Pre-impoundment study of biotic communities of Kistobazar Nala in Purulia, West Bengal

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The Purulia Pumped Storage Project on Kistobazar Nala in West Bengal is proposed to improve the peaking power scenario of the state. The project involves construction of two reservoirs which would result in stream impoundment. Pre-impoundment studies were carried out on the physico-chemical characteristics and the biotic communities at two sites (S1 and S2) located downstream of the proposed upper and lower reservoirs, respectively. Except water-current velocity, no significant differences were observed between the two sites in their physico-chemical characteristics. Epilithic diatoms and macrozoobenthos, representing biotic communities, also did not exhibit variations in their diversity indices at both the sampling sites. However, biotic communities differed significantly in their densities at sampling sites S1 and S2, with the latter represented by higher densities. These studies indicated that power development authorities should maintain optimal water discharge during lean/dry periods downstream of the proposed reservoirs, so as to maintain suitable ecological conditions of the Nala similar or near-similar to that observed during the present study. Also stringent measures need to be adopted to check eutrophication of the reservoirs. These measures would ensure development of a power project in the area without adversely affecting the aquatic biodiversity of Kistobazar Nala.

WATER is one of the most important and crucial natural resources which not only determines the productivity of land, but also is a cleaner source for hydro-electricity generation[1]. In India, the eastern region has been experiencing severe power shortage during the last decade and the use of electricity for industries, commercial purposes and domestic consumption has been drastically suppressed because of the gap between demand and supply[2]. To improve the power scenario in the region, the Government of West Bengal proposes to develop the Purulia Pumped Storage Project with an installed capacity of 900 MW (4×225 MW), which involves construction of two reservoirs on Kistobazar Nala. Though there are several reports of beneficial effects of river impoundment[3] and greater economic benefits of having hydro-power schemes compared to cutting and selling of timber from catchments[1], it is equally well-known that this leads to physico-chemical and biological changes in the aquatic ecosystem[4]. The artificial blocking of rivers is known to disrupt upstream and downstream riverine communities and result in the changes in species composition, by obstructing the natural processes of organismal dispersal[1,5]. Among the aquatic communities, diatoms are of great ecological significance because they comprise major portion of primary producers in an aquatic ecosystem[6]. They are also highly susceptible to altered physical and chemical properties of water[7] and any variations in their community structure get reflected in the corresponding changes in higher components of the food chain[8]. Though extensive studies have been carried out on the regulated European rivers, bringing out the effects of stream regulation on the structure and function of the aquatic ecosystems[9,10], only a few studies of this nature have been conducted in India, which are mostly confined to huge reservoirs[11,12]. There are no reports on the pre-impoundment studies of the biotic communities of lotic bodies in India. The present study focuses on the physico-chemical characteristics and biotic communities in unregulated stream of Kistobazar Nala and is aimed at generating baseline data, which can be later used in analysing the effects of stream regulation on the aquatic ecosystem.

Kistobazar Nala is a small springfed stream, originating at an elevation of 610 m in Ayodhya hills of Purulia district in West Bengal, which finally drains into Subernareka river. The proposed Purulia Pumped Storage Project on this Nala is located near Bagmundi, a small village in Purulia, situated between latitudes 23°11′ and 23°12′N and longitudes 86°05′ and 86°06′E. The project involves construction of two reservoirs, i.e. upper and lower, which are about 1.3 km apart. The scheme envisages pumping of water from the lower reservoir to the upper reservoir where water will be kept stored for the generation of power during the peak hours.

The sampling for this study was done during December 2000–January 2001 for physico-chemical and biological parameters at sites S1 and S2, which were located downstream of upper and lower proposed reservoirs, respectively (Figure 1).

