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Review Article

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A Review on Future Prospective of Cold Tolerance Rice (*Oryza sativa* L.) Breeding in East and North Eastern India

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Abstract

Rice is the foremost important crop in the region, East and North East India. Rice is the foremost staple crop and food for one third of the world. Rice is grown from hill to plain, tropical to temperate in different agro-climatic region and seasons in the world. Rice is the crop having wider diversity with its growing season to cultivation in practice with weather variability, genetic diversity and face with different biotic and abiotic challenges during cultivation and growth phases, whereas temperature is one of them importance stress in the climate changing world. Low temperature or cold affect on rice crop from seeding to it's all most all the growth phases *i.e.* germination, seedling, tillering and pollen development cum seed set, whereas; germination, seedling and pollen development are the most sensitive and critical phases to rice for its growth and development. Many agro-morphological, physiological and biochemical parameters and changes are also found to be linked to cold tolerance response. Agro-morphological traits like leaf length, leaf area index (LAI), biomass production, physiological trails like leaf rolling, greenness, root development, chlorophyll content, photosynthesis and biochemical trails like proline, α amylase, reactive anti-oxidant(RAO), para-oxydase, soluble sugar content etc are found to be liked to cold tolerance in rice. Mostly high yielding rice varieties are grown in the tropic are cold sensitive so in the present climate changing scenario, cold is one of the importance stress and understanding the genetics of cold tolerance for breeding cold tolerance variety is very importance for today's and futuristic world in the era of rice science. Therefore, cold tolerance breeding, respect to evaluation, rice germplasm for cold tolerance, understanding the cold tolerance behavior with respect to better execution future breeding program over the available rice genotypes to mitigate cold stress over climate changing scenario in the region and future need in the rice growing ecology specially during *Boro* season and need of the region.

Keywords: Abiotic, *Boro*, Breeding, Cold, Genetic, Physiological, Rice, Stress and Tolerance.

Introduction

Rice is the important stable food crop, widely cultivated in the different season throughout the year in North East and Eastern India. Different rice growing seasons, *Aus, Aman, Boro, Ahu, Sali, Jhum* are practiced in North East and East India. Majority, the farmers grow rice for the economic sustainability by means of nature and naturally as the important farming components in farm practices and farming patterns to meet the income from the farming and contributing food grain and fodder production. Rice grain is widely used by the majority of the consumers as major food from breakfast to launch and diner as major dietary requirement by means, Rice, Puff rice, Panta bhat, Chira, Khoi or Pitha which is made up of rice flour or payas which is made up of aromatic raw rice grain or some special drink in the tribal communities. Rice straw is used and consumed as fresh or dry fodder for the cattle as major cattle feed as well as thatching the roof in the region.

Table 1. Rice growing seasons and their brief description

Season	*Aus/Ahu/Bhadoi*	*Aman, Kharif.Sali*	*Boro/Summer*	*Jhum* Rice
Growing Period	February-August	May-November	November-May	June-October
Harvesting	August-September	Noverber-December	May-June	September-October
Duration of Varieties	Early	Mid-Late	Early-Mid Early	Early-Mid-Early
Duration- Days (Seed-Seed)	95-120	125-155	135-165	100-130
Type of Cultivation	Rainfed	Rainfed/Irrigated	Irrigated	Rainfed
Planting Method	Broadcasting	Broadcasting/Trans planting	Transplanting	Broadcasting
Lead Varieties	Bhadoi, Motichur, Bornhi, Moinagiri	Ranjit, Swarna, Bhalum -3, Tulaipanji, Gobinda Bhog, Dudheswar, BB 11	IR 64,Khitish, Satabdi, Nabeen, Ajit, MTU 1010	RCM 3, Black Rice, Cha -Khao
Cropping System	Mono - cropping	Mono-Cropping	Mono-Cropping	Mixed Cropping
Land Type	Up-land	All type of land	Mid-low land	Forest Hill Terrain
Management Practices	Traditional/Low	Medium - High	High	Natural Farming
Major Pest and Diseases	Bird, Blast, Gandhi Bug, Brown Plant Hopper(BPH)	Blast, BLB, Stem Borer, False Smut, BLB, Brown Plant Hopper(BPH)	Blast, Stem Borer, Blast, Bacterial Leaf Blast	Blast, BPH, Gandhi Bug.
Major Abiotic Stress	Drought	Flood, Cold	Cold	Terminal Drought
Cultivation Economy	Low	High-Medium	Medium	Low
Nutritional Status of the Varieties	High	Medium-Low	Low-Medium	High-Medium
Yield Potential	Low	Medium	High	Low
Yield Potential(qt/ha)	1.5-2.5	3.5-5.5	4.5-6.0	1.5-2.0

