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Building climate resilient agriculture through traditional floating rice in flash flood affected areas of the North bank plains zone of Assam

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Flash floods are a recurrent phenomenon in the North Bank Plains Zone (NBPZ) of Assam, India, causing wide spread damage to rice (*Oryza sativa* L.) crop growing during *Kharif* season. Therefore, it is imperative to identify indigenous technical knowledge and integrate this with mainstream technologies, ***Maguri*** and not only to enable more effective ways of coping with such extreme events but also to enhance the adaptive capacity of small-scale local farmers of the NBPZ. Identifying and evaluating traditional crop varieties in the NBPZ that are flood tolerant is one approach that may help manage weather hazards and build climate resilient agricultural systems. This research represents investigations on more flood-resistant local rice varieties. In 2013 and 2014, participatory on-farm trials were conducted in Ganakdoloni village, a community in NBPZ affected by flash floods. Thirty sites covering 20 ha were selected to evaluate the performance of five traditional floating rice (*bao*) varieties: ***Kekua, Tulshi, Dhushuri, Bahadur Rangabao***. In both the years, the rice fields were affected by flooding multiple times, to a depth of up to 173 cm. The rice varieties recommended for normal, submergence and deep water situations could not perform well and were damaged extensively. The traditional rice varieties generally growing in deep water situations, however, endured the flash floods, performing better and producing grain yields from 1628 to 3000 kg ha^{-1}. Amongst these traditional varieties, *Dhushuri* recorded the highest grain yield in both the years.

Keywords: Climate resilient agriculture**,** North bank plains zone, Assam, Flash floods, Floating or *bao* rice varieties

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Climate change and climate variability are major challenges impacting agricultural production in many parts of the world. Human induced climate change is likely to have adverse impacts on rice production in tropical countries, due to extreme events such as higher temperatures, drought, submergence and salinity[1]. Climatic variability in North east India has already been documented in terms of rainfall variability, including increased frequency of high intensity rains leading to localized flash flooding, a reduced number of rainy days, and occurrence of mid season/terminal dry spells[2]. Long-term rainfall data (1901–2010), indicates that there has been significant decreasing trend of annual as well as monsoonal (June to September) rainfall in both the Brahmaputra and Barak basins of Assam[3]. A similar decreasing trend in rainfall was also observed in North Bank Plains Zone (NBPZ) of Assam. Further, a critical analysis of rainfall data of this zone revealed that abnormalities in distribution of rainfall during the monsoon season have been increasing over the last 10 yrs and that the region has been experiencing an increased number of precipitation driven flash floods[3,4]. Traditionally, NBPZ is one of the most climatologically vulnerable agro-climatic zones of India, due to its location in the eastern Himalayan periphery, its fragile geo-environmental setting and its economic under-development. According to one estimate, out of 3.5 lakh ha of flood-affected rice area in Assam, 1.33 lakh ha (38% of the total) area is within this zone. Moreover, the presence of a network of Himalayan river systems, heavy rainfall and soil erosion in the upper catchment area in Arunachal hills, and deposition of new alluvial soils in riverbeds as well as on the plains intensifies the problems of flash flooding in NBPZ.

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The predominant rice mono-cropping in small farm holdings in NBPZ often results in damage from monsoon floods. Diverse varieties of rice are traditionally grown in Assam since unknown past to match with diverse land situations of the state encountered with varying growing season (Table 1)[5].

The innate problem of flash floods and complete submergence of the region's rice fields are likely to be aggravated in the future due to an increase in rainfall variability associated with climate change[2,6]. The occurrence of multiple waves of floods during the *kharif* season causes extensive damage, not only to the standing rice crop itself but to the soils, through heavy siltation of the fields, resulting in permanent loss of productive agricultural land. Although research on rice in various areas has helped to improve its productivity in shallow lowland areas, the new technologies have yet to make an impact in the flood-prone areas of NBPZ in Assam. Enhancing agricultural productivity in these areas requires identifying, evaluating and demonstrating practices or technologies that can withstand these flash floods, including crops and cropping systems that can tolerate a certain amount of flooding and help support climate resilient agriculture in the zone.