The methodology followed for analysis of various parameters was the same as that described in Standard Methods for the Examination of Water and Wastewater[13]. Temperature was recorded with the help of a graduated thermometer, while water-current velocity was measured by the float method. The pH was recorded with the help of pH scan. Other parameters like biological oxygen demand (BOD), dissolved oxygen (DO), nitrate and phosphate were measured by standard methods[13]. For analysis of biological components of Kistobazar Nala, diatoms, macrozoobenthos and fish

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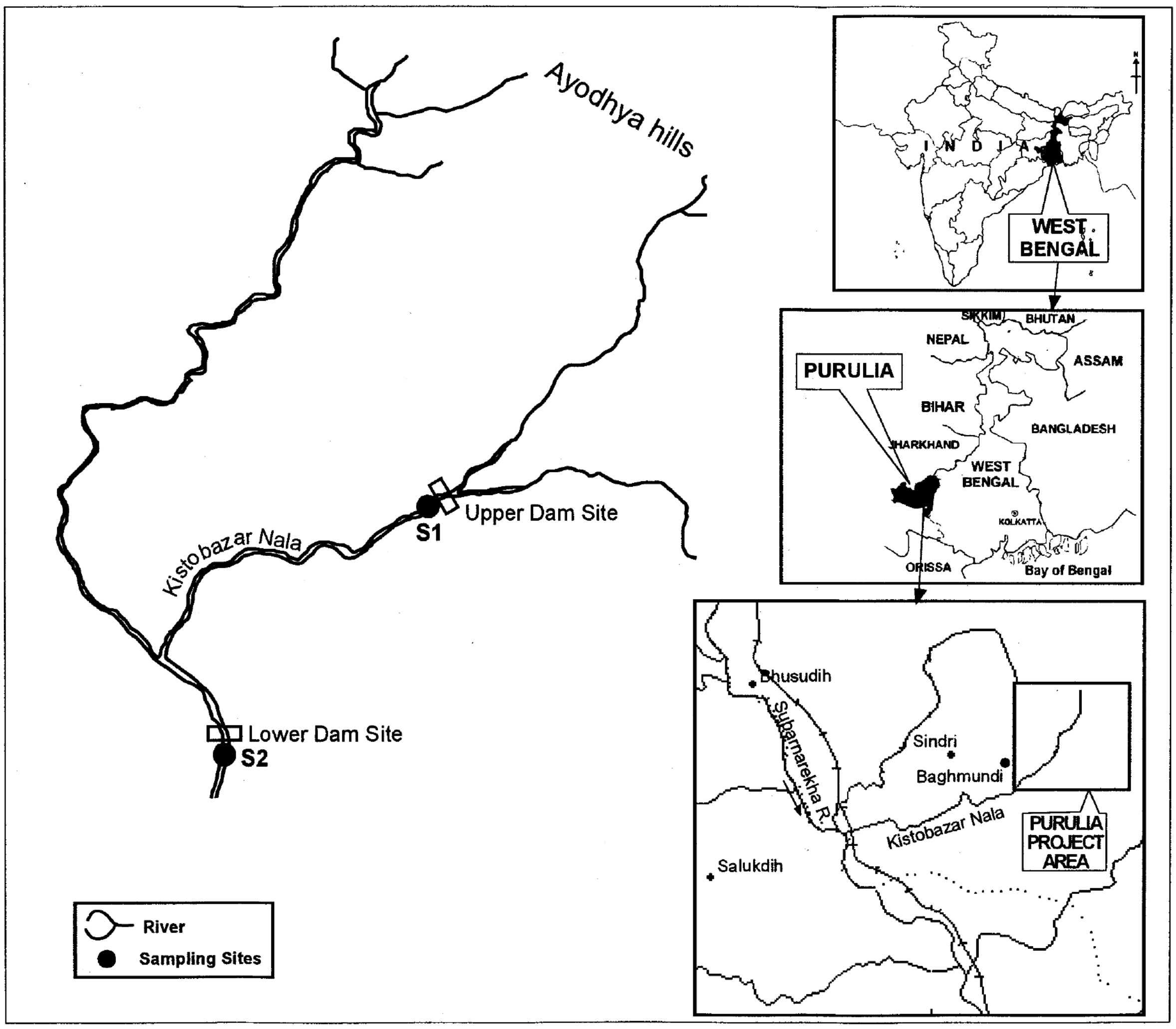

Figure 1. Kistobazar Nala showing location of sampling sites S1 and S2 and proposed dam sites.

