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Adapting to Climate Change: Conserving Rice Biodiversity of the Apatani Tribe in North East India

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Abstract

Owing to its highly diverse physiographic and agro-climatic landscapes, and sustained immigration over a millennium, the North Eastern part of India is one of the richest rice biodiversity regions of the world. With the migrants from the West bringing indica varieties and those from the East japonica varieties, the cumulative outcome is a combination of both these genetic strains, many developed exclusively by specific tribes. The Apatanis, who practice terraced cultivation, have evolved 16 such varieties with predominance of japonica strain of which those exhibiting low yields over a few consecutive seasons pass into oblivion. As the

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climate warms the japonica varieties are at higher risk of spikelet sterility caused by higher temperatures during anthesis. Shifting of terraced fields to higher altitudes to escape warmer temperatures is not a viable adaptation measure for Apatanis and alterations in the sowing season can only be done within a narrow window of time but controlling of microenvironment by manipulating shade and water availability could prove cost effective. Genetic introgression of Early Morning Flowering trait would help reduce spikelet sterility during anthesis. Ex-situ conservation of every nuance of genetic variability achieved so far need to be given a high priority.

Keywords: anthesis, Apatani, adaptation, flower opening time, japonica, spikelet sterility

The North Eastern part of India is perhaps the most rice biodiversity rich region in the world. The estimated diversity of rice found in the entire region is about 9650 (Mao et. al, 2009). The state of Arunachal Pradesh itself yielded around 616 germplasm collections of rice from 1987 to 2002 (Hore, 2005).

The region supports such a rich genetic resource owing to its highly diverse physiographic and agro- climatic landscapes. Natural selection coupled with the preference of farmers belonging to distinct ethnic groups has contributed to the development of wide range of rice varieties (Hore, 2005). Another reason for the rich diversity could be the fact that the rice varieties growing in the region has benefitted from the cross migration of people both eastwards and westwards over a very long period who carried with them the i*ndica* and the j*aponica* varieties of rice (Hore, 2005). In tropical Asia the highland germplasm is composed of both *Oryza sativa indica* and *Oryza* *sativa japonica*, while the lowland germplasm is largely *Oryza sativa indica* (Rerkasem and Rerkasem, 2005). *Indica* varieties have spread eastward to Southeast Asia and north to China from the Indian plains (Khush, 1997) while the tribes practicing shifting cultivation in the highlands of Northeastern India introduced *japonica* variety as they settled in these highlands from their earlier homes in South East Asia over the past millenium.

These rice varieties are maintained and preserved by the tribal cultivators who grow their own special varieties that they have inherited from their forefathers and the rich genetic diversity of rice is thus passed on from one generation to the next. The exchange of varieties among the tribes is very limited on account of the rigid physical, social and economic inter-tribe barriers.

The Apatanis of Ziro valley in lower Subansiri district of Arunachal Pradesh are one such tribe which grow a wide variety of paddy in very small land holdings. This tribe, known to be relatively advanced among other tribal societies, grows paddy varieties of unique grain characteristic, nutrition requirement, duration, productivity and resistance to disease and insect pests, in highly evolved wet paddy cultivation coupled with pisciculture. Wetland rice cultivation in Ziro valley is practiced in broad and well leveled terraces with strong bunds in which the hill streams are trapped, channelised and diverted into primary, secondary and tertiary networks to provide water in the terraces. Water from one terrace reaches another through bamboo or wooden pipes. Fish pits in the plots ensure water remains for pisciculture even when the field is drained off especially in the flowering and the grain maturity stage.

This unique pisci-agriculture practiced by the Apatanis over the past many centuries has led to the development of a large number of varieties of rice. The paddy varieties of Apatanis have been reported by different researchers and their accounts vary greatly (Dabral, 2002; Pulamte, 2008; Dollo et al, 2009; Nimachow et al, 2010) on account both of limited tools at their disposal as also the geographical areas actually explored. Dollo et al, 2009 reported 16 landraces grown amongst the Apatani tribe. These are: Ampu Ahare, Ampu Hatte, Radhe Eamo, Eylang Eamo, Ampu Puloo Hatte, Kogii Pyate, Zeehe Pyate, Pyate Pyapu, Tepe Pyaping, Pyapu Pyaping, Kogii Pyaping, Zeehe Pyaping, Pyare Mipye, Mishang Mipye, Mithu Mipye, Eylang Mipye (Dollo et al, 2009).