Submergence from flooding damages rice plants due to slow rates of gas exchange, severe shading by turbid water, mechanical damage from strong flow rates and solute carrying capacity of floodwaters[7]. In NBPZ, the occurrence of intermittent flash floods causing the standing rice crop to be continuously submerged for 7-15 days results in substantial reductions of grain yield or in extreme cases, complete destruction of the crop. Introducing submergence tolerant rice varieties is one option, but these varieties tolerate submergence only up to 15 days during the tillering stage, whereas generally in NBPZ, there is now continuous heavy rainfall up to mid-October, with every possibility of submergence of the rice fields even at the panicle initiation stage due to flash floods from the end of September and in October, leading to the crop failure. Fortunately, traditional deep water or floating rice land races, popularly known as *bao dhaan*, can withstand submergence up to a depth of 3–4 m. These varieties are generally grown in low-laying areas with water stagnation beyond 50 cm over more than a month in the season[8]. The local *bao dhaan* varieties have the ability for stem elongation and/or tolerance to being submerged[8] and also have kneeing ability. Land races of rice in Assam thus demonstrate variable adaptation to environmental stresses and tolerate a range of biotic and abiotic stresses like floods, drought, etc.[9]. Therefore, identifying and evaluating traditional rice varieties can allow crops to withstand extreme events like flash floods, which will help promote climate resilience in agriculture in flood affected areas in Assam[10]. Four medicinal landraces of rice from different areas of Kerala and Tamil Nadu, viz. *Navara, Kavuni, Veeradangan* and *kathanella* have improved by Scientist to make them stronger to withstand the onslaught of climate and ensure higher output[11]. In view of this, we conducted on-farm trials in NBPZ to identify and evaluate traditional deep-water rice varieties that are flash flood tolerant with an objective to enhance rice productivity in flash flood affected areas of the region.

Methodology

Participatory on-farm trials were conducted in during 2012, 2013 and 2014 in Ganakdoloni village (26°55′28″ N, 93°47′01″E with 80 m above mean sea

Table 1—Agricultural classes of indigenous rice in Assam

Class	Growing season	Duration (days)	Remarks
Ahu (Autumn rice)	March/April to May/June	80 to 130	Photoperiod insensitive, early maturing usually broadcast, grown under variable water depth (0-25cm).
Sali (Winter rice)	June/July to Nov/Dec	150-180	Photoperiod sensitive, long duration, grown transplanted under variable water depth (0-30cm)
Boro (Summer rice)	Nov to May/June	180-200	Photoperiod insensitive, cold tolerant at the vegetative stage, grown transplanted, traditionally in the *beel* and marshy land situation with minimal or no tillage.
Bao (Deep water rice or floating rice)	April/May Dec/Jan	270-300	Normally grown broadcast, can endure water depth >100 cm. Sown at the time when *ahu* rice is sown and harvested at the time when *sali* rice is harvested.
Asra (Medium deep water rice)	April/May Dec/Jan	240-270	Normally grown broadcast or transplanted in the low lying areas, can endure water depth<100 cm. Sown at the time of *ahu* rice is sown and harvested at the time when *sali* rice is harvested.

level) in Lakhimpur district of NBPZ, Assam, a community prone to recurrent flash floods (Fig. 1). The study area is located in the high rainfall zone with long term average annual rainfall of 2949.6 mm. The study was carried out under 'National Initiative on Climate Resilient Agriculture (NICRA)' by All India Coordinated Research Project for Dryland Agriculture (AICRPDA) centre, Biswanath Chariali, Assam Agricultural University.

Ganakdoloni village is situated in the foothills of Arunachal and a small tributary of the Brahmaputra, *viz. **Pichala*** river, passes through the village. When, there is heavy rainfall in the region or in Arunachal hill, ***Pichala*** river overflows its banks and the village is affected by 3 to 5 flash floods, each of 7 to 15 days duration, during June to October every year. ***Sali*** rice, the only crop grown by the small and marginal farmers of the village, is affected by multiple submergences, with flooding depth of more than 1.5 m, causing extensive damage to the crop almost every year. Daily rainfall (recorded at the nearest station) and the flash floods in Ganakdoloni village during June to the middle of October in 2012 and 2013 were recorded and are presented in Fig. 2. Flooding depths in two sites of the village's crop fields (Field-1 and Field-2) were monitored from June to mid October, 2014 and presented along with daily rainfall in Fig. 3.

On-farm trials were conducted at 30 sites in 20 ha area in the village. The trials were conducted in a randomized block design considering each site as one replication. Thirty farmers were selected for growing five traditional floating rice varieties. The same variety was replicated in the fields of three farmers, thus each farmer was considered as one replication. However, improved deep water varieties were grown in onsite in the village. Farmers were involved in recording data on submergence, water depth as well as crop data under required supervision. The performance of improved rice varieties, *viz. **Jalshree*** and ***Jalkunwari***, was also evaluated during the study period. During 2013, six traditional deep-water tolerant rice cultivars (***Kekua, Tulshi, Dhushuri, Bahadur, Maguri***, and ***Rangabao***) were collected from different parts of NBPZ (Lakhimpur and Dhemaji districts). These landraces could tolerate long duration floods, with flooding depths of more than 100 cm, and continuous flooding of the rice fields for at least 7-8 months. The performance of these ***bao*** varieties was evaluated for two crop seasons (2013 & 2014) and, as well, the performance of improved deep-water rice varieties (***Panchanan, Panindra, Basudev*** and ***Padmapani***) were evaluated during 2014 and compared with traditional ***bao*** rice varieties in their ability to withstand intensive flooding.

