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Management of drought in *sali* rice under increasing rainfall variability in the North Bank Plains Zone of Assam, North East India

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Abstract
The intermittent dry spells during growing season of winter or *sali* rice, cultivated in NBPZ of Assam located in the foothills of Eastern Himalayan region, is a major weather risk causing widespread damage to the crop. Herein, variability of rainfall in Lakhimpur district situated in NBPZ was studied. A significant decreasing trend of annual and seasonal rainfall was observed. Significant decrease in monsoon rainfall and increase in monthly rainfall variability clearly explains the recent rainfall fluctuations with increasing frequency of intermittent dry spells and flash floods. A participatory evaluation trial was conducted in Chamua village of Lakhimpur district having different land situations to identify climate resilient technologies to cope with seasonal drought in *sali* rice. High-yielding short-duration varieties, viz., Dishang, Luit, Lachit and Kolong, and medium-duration varieties, viz., Basundhara, Mohan, Mulagabhoru and TTB-404 performed consistently better than the long-duration HYV or the traditional varieties under upland and medium land situations, respectively. Though the effect of dry spells on long-duration varieties cultivated on low lands was least, yield of these varieties reduced up to 43.07% when sowing was delayed beyond 23rd of June. Performance of the delayed sown varieties was further declined, when exposed to dry spells at later growth stages. However, adverse impact of dry spells can be managed effectively by replacing farmers' varieties with short and medium-duration high-yielding varieties in upland and medium lands, respectively, and manipulating sowing time of long-duration varieties for low lands.

Keywords Seasonal drought · *Sali* rice · Dry spells management · Alternate variety

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1 Introduction

The climate change and climate variability are the major challenges impacting agricultural production in many parts of the world. Climate change is likely to have an adverse impact on crop production in tropical and subtropical countries through increased vulnerability to droughts and other extreme weather events (Wassmann et al. 2009). In India, increasing trend of temperature at the order of 0.60 °C per year during the last 112 years (Rathore et al. 2013) and increase in heavy rainfall events, particularly in Central India (Goswami et al. 2006) were reported. The frequency of droughts, cyclones and hailstorms has increased in the recent past, with 2002, 2004, 2009, 2012 and 2014 being severe drought years (Srinivasa Rao et al. 2016). Frequent and more intense extreme events may become a norm of the day for common farming community (IPCC 2013). Many recent studies have shown negative impact of change in temperatures and precipitations on Indian agriculture, which may further worsen in the future (Aggarwal et al. 2010; Sapkota et al. 2015). According to an estimate, due to climate change, country wide crop loss in 2030 is expected to be over $7 billion; however, this loss could be reduced by 80% through implementation of cost effective climate resilient measures (Srinivasa Rao et al. 2016).

North East India is characterized by agrarian society, over exploitation of natural resources, rainfed agriculture, subsistence farming, dominance of small and marginal farmers, monocropping of rice, poor farm mechanization, poor rural and marketing infrastructure etc. which make the region more vulnerable to climate variability and climate change (Barah 2006; Ravindranath et al. 2011). Climatic variability at higher magnitude in the region has already been documented as erratic behavior of rainfall in terms of changing rainfall pattern, increase in frequency of high intensity rains leading to localized flash flood, reduced number of rainy days, and occurrence of midseason and terminal dry spells (Patle and Libang 2014). Assam is the only plain state of North East India surrounded by hills and networked with as many as 176 major and small rivers. Analysis of long term rainfall data indicated decreasing trends in annual and monsoon rainfall with increasing number of rainfall deficient years from 2001 onwards in both the Brahmaputra and Barak basins of the state (Deka et al. 2013; Rathore et al. 2013). According to India Meteorological Department, temperature in the state continues to rise and may increase by 1.7 to 2.0 °C during 2021 to 2050 with increasing frequency of the extreme rainfall events (ASSAPCC, 2015).