Four varieties have been reported by Nimachow et al, 2010 locally known as ampo, mipya, layi and misang amo. Misang amo variety originally belongs to the nieghbouring Nyishi tribe and not cultivated widely by the Apatanis. Mipya, an early variety is harvested in the early part of July whereas Ampo being a late maturing variety is harvested in the month of October (Nimachow, 2010).

Pulamte, 2008 reported that low yielding varieties get less share of the tribal land. In his study area Amo (or ampo) covered 68% of the fields with an average yield of 5.2 t/ha whereas the varieties like Pyaping with an average yield of 4.0 t/ha, and Pyate with average yields of 3.2 t/ha, covered 15% and 10% of paddy fields in the Apatani villages (Pulamte, 2008). Dollo et al, 2009, stated that Ampu Pullo Hatte, a late variety is not grown anymore. Nimachow and co workers (2010) found that Mipya is a low yielding variety and not preferred much by the farmers who give more emphasis on other varieties for higher productivity and quality. There might be many more varieties in the future that may deliver lower yield, leading to their subsequent discontinuation, and eventually increasing the threat of erosion of the genetic resource of rice in tribal areas.

The varieties giving low yield are gradually abandoned by the farmers and the indigenous knowledge of farming practices of such varieties passed on to succeeding generations is lost. The unwillingness of younger tribe members to continue with the traditional practices and their migration to distant places in search of better economic avenues further aggravates these losses.

This situation may only worsen in the changing climate scenario. A recent report by the Indian Network for Climate Change Assessment (INCCA) has projected significant changes in temperature and precipitation regimes of North East India. The projected rise in mean temperatures in the region by 2030s with respect to 1970s ranges from 1.8 to 2.1°C with the minimum temperatures likely to rise from 1 to 2.5°C and maximum temperatures rising by 1 to 3.5°C. Thus a minimum decadal rise by 0.3°C in mean annual minimum temperature in the region is projected in the period leading to 2030 as against the average decadal warming by 0.2°C in pan-India mean minimum temperatures during the period 1975-2010 (INCCA, 2010).

The increase of mean annual precipitations in the 2030s, with respect to the 1970s, is of the order of 0.3% to 3%. A rise of 0.6% is projected in the monsoon rainfall in the months of June, July and August by 2030s. However, the number of rainy days is likely to decrease by 1–10 days resulting in increase in the intensity of rainfall in the region by 1–6mm/day (INCCA, 2010). Decreasing trends in sunshine duration or in other terms increased cloud cover have already been observed on annual, seasonal and monthly cycles for North East India (Jhajharia and Singh, 2010) and a 2 % increase in cloud cover over the mid latitude land areas during the 20th century has been reported by IPCC in its Third Assessment Report. This trend is likely to continue further with slight increase in rainfall projected till 2030.

In the period leading to 2030 significant increases in temperature are likely while the changes in rainfall and photo period may be only marginal. Thus only changes in temperature need to be factored in the analysis of the effect of climate change on rice productivity. Extensive researches over the years have thrown light on the impact of rice yield and quality due to changing climate (Matthews, 1995; Mathews et al, 1997; Peng et al, 2004; Welch et al, 2010). Though as yet no evidence has emerged from experimental studies of possible impacts of climate change on traditional rice production in Arunachal Pradesh specifically, it is reasonable to assume that yield and quality of rice grown in the area would also be affected.

