d***, Mature panicle of a Bao rice with long awn.

thickness of phloem remain the same compared with plants that are not grown under deep-water condition[5]. Plants that grown under normal water condition show rapid tillering as compared to plants grown under deep water condition though primary tiller in DWR is taller than the other tillers. Branching does not take place as the water level rises[6]; below the surface water a few nodes start forming branches when the water level stabilizes[7]. Branching increases with warm water during summer months along with prolonged submergence. Adventitious roots first develop from the uppermost nodes below the water surface and are capable of extracting nutrients from the water[8,9]. As the plant grows under water, the first node develops a few coarser and unbranched roots. Interestingly, DWR has a greater number of leaves, longer panicle and a large number of spikelets per panicle compared to crops grown without deep water situation[10,11], indicating their hydrophilic nature. Elongation of internodes is faster before panicle emergence than post-panicle emergence[12,13]. In basal tillering of DWR, primary culm comes from the main culm at the base of the plant; secondary tillers originate from the primary tillers and tertiary tillers from the secondary, and so on, up to quaternary tillers[14].

Traits

Assam has several traditional DWR varieties; some of the popular ones are Kekowa, Amona, Negheri, Bezel, Maguri, Jul and Phuti. Bao Dhan being organic in nature has high nutritional value in comparison to other improved rice varieties. Besides, some DWR varieties, viz. Jul Bao and Negheri Bao possess significantly higher content of protein in comparison to other rice varieties[15]. They are also considered to be nutritious, being rich in iron, zinc, vitamins, minerals and anthocyanin[16]. Although DWR is tolerant to most types of biotic stress, Ufra diseases caused by a rice stem nematode (*Ditylenchus angustus*) is prominent, which causes yield loss of 30–100% depending on the severity of infection[17–19]. Due to infection, the leaf first turns whitish and then the tips turn brown; stems become distorted above the last node. There is also arrest of growth and development of the ear and a severe attack leads to death of the entire plant. The incidence was first reported in Uttar Pradesh, with a crop loss of 50% (refs 18, 20, 21). Later, it was reported in West Bengal that under severe infection up to 80% of crop loss occurred[22]. Another important trait of DWR is the weedy competitiveness. The spreading character of tillers at the early vegetative stage can suppress weed growth, and conserve soil moisture by reducing soil evaporation, though this trait is genotype-dependent and is not present in all the Bao genotypes.

Cultivation

Sowing of all DWR varieties in Assam is done during March to April, as they take more than 300 days to mature. There are many different methods of sowing in the state. For Ahu areas, seeds of Ahu and Bao rice are mixed in the ratio 4 : 1 and for Bao areas, monoculture of Bao rice is recommended. Seeds are normally sown directly in the soil at 60–130 kg/ha before the rainy season. In some areas puddled land is also used for sowing the seeds directly. In some areas of upper Assam, seedlings grow under upland condition due to low moisture in the soil. As a result, early seedling stage may encounter a drought-like situation in the early stage of growth. However, early submergence during seed sowing and early vegetative stage may lead to the death of plants. Harvesting is done after the flood water recedes. Early and medium maturing varieties are usually harvested with the help of boats due to the presence of high level of water. Chemical fertilizers are not used, though some progressive farmers use neem-coated urea @ 30 kg N/ha in limited areas in two equal splits as basal and at maximum tillering stage as pesticides to control Ufra disease.

Marketing at commercial scale

Owing to its high nutritional value coupled with its default organic nature, Bao Dhan has seen a steady rise in demand in the international market. For example, recently, the US-based Lotus Food Inc. has imported 70 q of DWR from Dhemaji district, Assam, through its partner company Nature Biofoods India Ltd, Haryana. The demand in the domestic market of Assam alone for DWR was 3000 q in 2012–13, which has increased to 12,000 q recently (Dhiren Chaudhary, pers. commun.). However, for a fully commercial venture, there is a need for systematic supply chain, and the involvement of more entrepreneurs for both cultivation as well as export of DWR to other parts of India and abroad. Major beneficiaries of the increased cultivation of DWR will be the marginal farmers, who will get high returns on their investment as the demand for Bao Dhan in the market is gradually increasing.

Research gap and conclusion

One of the major areas of concern in DWR cultivation is its low yield. This may be attributed to the fact that most varieties lacks high-yielding characters such as broad, erect, dark leaves, photoperiod insensitiveness or multiple productive tillers with heavy panicles. Unfortunately, till today there is no systematic efforts has been made to improve DWR. Transfer of appropriate traits from high-yielding popular genotypes to traditional DWR genotypes along with the incorporation of biotic stress tolerance genes would be an appropriate option, which can be addressed using marker-assisted breeding technique. Advances could lead to enhanced tolerance levels by pyramiding desirable agronomic traits to produce novel genotypes. Novel allele if identified for various traits related to deep-water stress tolerance, will be useful for developing new varieties for flood-prone regions not only for Assam, but for the whole country as well.