In the North Bank Plain Zone (NBPZ) of Assam, increased variability in amount and distribution of rainfall has also been observed in recent years along with increase in numbers of wet spell driven flash floods and seasonal droughts (Neog et al. 2016). Though probability of getting two consecutive wet weeks with 40 mm assured rainfall at 70% confidence level during *sali* rice growing season is 10 weeks, the area is susceptible to drought and the duration of agricultural drought is as long as 4 and 11 weeks during *kharif* and *rabi* season, respectively (Sarmah et al. 2013). The observed rainfall fluctuations in recent years with large amplitudes indicates greater degree of likelihood of heavy floods as well as short spell droughts which is bound to pose major challenge to agriculture in the area in future (Deka et al. 2013). The predominantly small farmer-oriented mono-cropping of rice in the zone is affected both by monsoon floods and intermittent dry spells. As the zone is a narrow valley comprising of new alluvial soils with poor water retention capacity and have the network of river system, draining out of water from the zone is very quick. Therefore, *sali* or winter rice grown between June/July and November/December (Pathak et al. 2015) in the zone is affected by both flash floods and dry spells. In recent years, intermittent dry spell during growing season of *sali* rice is becoming the major weather risk causing widespread damage to the crop.Generally, long-duration rice varieties transplanted in the low land fields were not affected by midseason or terminal dry spells (Neog and Sarma 2014); but, if sowing has to be postponed beyond the third week of June on account of delay onset of monsoon, these varieties suffered from low temperature stress (below 20 °C) during anthesis (Fig. 1) will lead to reduction in grain yield. The yield loss due to delay in sowing could be avoided by sowing of long-duration varieties within third week of June by using harvested rainwater during pre-monsoon months.

Farmers of the zone are mostly resource poor with poor adaptive capacity, so aberrations of rainfall make the rainfed agriculture of the zone highly vulnerable, risk prone and unprofitable. Therefore, identification of various adaptation strategies including use of climate resilient crops and cultivars are to be identified to cope with seasonal droughts and sustain higher productivity in the zone. Considering the presence of enormous variability in varietal types of rice in this area, there is the possibility of successful management of seasonal drought through identification of alternate rice varieties suitable for different land situations. Hence, nontraditional rice varieties of varying growth duration and adaptability with specific land situations may be sorted out to cope with the dry spells of various durations during the *sali* season along with manipulation of agronomic practices like modification of sowing dates, completion of timely farm operation (s) etc. Despite presence of variability in varietal types and possibility of harvesting and recycling rain water for sowing of *sali* rice in time, holistic analysis for evaluating climate resilient adaptation potential of these agronomic measures is still lacking in the zone. In this study, an attempt has been made to study the rainfall variation in relation to occurrence of seasonal drought during *sali* rice growing season in NBPZ of Assam. Moreover, climate change adaption potential of various agronomic practices like introduction of alternate varieties and manipulation of sowing time were evaluated using crop data generated from the experiments conducted at farmers' field.

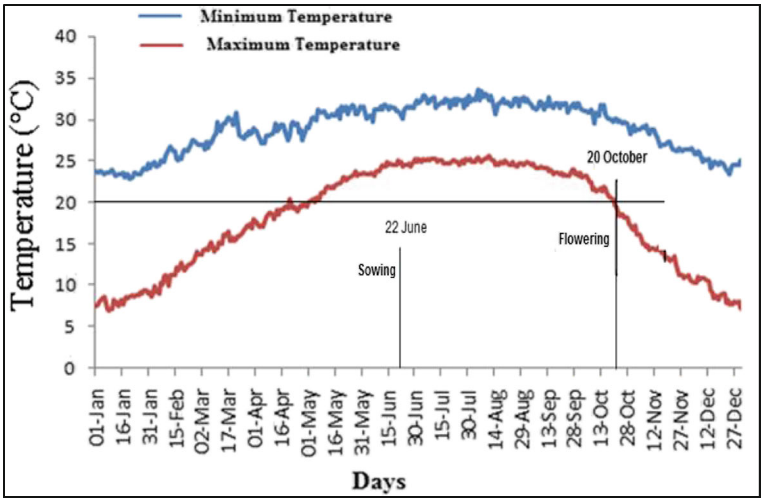

Fig. 1 Exposure of anthesis of long-duration *sali* rice varieties to low daily temperatures in North Bank Plains Zone of Assam, India

2 Methodology

The present investigation comprises of the analysis of long-term rainfall data in relation to intermittent dry spells and their effects on *sali* rice. For this purpose, a village named Chamua (Lat: 27° 02′ 18″, Long: 93° 52′ 46″) of Lakhimpur district in the domain area was selected (Fig. 2). Participatory on-farm trials for evaluating effect of intermittent dry spells on *sali* rice were conducted during 2011 to 2015. The village is situated in the foothills of Himalaya with altitude ranging from 83 to 90 m and characterized by 'subtropical monsoon rainfall' type of climate with high humidity and heavy rainfall. The village receives annual rainfall of 2848.5 mm out of which 67.9 and 5.0% receive during monsoon and post-monsoon season, respectively.

The soil in the crop root zone in the village varies from coarse loam to moderately fine loamy with silty loam to silty clay loam surface texture (Dutta et al. 2015). *Sali* rice, the single major crop of the village, is grown under diverse situations ranging from upland to low lands and represents all major types of rice growing situations of the zone. Though the study area receives very good quantum of annual rainfall, the *sali* rice grown in the village is affected by multiple dry spells in almost every year. The effect of dry spells is more prominent in the well-drained uplands as compared with moderately drained medium land situation, while the effect is very less in low land situation.