The most crucial time is the grain or seed setting period since higher maximum temperature during grain setting stage may cause spikelet sterility (Matsui et al, 1999; Matthews et al, 1997; Jagadish et al, 2007; Wassmann et al 2009; Welch et al, 2010). This sterility is related to the number of viable[i] pollens reaching the stigma following the dehiscence of anther, a process which is highly sensitive to temperature (Wassmann et al, 2009). Anthesis[ii] occurs after about 5 hours from the onset of daylight (Zhang et al, 1999) when the anther dehisces and pollen grains fall onto the stigma causing pollination following which pollen tube is formed which elongates to reach the embryo sac. Jagadish et al (2007) found that temperature of 33.7 °C and more at anthesis for an hour was enough to induce sterility in rice and also noted that even shorter periods could cause harm. Their study also found that spikelets undergoing anthesis before the high temperature is reached were also affected if the high temperature point was reached when the florets were still open even though pollination may have already occurred. Weerakoon et al (2008) experimented with a combination of high temperatures (32- 36 °C) and relative humidity (60% and 85%) and found that high spikelet sterility could also occur with simultaneous increase in temperature and relative humidity.

Even before anthesis, prolonged high temperatures of 35°C during pollen grain formation, or microsporogenesis stage, could result in 34% decline in fertility of spikelet (Yoshida et al, 1981). However, the criticality of anthesis lies in the fact that only a very short period of exposure to high temperature is enough to induce sterility which makes it difficult for any sort of acclimation to occur.

A rise of 2-3°C in night temperature particularly during the sensitive reproductive and early grain-filling stages of rice (*Oryza sativa* L.), leads to reduced biomass, low grain yield and change in quality (Nagarajan et al, 2010). Grain yield can decline by 10% for each 1℃ increase in minimum temperature (Peng et al, 2004). Mohammad et al, 2010, subjected rice crops to high night temperature (32℃) in the greenhouse and found that it decreased yield by affecting spikelet sterility, and grain length, width and weight. Moreover, the limited stomatal activity at night makes rice vulnerable to rapidly increasing night temperature.

Increased CO_2 concentration may however result in increased productivity due to increased photosynthesis (Jagadish et al, 2007) unless there is a simultaneous increase in temperature which is high enough to enhance stomatal closure and lead to reduced transpirational cooling and thus affect fertility of the spikelet. A simultaneous increase in temperature and CO_2 concentration could decrease the high temperature threshold that causes spikelet sterility by 1℃ (Matsui et al 1997, in Jagadish et al 2010).

Japonica varieties are suggested to be less tolerant to high temperature than *indica* spp. though heat tolerant genotypes are found in both the sub species (Jagadish et al, 2007). Most varieties in the terrace fields of the Apatanis are of j*aponica* type (Hore, 2005).

A study carried out in Japan by Kobayasi et al, 2009, reported that flower opening time varies among rice cultivars signifying that it is largely under genetic control though the environmental factors may also play a role. They examined about 100 widely diverse cultivars and found that the flowering opening time varied from 0901 hours to 1235 hours during the day. Dividing this time range of 214 minutes (0901 to 1235 hours) into four quartets with each of 53.5 minutes (table -1), we find that most cultivars, 34% and 40%, flowered in the 2nd and the 3rd quartet respectively whereas only 8% and 18% flowered in the first and the last quartet respectively. Within the rice varieties there was a clear distinction between japonica and other varieties. Of those with flower opening time in the last quarter, 78% were japonica and 50% of all those flowered in the 3rd quartet were also japonica compared to 2.9% of all in the 2nd quarter. None of the *japonica* variety flowered in the 1st quarter. It can thus be concluded that *japonica* varieties generally flower later in the day and thus *japonica*, found more in the higher altitudes of North East India including the Apatani area is likely to be more vulnerable to the negative impacts of high temperature on spikelet fertility.