Rice, East and North East India: Rice cultivation in the East and North East means in the state, West Bengal, Odisha, Chhattisgarh, Bihar, Eastern Uttar Pradesh, Assam, Sikkim, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram and Tripura. The region contributes a major contributing to the genetic and cultivation variability in practices with the present of genetic diversity from the beginning on rice cultivation history and cultural richness with rice cultivation and rituality among the rice farmers in the region. The festivals, Bihu, Sankranti, Nabanya, Naba-khuya, Tilak, Ghat sthapana or Laxmi puja all are the festival without rice is not possible either in Assam, Bengal, Bihar, Chhattisgarh, Odisha, or Uttar Pradesh in the region as a whole, which is the culture in the blood, the rice farmers.

Rice Growing Seasons: Rice cultivated area was higher in *Kharif/Aman/Sali* followed by *Aus/Ahu* and *Boro/Summer* in the earlier days but presently drastically decreased the cultivated area under *Aus/Ahu* segment due to low yield and higher labor cost. *Jhum* rice cultivation only practiced in the north eastern hill by the tribal farmers under Jhum or shifting cultivation practices. Due to change in cropping pattern and adoption, intensive cultivation and low management crop like Corn, decreasing the *Boro* Rice area in the Bihar adjoining part of West Bengal on the other hand decreasing the traditional long duration kharif rice varieties area due to adoption of rice-mustard- rice cropping system in East and North Eastern India.

Impact of Cold on *Boro* Rice Cultivation: Due to advancement and adoption of better irrigation and management practices, people are growing more rice in *Boro/Summer* season on the other hand due to better yield but again presently *Boro/Summer* rice area is decreasing due to high water consumption and least management crop like corn is getting place in place of *Boro* rice in some part of the region. Parallels, due to cold intensity and injury on rice, *Boro* season is gradually being shifted towards late *Boro* or early *Ahu* segment due to cold affect during winter.

Boro rice growing season is the most important due to the higher crop yield in the region due to shifting from original sowing time, yield is being reduced and on the other hand, due to cold affect on germination and seedling stage is getting affected and farmers are facing challenge on raising seedling stage. Nurseries, at low temperature in night during *Boro* season adversely affected, on the other hand majority of the *Boro* varieties are cold sensitive, so challenges on raising healthy seedling is too Priyanka *et al*., (2015), Zhang and Li, (2017). Different rice cultivation seasons and their brief description as have been given (Table-1) for the region, East and north East India.

Rice cultivation system has been evolved by means, availability of different diverse rice genotypes suitable for the cultivation in different ecology and growing seasons with the cultivation practices, practiced by the growers, generation after generation and captures the knowledge. After the advancement of rice science with the dedicated effort by the researchers and passionate rice farmers, developed the different modern technology and management techniques for the better uplift- man of life of the rice farmers with the dialogue “rice is life”.

Table 2. Major Boro Rice Area and Growing States and Districts in East and North East India

State/ Area	District
Eastern Uttar Pradesh	Basti, Ballia, Gorakhpur, Gazipur
Bihar	Purnia, Katihar, Madhepura, Madhubani, Darbhanga, Saharsha
West Bengal	Burdwan, 24 Parganas, Nadia, Medinapore, Bankura, Uttra Dinajpur, Dakshin Dinajpur, Jalpaiguri, Coachbehar, Malda
Orissa	Balaroe, Bhadrak, Kendrapara
Assam	Dhubri, Bangaigaon, Nagaon, Morigaon, Kamrup, Tejpur, Darrang, Karimganj, Hailakandi, Silchar
Tripura	Dharmanagar, South Tripura

Cold Stress Affect on Rice Plant: Low temperature is one of the most limiting environmental factors for the plant growth, productivity, and geographical distribution of crops; it can be categorized into two major types: a. Chilling stress (0-15 ^{o}C) and, b. freezing stress (<0 ^{o}C) Zhu *et al*., 2007. Rice originated in tropical to tropical regions, it sensitive to temperatures below 15-17 ^{o}C reported by Koseki *et al.*, (2010). Cold stress in rice negatively affects chlorophyll content and photosynthesis, which impacts the growth and productivity of the crops Kanneganti and Gupta, (2008) and, Kim *et al*., (2009). Depending upon the crop growth stage of rice plant, cold stress can cause different symptoms and damage in rice plants Yoshida, (1981) which is well proved and understood.