species were sampled. Epilithic diatom samples were obtained by scraping the rocks and boulder surfaces (3 mm^2) with the help of a sharp-edged knife. Two to three replicates obtained from each site were pooled and preserved in Lugol's solution till further analysis. The epilithic diatom samples obtained were cleaned with nitric acid and potassium dichromate[13]. For estimation of density and relative abundance, the diatom samples were centrifuged at 10,000 rpm for 10–30 min and the supernatant was decanted. The pellet was washed twice with iso-propanol, followed by a single wash with xylene. The pellet was suspended in distilled water and permanent mounts were prepared in Canada balsam. Qualitative analysis of diatoms was carried out as described by Sarod and Kamat[14] and Krammer and Bertalot[15]. Diversity index was determined by using the Shannon and Weaver method[16]. For quantitative analysis of the diatom samples, the total volume of the scrapings was made up to 100 ml with distilled water. The diluted samples were thoroughly mixed and 1 ml each of this sample was then transferred to Sedgewick–Rafter cell. Diatoms were counted randomly in 100 chambers and the counting was repeated thrice. The total density was computed as follows:

$$\text{Cells (mm}^2) = \frac{N \times At \times Vt}{Ac \times Vs \times As},$$

where N is the number of organisms counted; At, the total area (mm^2) of chamber bottom; Vt, the total volume (ml) of original sample suspension; Ac, the area (mm^2) counted; Vs, the sample volume (ml) used in the chamber; and As, the surface area of substrate.

Relative abundance of each species was computed as percentage of total cell count[13].

The macrozoobenthos were obtained with the help of a square-foot Surber's sampler. The substrate, mainly stones, was disturbed and immediately transferred to a bucket underwater and later rinsed thoroughly to dislodge all the attached macrozoobenthos. The material was sieved through 100 μm sieve. Three replicates were obtained and pooled for analysis. The organisms obtained were then counted after identifying them up to order level by the procedure described by Pennak[17] and Edmondson[18]. Fishes were collected by damming method, as it was not feasible to use the cast net or gill net in a small stream. Some fish samples were also collected from local fishermen. Fishes were preserved in 5% formalin and identified in the laboratory. The species diversity index for macrozoobenthos and fishes were computed as described for epilithic diatoms.

During the survey period, which was the lean season, the stream bed of Kistobazar Nala at the upper site was stony, while the lower site consisted mainly of boulders, gravel and pebbles. Table 1 gives the physico-chemical characteristics recorded at two sites. Temperature varied between 16 and 17°C at S1 and S2 sites, respectively. Water was alkaline (pH 7.5) at both the sites. However, water-current velocity was found to differ significantly at the two sites and the values were 0.3 ms^{-1} and 0.6 ms^{-1} at S1 and S2, respectively. Due to the shallow nature of water, low values of DO, ranging between 6.7 and 6.9 mg l^{-1} at S1 and S2, respectively were recorded. Likewise, BOD values in general, were low throughout the stretch of Kistobazar Nala. The BOD values were comparatively higher at the upper (1.6 mgl^{-1}) compared to the lower site (1.0 mg l^{-1}). The concentrations of nitrate and phosphate were low at both the sites; the upper site showed a slightly lower concentration of nitrate (0.06 mg l^{-1}) compared to the lower site (0.07 mg l^{-1}), whereas the concentration of phosphate (0.01 mg l^{-1}) was identical at both the sites.

Table 2 gives the density and diversity index of biotic communities in Kistobazar Nala. The density of epilithic diatoms was observed to be 1583 and 3282 cells mm^{-2} at S1 and S2, respectively. The macrozoobenthos also exhibited a similar trend of higher density at site S2 (1689 m^{-2}) compared to site S1 (553 m^{-2}). However, the variations in the densities of diatoms and macrozoobenthos at these sites were not correlated with their diversity index values, which were almost identical at both the sites. On the contrary, the fish species revealed a higher diversity index value at S2 (1.76) compared to that at S1 (1.46).

Table 3 gives the relative abundance (%) of epilithic diatoms at S1 and S2 sampling sites. The epilithic diatom communities at S1 and S2 were represented by 33

Table 1. Physical and chemical characteristics of the sampling sites at Kistobazar Nala

	Sampling site	
Parameter	S1	S2
Temperature (°C)	16.0	17.0
pH	7.5	7.5
Water current velocity (m s^{-1})	0.3	0.6
DO (mg l^{-1})	6.7	6.9
BOD (mg l^{-1})	1.6	1.0
Nitrate N (mg l^{-1})	0.6	0.7
Phosphate P (mg l^{-1})	0.1	0.1

Table 2. Density and diversity index of biotic communities of the sampling sites at Kistobazar Nala

	Density†		Diversity index	
	Sampling site		Sampling site	
Biotic parameter	S1	S2	S1	S2
Phytobenthos	1583	3282	2.7983	2.7539
Macrozoobenthos	553	1689	0.9167	0.8425
Fishes	*	*	1.4659	1.7605

*Data not recorded.