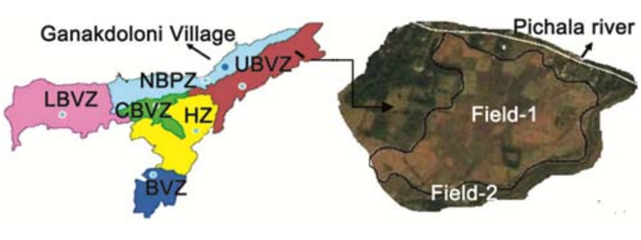

Fig. 1—Map of the study area

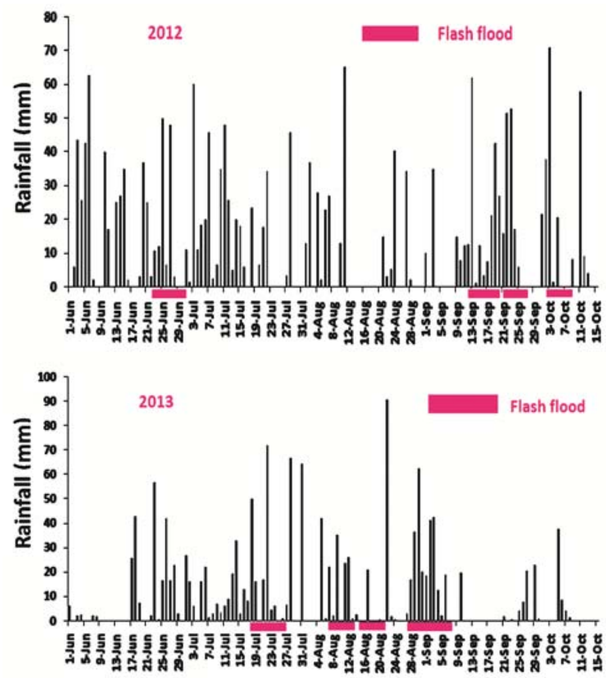

Fig. 2—Rainfall and occurrence flash floods in Ganakdoloni village during 2012 and 2013

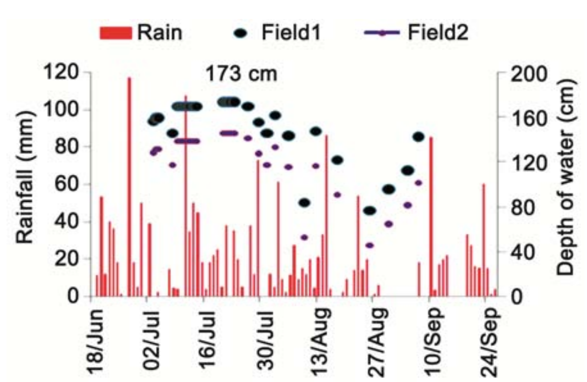

Fig 3—Depth of water (cm) and rainfall (mm) at paddy field of Ganakdoloni during 2014

Results and discussion

The performance of submergence tolerance rice varieties

During 2012, seedlings of submergence tolerant rice varieties – *Jalashree* and *Jalkunwari* – at the early seedling stage in the nursery bed (three days after sowing) were exposed to flash flood submergence continuously for 9 days (23 June to 1 July). The seedlings of both varieties survived despite the prolonged submergence. Subsequently, in the main field, varieties were submerged for three separate time periods (12-19 September, 21-28 September and 2-8 October, 2012). *Jalashree* endured the intermittent submergences, but *Jalkunwari* could not survive these. Because *Jalkunwari* was completely damaged by three spells of submergences, the evaluation of this variety did not continue in the next season (2013). However, evaluation of *Jalashree* was continued in the next crop season (2013).

During 2012, while the rice varieties were at tillering and/or at the panicle initiation stage in the main field, the rice field was affected by three spells of submergence (Table 2). The normal farmers' varieties including *Ranjit*, *Mahsuri*, and *Punjublahi* were completely damaged by the flash floods (Fig. 4). Even the submergence tolerant variety *Jalkunwari* was not able to survive the multiple submergences of this year and failed to yield any grain. The total failure of the supposedly submergence tolerant variety *Jalkunwari* might be due to its submergence for 7 days (2 - 8 October, 2012) at the panicle initiation stage.