***Boro* Rice and Cold** : The *Boro* rice season start in winter season, means while sowing started in the month, November- December, where temperature persisted very low up to 5 0^{C} in some part of the region and in the main sowing period that is 15th November to 15th December and in the same time germination as well as seedling development affected drastically due to cold injury. Farmer are failed some time to raise healthy seedling which ultimate affect the crop season and yield as well as economic loss to the rice farmers in the region. Cold injury during winter is the one of major stress or challenge on raising a successful crop in the region for the cultivation, the *Boro* Rice in East and North Eastern India under the climate changing world Naidu *et al.*, (2005), Bertin *et al*., (1996), Pathak, (2003); Das, (2015).

Cold and Rice Growth & Development: Rice is preferred to grow under warmer, humid and clear sunny day or weather conditions for better performance by means of growth and development and yield. On the other hand 27-32 0^{C} is the most ideal temperature range for its normal growth and development but low temperature(<15 0^{C}) adversely affect the normal growth and development of rice plant. The Rice plant come under stress and indicates, its stress below 15 0^{C} with respect to chlorophyll synthesis, content, leaf rolling, wilting due to cold, stunting growth and development as well as weight loss, release of soluble sugar, exhibiting the reactive oxygen activities, reducing the metabolic activities and Cyto-chemical changes etc. Cold adversely affect on germination, seedling and reproductive phase, rice plant growth and development Oidaira *et al.,* (2000), Yashida *et al*., (1996).

Germination and affected due to Cold: During germination phage, normal temperature reach to 5 0^{C} during winter, particularly in the month and end, December by which germination adversely affected. Due to poor germination rice seed rate increase naturally and cost of cultivation increased proportionately. Germination percent reduced due to cold at the time of germination by means of ridicule, coleoptiles, root and shoot development during germination stage as well as fail to establish the seedling in field or nursery Cruz and Milach (2000), Pan *et al*. (2015), Sharifi (2010), Uneo and Miyaoshi (2005).

Seedling Injury Due to Cold: Seedling development start naturally after the seed sowing means on 15th December onwards when air and night temperature goes down up-to 5 0^{C} which is too low with respect to rice cultivation or seedling growth and development. Due to low temperature seedling growth and development affected with cold injury and some time farmers, otherwise failed to raise the healthy seedling or need more seed, means seed rate increased due to cold affect on seedling raise. The seedling cost to the farmers or on the other hand due to unhealthy or poor seedling growth and development or performance of the seedling which finally affect on the crop performance with respect to yield components, the crop and ultimate loss to yield and economic yield Krishnasamy and Seshu (1989), Shimono *et al*. (2002); Cruz *et al*. (2013).

Cold and Reproductive Stage: Cold effect adversely on the growth and development of the rice plant and reproductive phase, like germination and seedling stages. Due to cold, hampered the normal growth and development at reproductive phase during mega –spore or pollen development, whereas due to cold, develop the sterile pollen development take place in the pollen sac, which ultimate leads to sterilities and failed in fertilization and as a results non development of seed. Sterile pollen development leads to sterility and development of chaffy grain in the panicle and as results, yield loss leads to economic loss to the farmers Satake and Hayase (1970), Kaneda and Beachell (1974), Nishiyama (1984).