†Densities of phytobenthos and macrozoobenthos were calculated per mm^{-2} and m^{-2}, respectively.

Table 3. Relative abudance (%) of epilithic diatoms of the sampling sites at Kistobazar Nala

	Sampling site	
Species*	S1	S2
Achnanthes biasolettiana	10.50	11.07
A. minutissima	3.12	6.38
A. minutissima var. *cryptocephala*	5.20	7.44
A. exigua	2.08	1.06
A. lanceolata	1.04	3.19
A. gibbrula	2.08	1.06
A. microcephala	2.08	3.19
A. haukiana	2.08	1.06
Amphora nagpurensis	3.12	0.00
Cocconeis plecentula	7.29	17.50
C. plecentula var. *euglypta*	3.12	2.12
Cymbella affinis	8.33	15.90
C. laevis	2.08	1.06
C. leptoceros	1.04	2.12
C. tumida	2.08	2.12
Fragilaria capucina	13.50	6.38
F. intermedia	1.04	1.06
Gomphonema sphaerophorum	6.25	2.12
G. intricatum var. *pumilum*	1.04	1.06
G. constrictum	3.12	0.00
G. nagpurense	2.08	0.00
G. olivaceum	0.00	3.19
Navicula rhynchocephala	2.08	2.12
N. halophila var. *subcapitata*	1.04	3.19
N. subdapliformis	1.04	2.12
N. pupula	0.00	1.06
Stauroneis anceps	1.04	1.06
Surirella ovata	0.00	2.12
Synedra ulna	6.25	2.12
S. ulna var. *contracta*	2.08	3.19
S. ulna var. *oxyrhynchus* f. *mediocontracta*	2.08	1.06
S. ulna var. *danica*	2.08	1.06
S. tabulata	1.04	1.06

*Species exhibiting values > 10% were treated as abundant.

species belonging to 10 genera. An analysis of the epilithic diatom genera during this period revealed that majority of them exhibited continuous occurrence at both the sites, with notable exception of *Amphora* sp. and *Surirella* sp. which were observed only at sites S1 and S2, respectively. Though other diatom genera, i.e. *Navicula* sp. and *Gomphonema* sp. were present at both the sites, some of their species exhibited discontinuous distribution. A total of 30 species was recorded from both the sites, mostly showing random variation in relative abundance at these sites. Fourteen species at S2 and 13 species at S1 exhibited higher relative abundance. However, some of the species such as *Fragilaria intermedia, Synedra tabulata* and *Cymbella tumida* did not reveal any significant variation in relative abundance values at both the sites. *Fragilaria capucina* was the most dominant epilithic diatom species observed at site S1 comprising 13.5% of the total density, while it constituted only 6.3% at S2. Similarly, *Cocconeis plecentula* was the most dominant species at S2 and showed a similar trend of lower density (7.2%) at S1. *Achnanthes biasolettiana* was the only species which was abundant (> 10%) at both the sites. Overall, two species at S1 and three species at S2 were abundant. About 50% of the diatom species represented by less than 2% relative abundance was recorded at both the sites, of which 27% was found at S1 and 37% at S2. *F. intermedia*, *S. tabulata*, *Stauroneis anceps* and *Gomphonema intricatum* var. *pumilum* were some of the least abundant species recorded at both the sites. Some of the epilithic diatom species, i.e. *Amphora nagpurensis, Gomphonema constrictum* and *G. nagpurense* were present only at site S1, while *Navicula pupula, G. olivaceum* and *Surirella ovata* were observed only at site S2. None of these site-specific species were abundant and each of them comprised about 1 to 4% of the total diatom community.