Unlike *Jalkunwari*, *Jalashree* showed relatively greater tolerance to submergence which might be due to the observed greater regeneration ability and extended vegetative growth period of the variety under heavy submergence up to first week of October, 2012. During 2012, the grain yield of *Jalashree* was only 900 kg/ha, which is very low and not economically viable. During 2013, though *Jalashree* was exposed to four waves of flash floods at its tillering stage, it was able to withstand intermittent submergence of total 36 days. On the other hand, the normal varieties grown by the farmers during the crop season (2013) were completely damaged by intermittent submerges ranging from 7 to 12 days.

Table 2—Crop growth stages of rice crop and period of submergence during 2012 and 2013

2012		2013	
Crop stage	Duration in days	Crop stage	Duration in days
Seedling	9 (23 June to 1 July)	Tillering (early)	10 (18 -27 July)
Tillering	8 (12 to 19 Sept)	Tillering	7 (07 -13 August)
Tillering	8 (21 to 28 Sept)	Tillering	7 (14 -20 August)
PI stage	7 days (2 to 8 October)	Tillering	12 (28 Aug to 8 Sept)
Total	32 days	Total	36 days

During 2013, the grain yield of *Jalashree* was 2850 kg/ha which was substantially higher as compared with the previous year. The considerable reduction of *Jalshree*'s grain yield during the first crop season might be due to continuation of intermittent submergences up to the panicle initiation stage, whereas in the second crop season (2013), only the tillering stage was affected with multiple submergences in between 18 July to 8 September. Thus *Jalashree* had an advantage over *Jalkunwari* or other regular varieties, although it failed to perform in the case of the occurrence of flash floods during last week of September or in October.

The performance of deep water or bao rice varieties

During the study period (2012-2014), due to occurrence of multiple flash floods during June to

Fig 4—Field view after transplanting of *Sali* rice and at grain filling stage at Ganakdoloni village during 2012

mid-October, popular varieties adopted by the farmers were damaged repeatedly. Even submergence tolerant rice varieties did not perform well or exhibited total crop failure in cases when the plants at the panicle initiation (PI) or grain filling stage were exposed to submergence during latter part of September or in October (2012). During 2013, six traditional deep water *(bao)* rice varieties (*Kekua, Bahdur, Tulshi, Rangabao, Dhushuri* and *Maguri*) were evaluated for tolerance to intermittent flash floods with flooding depth more than 150 cm, while in 2014, along with these traditional varieties, four standard deep water varieties (*Panchanan, Panindra, Basudev* and *Padmapani*) were also evaluated. In both the years, *bao* varieties were sown in the main field between mid March and mid April.

The performance of traditional *bao* rice varieties in terms of height and special characteristics like elongation ability and kneeing ability during two crop seasons is presented in Table 3.

All traditional deep-water rice varieties except *Bahadur* had both stem elongation and kneeing ability; *Bahadur* had only the stem elongation ability. Amongst the varieties, *Tulshi* had the highest stem elongation ability (4.6 m), followed by *Rangabao, Maguri, Dhushuri, Bahadur* and *Kekua.*

During 2013, despite four intermittent flash floods of a total of 36 days between 18 July and 8 September, all six traditional deep-water rice varieties endured flash floods and performed well, whereas all normal varieties grown by the farmers of the village were completely damaged by flash floods (Fig. 5). Similarly, during 2014, in spite of prolonged (> 90 days) flooding with greater water logging depth of more than 100 cm, traditional deep-water varieties performed well, whereas, along with the normal *Sali* rice varieties, all improved *bao* varieties (*Panchanan, Panindra, Basudev* and *Padmapani*) could not withstand such prolonged flooding with a water logging depth up to 177 cm (Fig. 6).

The average grain yield of *bao* varieties (Table 4) varied from 1628 to 3000 kg/ha in two different crop seasons (2013 and 2014). Amongst the varieties, *Dhushuri* recorded the highest grain yield (2719 kg/ha) while *Rangabao* recorded the lowest grain yield (1764 kg/ha). The relatively higher grain yield was also recorded with other traditional *bao* rice varieties [i.e. *Bahadur* (2582 kg/ha), *Maguri* (2567 kg/ha) and *Kekua* (2476 kg/ha)] and there was no significant difference in yield among these varieties. *Tulshi*, which had the highest elongation ability, recorded significantly higher grain yield (2250 kg/ha) as compared to *Rangabao*; however, the limitation for this variety is that the farmers found it difficult to harvest, as ripened panicles of this variety rested in all the directions. The yield of all *bao* varieties was substantially higher during the first crop season (2013) as compared to the second crop season (2014), possibly due to severe moisture stress at the seedling stage of all the varieties, which continued from sowing to the first week of May, 2014.