Table 1: Distribution of Flowering Opening time of japonica Varieties between 0901 to 1235 hours (adapted from Kobayasi et al, 2009)

	Time range	Number of cultivars undergoing anthesis	Number of japonica varieties undergoing anthesis	Percentage of japonica varieties undergoing anthesis
1st quartet	0901 hrs -0954 hrs 30 sec	8	0	0%
2nd quartet	0954hrs 30 sec -1048 hrs	34	1	2.9%
3rd quartet	1048 hrs -1141 hrs 30 sec	40	20	50%
4th quartet	1141 hrs 30 sec-1235 hrs	18	14	78%

Some rice varieties (*Oryza glabberina* and *Oryza officinalis)* which flower early in the morning avoid the high temperature stress at anthesis (Yoshida et al, 1981; in Wassman et al, 2010; Ishimaru, 2010). Germplasm with Early Morning Flowering Trait (EMF) introgressed into the traditional varieties may offer an adaptation option at the genetic level but demands very high level and in depth research. This may enhance yield of rice and help farmers improve their income but certainly cannot be an option for conservation of the traditional rice genetic diversity of the Apatanis.

Easy availability of water for the wet terrace cultivation of Apatanis offers opportunity for maintaining temperature under control by using irrigation inflow for temperature control. Also shade trees can provide a cooler micro climate for the plant. Though agroforestry is not common in rice fields of the area, it may be introduced in the lines of intensive rice agroforestry cultivation systems in Bali and Thailand (Gutteridge et al, 2004, Grandstaff et al, 1984).

Rice crops in terraces are infected by folder, rice hispa, gundhi bugs (*Leptocorisa oratorius*) and grasshopper. Commonly growing weeds in paddy fields of uplands of North east India are *Eichinochloa glabrescens* and *Cyperrus iria* (Chanu et al, 2010). Though Apatanis have over centuries innovated different traditional methods to repel pests and weeds from their rice fields, they might find it difficult to control pests only with these methods in the future when climate change induced pest attacks are likely to increase (Rosenzweig et al, 2001). There might be a need to improvise on their traditional methods and use viable methods backed by latest technology to reduce pest attack and plant disease.

In the face of warming shifts towards higher altitudes is generally considered as an option. The Apatanis occupy land at an altitudinal range of about 1000 to 1600m but terrace cultivation is most intense around 1300m to 1500m. In the warming climate scenario, altitudinal change for good yield from rice fields is not a viable option because abandoning terraces made over the past 500-600 years and making new terraces at a higher elevation would require very high levels of investments presuming suitable lands are available.

Another adaptation option could be alterations in the sowing season. In a warming climate scenario if the response of crop to possible temperature change can be controlled by altering the sowing period, loss could be reduced. But the window of time for such measures is very small as the interplay between dry season and rains offers a very small leeway for planting rice.

Intervention by the Government through schemes that support farmers to grow varieties, no longer preferred due to their low productivity, over atleast a fixed minimum area is often discussed as an option to conserve rice biodiversity. But such a system is only likely to encourage corruption as it would be very difficult to oversee its implementation. Ex situ preservation in a dedicated laboratory in a few leading technical university in the region is a far better option.

Efforts to preserve ex situ have already been undertaken in the region for the past many decades. In collaboration with the US Department of Agriculture (USDA), the Indian Council of Agricultural Research (ICAR) in the period 1968-71 undertook the Assam Rice Collection (ARC) program and collected a total of 6630 accessions from Arunachal Pradesh, Nagaland, Manipur, Meghalaya, Tripura and Assam. Similar efforts from 1987 to 2002 by the National Bureau of Plant Genetic Resources (NBPGR) yielded and preserved 616 germplasm collections of rice from Arunachal Pradesh. There have been attempts by other institutions like the Assam Agricultural University as well. However, the gene banks of the country do not represent the entire diversity of rice of the North eastern region as many areas remained unexplored during the major germplasm collections in the past (Hore, 2005). It would be advisable to assign this task to atleast two or three research institutions or university departments of repute to ensure that every nuance of genetic variability achieved so far in rice is preserved forever even if it means some overlap of work among the institutions.

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[i] *Pollen grains of rice remain viable for just about 10 minutes.*

[ii] *Opening of spikelet/floret or flowering; also represents the events occurring between opening and closing of spikelet*

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