Table 4 shows the density and diversity index of different orders of macrozoobenthos at sites S1 and S2. Four major groups of macrozoobenthos, namely Ephemeroptera, Trichoptera, Diptera and Coleoptera were observed in Kistobazar Nala. The macrozoobenthos were dominated by the order Ephemeroptera at both the sites, followed by Diptera at S1 and Trichoptera at S2. The higher density of Ephemeroptera compared to Diptera indicated that the stream beds at the sampling sites are less sandy and mainly consisted of boulders, gravels and pebbles. The group Coleoptera showed lowest density at S2 and was absent from S1. Ephemeroptera and Trichoptera showed higher densities at S2 compared to site S1. Diptera was the only order which was represented by higher density at the S1 sampling site compared to the S2 sampling site. Though the density of Ephemeroptera was low at S1, it showed greater species diversity compared to that at the other site. However, diversity index values of Tricoptera and Diptera at both the sites showed similar trend as observed for their densities. Order Coleoptera exhibited the lowest diversity at site S2.

Table 4. Density and diversity index of different orders of macrozoobenthos of the sampling sites at Kistobazar Nala

Order	S1 Density (m^{-2})	S1 Diversity index	S2 Density (m^{-2})	S2 Diversity index
Ephemeroptera	247	0.3306	1156	0.2604
Trichoptera	41	0.2179	410	0.3441
Diptera	165	0.3678	82	0.1473
Coleoptera	–	–	41	0.0905

Table 5. Fish species composition at sites S1 and S2 at Kistobazar Nala

Species	Sampling site S1 (%)	Sampling site S2 (%)
Barilius bendelisis	5.0	2.0
Puntius ticto	45.0	41.6
P. chola	25.0	18.7
P. conchonius	10.0	6.2
Chela fasciata	–	8.3
Pseudambassis ranga	5.0	6.2
Nemacheilus jonatus	10.0	4.1
N. montanus	–	2.0
Lepidocephalus guntea	–	10.4

Table 5 shows the composition of fish species at the two sites surveyed. A total of 9 species were identified from site S2, whereas only 6 species were recorded from site S1, with notable absence of *Chela fasciata, Nemacheilus montanus* and *Lepidocephalus guntea* at this site. At both the sites, *Puntius ticto* constituted the dominant fish species followed by *P. chola*. Other species observed at these sites were *Barilius bendelisis*, *Puntius conchonius*, *Pseudamassis ranga* and *Nemacheilus jonatus*.

The present study reports the physico-chemical characteristics and the trophic structure of the unregulated Kistobazar Nala. Physico-chemical characteristics of water, such as temperature and pH have been shown to influence the density and diversity of the aquatic phytobenthic communities[19]. The mean pH values of water at the sampling sites were in the alkaline range and temperature also did not show any significant variation at the surveyed sites. Diversity index values of phytobenthic and macrozoobenthic communities were also comparable at the two sampling sites. However, the proposed stream regulation is likely to cause changes in the physico-chemical characteristics of water. In addition, anthropogenic activities upstream of the dam are likely to cause eutrophication of the proposed reservoirs. It has been reported to influence carbonate–bicarbonate ratio and the concentration of carbon dioxide that would result in decline of the mean pH values of the water, ultimately affecting the diversity of the benthic communities[20].

DO values are greatly affected by the changes in physico-chemical characteristics of the running waters[21] and levels below 6 mg l^{-1} for any length of time indicate the polluted state of the water body, which could be lethal to aquatic biotic communities[22]. DO values of ~ 6–7 mg l^{-1} at the sampling sites were relatively low but not lethal for the biotic communities of Kistobazar Nala. Lower DO values at the sampling sites could be attributed to the shallow waters of the stream and low discharge. The shallow waters coupled with low discharge lead to higher water temperatures, which are known to adversely affect the reproductive efficiency of fishes[23]. Lower levels of BOD and nutrients, i.e. nitrate and phosphate at the sampling sites further indicated that the Kistobazar Nala is not polluted by sewage disposal, animal waste, etc. and this could be attributed to sparse distribution of agricultural fields in its catchment area. The lower sampling site S2 showed slightly higher nitrate concentration compared to that at the upper sampling site S1, which could be due to the gradual accumulation of the nutrients with the downward flow of the river. However, the difference in the nitrate concentrations at the sampling sites was not significant enough to have any influence on the densities of biotic communities. Water-current velocity was the only factor which showed a significant difference between the sampling sites at S1 and S2. This was basically due to the difference in their topographical features. Various studies have suggested that difference in water-current velocity in a river has significant effect on the distribution and structure of phytobenthic diatom community, which forms the primary trophic level of an aquatic ecosystem[24]. Phytobenthic diatoms are also known to respond quickly to environmental changes due to their short life-cycles and thus serve as good indicators of water quality[25]. The present study clearly revealed higher density of the epilithic diatom community at sampling site S2 compared to that at site S1, which could be correlated with the observed differences in the current velocities and topographical features at these sites. Based on the criterion of Palmer[25], the present study revealed that the diatom community at the sampling sites at Kistobazar Nala comprised species characteristic of non-polluted water bodies. Pollution-tolerant diatom species such as *Nitzschia palea* and *Synedra* spp., *Navicula cryptocephala* were not observed at the sampling sites, which indicated less stress in the aquatic ecosystem and ecological conditions suitable for natural plant and animal life in the river in these stretches.