The soil moisture deficit during the sowing and seedling establishment stages resulted in poor germination, heavy weed infestation, poor crop stand and lower grain yield of the traditional *bao* varieties during 2014. Further, during 2014, the rice crop was under submergence with a greater flooding depth (>100 cm) for more than three months (July to September), which caused poor growth and yield of the *bao* varieties. Similar results were reported in earlier studies[12].

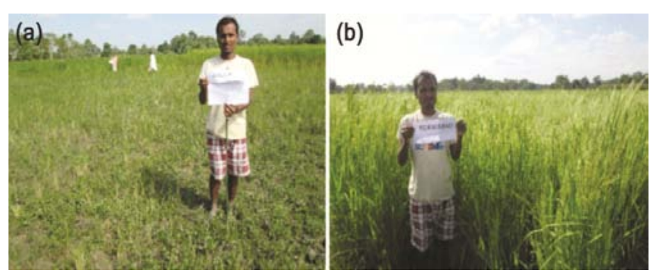

Fig 5—Performance of (a) normal *Sali* rice (Cv.-Mahsuri) and (b) *Bao* rice in Ganakdoloni village during 2013

Table 3—Height and characteristics of *bao* varieties grown at Ganakdoloi village during 2013 and 2014

Sl No	Name	Mean Height (m)	Characteristics
1	*Kekua*	2.2	Having both elongation and kneeing ability
2	*Tulshi*	2.5 to 4.6	Having both elongation and kneeing ability. Having maximum elongation ability.
3	*Dhushuri*	2.0	Having elongation, keening and submergence ability
4	*Bahadur*	1.9	No Kneeing ability, but have good elongation ability
5	*Maguri*	2.1	Having both elongation and kneeing ability
6	*Ranga Bao*	2.5 to 3.5	Having both elongation and kneeing ability

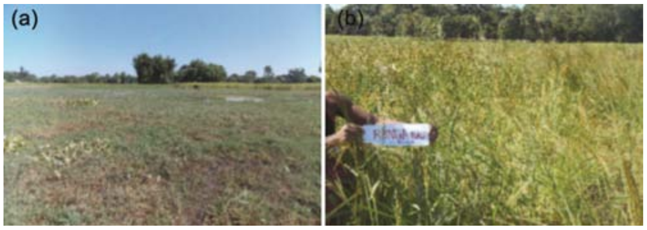

Fig 6—Performance of (a) improved *bao* varieties and (b) traditional *bao* rice during 2014.

Table 4—Yield of traditional *bao* varieties at Ganakdoloni village during 2013 and 2014

Varieties	Yield (kg ha^{-1})		
	2013	2014	Pooled
Dhusuri	3000	2438	2719
Bahdur	2963	2200	2582
Maguri	2813	2321	2567
Kekua	2672	2275	2474
Tulshi	2400	2100	2250
Rangabao	1900	1628	1764
CD (P=0.05)	43	91	136

Conclusion

The innate problem in NBPZ of Assam of the occurrence of 3 to 5 flash floods, each of 7 to 15 days' duration, during the monsoon season, and complete submergence of the rice fields in a sizable area of the region is likely to be aggravated in the future due to a predicted increase in rainfall variability driven by climate change. The multiple waves of floods during the monsoon cause extensive damage to the standing rice crop in the zone. Though submergence tolerant rice varieties can withstand submergence up to 15 days during the seedling and tillering stages, the same varieties fail to survive if exposed to submergence for a few days during or after the panicle initiation stage. Therefore, submergence of the rice fields at the panicle initiation stage causes total crop failure in the case of these varieties. Against the failure of normal, submergence tolerant, improved deep-water rice varieties evaluated in different crop seasons, six traditional *bao* varieties evaluated in the study area could survive intermittent submergences in both the crop seasons (2013 & 2014). We conclude that the problem of intermittent submergence due to multiple flash floods during *kharif* season in NBPZ of Assam can be addressed by introducing traditional deep water or floating rice varieties, which can tolerate both flash floods and the occasional drought and possess genes for stem elongation, kneeing ability and submergence tolerance. However, genetic diversity of local *bao* varieties should be evaluated for several years and at different locations to identify the best varieties with the widest adaptation to environmental stressors like floods and droughts and suitable for developing climate resilient agriculture in flash flood affected areas of NBPZ of Assam. Moreover, a breeding programme involving the traditional *bao* varieties should be initiated to develop high yielding resilient varieties for flash flood affected areas of the region.

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