1. Sugarwara, T. and Horikawa, T., *Bull. Coil. Agric. Utsonomiya L.rnh*., 1971, **8**(1), 25–46.
2. Chowdhary, M.-A. and Zaman, M. H., In 13th International Rice Commission working party Rice Production and Protection, Iran, Paper IRC/PP 70/V11/6. 1970, p. 20.
3. Ramiah, K. and Ramaswami, K., *Indian J. Agric. Sci*., 1941, **11**, 1–8.
4. Vergara, B. S., Jackson, B. and De Datta, S. K., In *Climate and Rice*, International Rice Research Institute, Los Banos, Philippines, 1976, pp. 301–319.
5. Basu, N. C., DeDatta, S. K., Basu, R. N. and Sen, P. K., *Indian J. Agric. Sci*., 1970, **40**(1), 36–44.
6. Kondo, M. and Okamura, T., *Ber. Ohara Inst. Landwirtsch. Forsch*., 1932, **5**, 347–374.

7. Borthakur, D. N., *Indian Farm.*, 1971, **21**(9), 33–34.
8. Alim, A., Zaman, S. M., Sen, J. L., Ullah, M. T. and Chowdhary, M. A., *Review of Half a Century of Rice Research in East Pakistan*, East Pakistan Government Press, Dacca, 1962, p. 199.
9. Yantasasi, O. A., Prechachat, C. and Jackson, B. R., *Thai J. Agric. Sci*., 1970, **3**, 119–133.
10. Yamaguchi, T. and Sato, T., *Sci. Rep. Hyogo Univ. Agric.*, 1961, **5**(1), 15–19.
11. Yamaguchi, T., *Proc. Crop Sci. Soc. Jpn*, 1973, **24**, 151–153.
12. Morishima, H. and Oka, H. I., In *Adaptability in Plants*, University of Tokyo Press, Tokyo, 1975, pp. 133–140.
13. Bekhasut, P., Puckridge, D. W., Wiengweera, A. and Kupkanchanakul, T., *Field Crops Res*., 1990, **24**(3–4), 195–209.
14. Ohta, Y., In International Deepwater Rice Workshop, Bangkok, Thailand, 2–6 November 1982.
15. Mudoi, T. and Das, P., *Bull. Environ. Pharmacol. Life Sci.*, 2018, **7**(7), 10–14.
16. Chowdhury, D., Sharma, K. K. and Maibaongsa, S., Monograph No. AAU/DR/17 (mono)129/2016, 2016.
17. Rao, Y. S., Prasad, J. S. and Panwar, M. S., *Int. Nematol. Network Newsl.*, 1986, **3**(4), 24–26.
18. Prasad, J. S., Panwar, M. S. and Rao, Y. S., *Trop. Pest Manage.*, 1987, **33**(2), 108; 127–136.
19. Das, D., Sarma, N. K., Borgohain, R. and Das, P., *Int. Rice Res. Notes*, 2000, **25**(3).
20. Singh, U. B. and Garg, D. N., *Plant Prot. Bull.*, 1949, **1**, 1.
21. Singh, B., Some important diseases of paddy. Agriculture and Animal Husbandry, 1953, 3, pp. 27–30.
22. Chakrabarti, H. S., Nayak, D. K. and Pal, A., *Int. Rice Res. Newsl.*, 1985, **10**, 15–16.

Megha Rohilla, Nagendra Kumar Singh and Tapan Kumar Mondal are in the ICAR-National Research Centre of Plant Biotechnology, LBS Centre, Pusa, New Delhi 110 012, India; Priyanka Roy and Priyabrata Sen are in the Department of Agricultural Biotechnology, Assam Agricultural University, Jorhat 785 013, India; Dhiren Chowdhury, Kishore Kumar Sharma, Prabal Saikia are in the Regional Agriculture Research Station, Assam Agricultural University, North Lakhimpur 787 051, India.*
**e-mail: mondaltk@yahoo.com*

FORM IV

Particulars of *Current Science*—as per Form IV under the Rule 8 of the Registration of Newspapers (Central) 1956.

1. Place of Publication: Bengaluru
2. Periodicity of Publication: Fortnightly
3. Printer's Name and Address:
   G. Madhavan
   Current Science Association, Bengaluru 560 080
4. Publisher's Name, Nationality and Address:
   G. Madhavan
   Indian
   Current Science Association, Bengaluru 560 080
5. Editor's Name, Nationality and Address:
   S. K. Satheesh
   Indian
   Current Science Association, Bengaluru 560 080
6. Name and Address of the owner:
   Current Science Association
   Bengaluru 560 080

I, G. Madhavan, hereby declare that the particulars given above are true to the best of my knowledge.

Bangalore
1 March 2019

(Sd/-)
G. Madhavan
Publisher, *Current Science*