Sources of Cold Tolerance in Rice: Traditional rice is grown by the farmers in east and north eastern India and many varieties are grown from long back but typical *Boro* rice was started by the farmers in the localities in low laying areas, where additional water or moisture is readily available pond backyard, river basin or land with irrigation facility mainly Dan. Some old varieties like Khoi barua, BR 28 in the Barak valley region, Assam, BR 29, IR 64 in Central Brahmaputra Valley; Abhishek and Nabeen in Tripura, Boro Type (Awaned), IR 8, China irri, IR 64, IH 36, Khitish, Satabdi and Gourab in West Bengal, Gourab in Bihar and IR 64, Nabeen, Abhishek and Prakisha in Odisha as well as IR 64, MTU 1010 in Chhattisgarh as per suitability of land and water availability. After the improvement and development of rice management practices under the flagship, International Rice Research Institute (IRRI), National Rice Research Institute (NRRI/CRRI) and Indian Institute of Rice Research (IIRR/DRR) under different network programs, many high yielding varieties as well as hybrid have been evolved with better management practices to lead the farmers with more productivity and production income with the rice crop. In general the *temperate japonica* was the major source of cold tolerance or wild rice Kaneda and Beachell (1989), but due to modern breeding intervention transmission of cold tolerance gene or trait had been incorporated in the different background of Indica as well as Javanica or tropical Japonica varieties as commonly said high yielding modern varieties. Some varieties were naturally evolved due to cultivation traditionally in the temperate region, the world. The varieties those were grown in the Himalayan train face the cold stress naturally and performing well so long therefore, these varieties may be cold tolerance. Some popular hill rice varieties are Bhalum 3, Lo Panha, RCM 3, RCM 1, RCM 2 in Meghalaya, Jelam, Barkat, SR 5, China in Jammu and Kashmir, K 84, Barkat etc. Some newly reported varieties are, Gourab, CR Dhan 601, Bhalum 3, Shraboni, Co 51, Shyamala, Barhashal, R. Bhagabati, China Irri, Maharaja, Radha found to cold tolerance Ghosh and Dasgupta (2021), Biswas *et al*, (2019), Singh *et al*. (2012), Satya and Saha (2010), Hamdani (1979).

Future Need of Cold Tolerance Breeding: Due to cold during winter as per the temperature record noticed somehow 5 0c or less perceived in the east and north eastern region specialty by end, December to first week of January in many locations which is adversely affecting the germination of the rice seed as wells and the seedling growth and development. In North Bengal, during winder die to low temperature, some varieties like Khitish, Satabdi some time failed on cold spelled which might by due to the cold stress in the *Boro* season affected the rice cultivation as well as the seedling performance and finally the crop yield performance due to poor seedling growth and farmers need more seed rate or seed bed to overcome the issue and cost more on seed cost as well as seedling management purpose during *Boro* in the region Satya and Saha (2010), Das (2015), Pathak *et al.*, (2004).

Low temperature is a major climatic problem for all rice growing countries including, Australia, China, Japan, Nepal, Russia and South Korea (Farrell et al., 2004). The Austalian rice industry, which has highest yield (10 t h^{-1}) in the world experiences cold stress one in about every 4 years and resulted in about 30-40% yield loss accounting $120 million due to cold induced –sterility Naidu *et al.*, (2005). In Asia and South East Asia about 7 million hectare area affected due to low temperature Brady, (1979).

Conclusion

Looking to the above strategies on the *Boro* rice cultivation in the East and North Eastern India, identification of cold tolerance cultivar and cold tolerance varieties may be adopted for the cultivation during the *Boro* season with better yield potential. Breeding program for the development cold tolerance in the background of cold sensitive popular high yielding varieties may be carried out looking to the need, the region with respect to cold during the *Boro* rice season for better prosperities, the rice farmers in the region, East and North Eastern India in the climate changing world for better sustainable future of the Rice farmers.

Some leading varieties for the region are IR 64, MTU 1010, Swarna, Swarn Sub -1, Ranjit, Ranjit Sub-1, Khitish, Satabdi, BB 11, BINA 11, BR 29, Tulaipanji, Dudheswar, Gobindabhog, Kalabhat, Paijam, Aijung, Bahadur, Kalo Nunia, Moinagiri, Aghoni Bora, Kamol, Kalirai, Jalkouri, Jalamagna, Jaladhi, Bhadoi, Pankaj, Tulsibhog, Joha, Bhalum 3 Ketaki Joha, CR Dhan 601, Krishna Hamsa, Tel Hamsa, CU 48, Kalinga III etc.

Therefore, identification or screening, the rice varieties for cold tolerance improvement and improvement of the cold sensitive high yielding *Boro* varieties are importance looking to the need of the region, East and North East India and benefit of the farming society.

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