Structure and density of a phytobenthic diatom community have been reported to influence the structure and composition of higher components of an aquatic ecosystem[26]. The present study also demonstrated that higher density of macrozoobenthos at site S2 was positively correlated with the higher density of epilithic diatom community at this site. The distribution and density of macrozoobenthos are also influenced by the nature and the substratum of the river bed[27,28]. The phytobenthic diatoms and zoobenthos in the Kistobazar Nala provided sufficient food to support the growth of herbivorous (*Barilius bendelisis*), omnivorous (*Puntius* spp.) and carnivorous (*Nemacheilus* spp.) fish species. None of the fish species collected from the sampling sites were of any commercial importance. However, they contributed a small part of capture fishery in the region.

The present study indicates that Kistobazar Nala is a non-polluted, biologically-rich and a healthy aquatic ecosystem. However, the proposed regulation of Kistobazar Nala would convert the upstream stretch of lotic water-body into the lacustrine form, which would result in the discontinuity of water flow downstream and eutrophication of the impounded water[29]. Eutrophication of the reservoirs, which operate as traps for the nutrients along the river continuum, results in the appearance of toxic and carcinogenic blue-green algal blooms which produce neuro- and hepato-toxins and cause heavy loss to the aquatic fauna[30].

Based on the present study it is suggested that the power development authorities should maintain optimal water discharge downstream of the proposed reservoirs during lean periods and implement stringent measures for the treatment of the reservoir to reduce any possibility of eutrophication of the impounded water. Artificial circulation applied to eutrophic impoundment has been reported to improve the water quality of the reservoir and tailwater[31].

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Stability and yield performance of genotypes: A proposal for regrouping world rice area into mega-environments

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Rice ecosystems are characterized by elevation, rainfall pattern, depth of flooding and drainage, and by the adaptation of rice to these agroecological factors. Many divisions were made in the attempts at defining and identifying specific ecosystems and their breeding objectives. Genotypes are evaluated every year in multilocational trials. The aim was to study the performance of breeding lines developed for various ecosystems and to identify stable genotypes with wide adaptability. The data from 1341 all-India coordinated experiments (1970–94), and 1305 international experiments (1975–94) on the performance of rice cultivars were used. Mean yield, coefficient of variation and regression analyses identified several cultivars, developed at different centres, as stable for yield. These genotypes, with varying genetic makeup that crossed geographic boundaries and spread over ecosystems based on their sensitivity or insensitivity to photoperiod and maturity duration, are identified as universal genotypes for a specific mega-environment. They differ in the genetic expression of maturity period and photosensitivity. The diversity in these genotypes has successfully prevented vulnerability and yield instability in mega-environments. In this study, no genotype was found to significantly surpass the grain yield of 10 t/ha, established by the photoinsensitive universal genotypes, IR 8 and Jaya with medium maturity period, developed in 1966 and 1968, respectively. The singular reason for this dismal performance is the plethora of breeding objectives assumed essential for the targeted ecosystems. We, therefore, suggest a regrouping of rice habitats into four mega-environments: (1) rainfed unfavourable uplands requiring varieties with photoinsensitivity and very early maturity (< 90 days); (2) rainfed favourable uplands and irrigated areas requiring varieties with photoinsensitivity and early maturity (90–110 days); (3) irrigated areas requiring varieties with photoinsensitivity and medium maturity (120–135 days); and (4) rainfed lowlands requiring varieties with photosensitivity or insensitivity and late maturity (> 140 days). This delineation can motivate rice breeders to push yields of universal genotypes beyond the 10 t/ha barrier.

RICE (*Oryza sativa* L.) is produced over a wide range of locations and climatic conditions. The bulk of rice area

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