Daily rainfall data for the period 1984–2016 was collected from the nearest weather station located at Regional Agricultural Research Station, Assam Agricultural University, Lakhimpur (27° 17′ N latitude, 94° s10′ E longitude, and 87 AMSL altitudes) to study the variation of monthly and seasonal rainfall. Annual, seasonal and monthly rainfall data were analyzed by subjecting them to non-parametric Mann-Kendall test (Mann 1945; Kendall 1975) to detect the plausible positive or negative trends, and the trends were determined by using Sen's slope method (Sen 1968). Coefficient of variations (CV) of monthly rainfall was calculated, and the trends of coefficient of

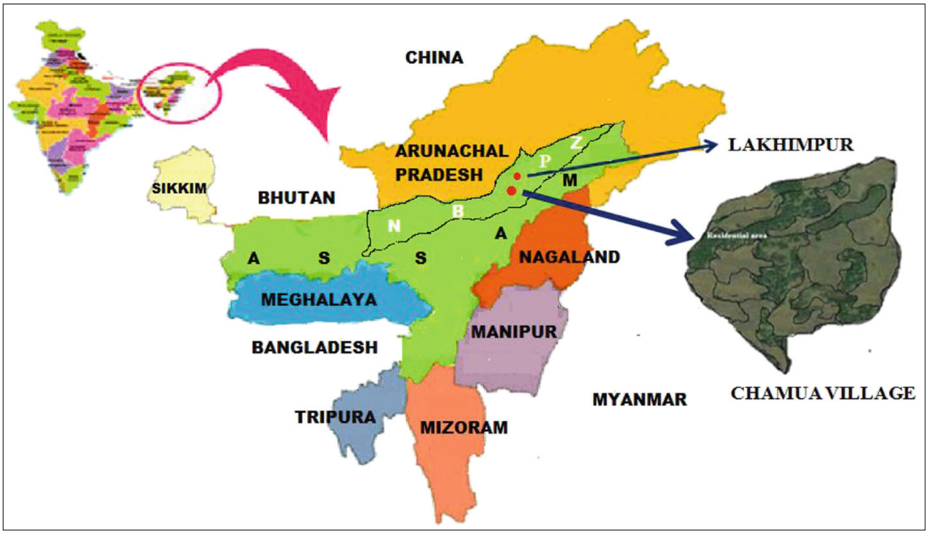

Fig. 2 Map of the study area

variation of monthly rainfall for a 5-year moving period were worked out, and the months with significant trend were identified by performing *t* test. The daily rainfall data recorded in the mini weather station of Chamua village was critically observed during the period of study, and the daily rainfall data were used to identify the occurrence of intermittent dry spells during the growth period of *sali* rice (June to November). A rainless period of 1 week or more with the characteristics of agricultural drought for *sali* rice was considered as the dry spell. Because the soil with moderately fine loam surface texture and course loam soil column (in extreme cases) has poor water retention capacity and no rainfall for a period of 7 days is sufficient for showing indication of agricultural drought by the crop.

On-farm trials were conducted in the village involving 40 farmers covering an area of 20 ha representing different land situations. Three groups of high-yielding rice varieties comprising of four short-duration, four medium-duration, and three long-duration varieties (Table 1) were evaluated and were compared with famers' varieties for upland, medium land, and low land situations, respectively, in replicated field plots considering one site (farmer) as one replication. Farmers' varieties consisted of traditional as well as long-duration high-yielding varieties which were grown irrespective of land situations of the village. Standard package of practices was followed for growing the varieties. High-yielding short-duration rice varieties viz., Dishang, Lachit, Kolong and Luit were evaluated for upland situation, while four high-yielding medium-duration rice varieties viz., Bashundhora, Mohan, Mulagabhoru and TTB-404 were evaluated for medium land situation. With a view to infuse contingency measure for avoiding delayed sowing of long-duration varieties, we took the advantage of delayed onset of monsoon situation during 2011, 2013 and 2014, when onset of monsoon was delayed by 12–18 days. Three long-duration varitieis viz., Ranjit, Gitesh and Moniram were evaluted under delayed sowing beyond third week of June, and normal sowing utilizing harvested rainwater and performances of the varieties in terms of yield, net income, and benefit-cost (B:C) ratio were evaluated and compared. Cost of cultivation necessary to calculate the net income and B: C ratio was determined over variable inputs by multiplying with respective market price.

Table 1 Characteristics of rice varieties evaluated for management of seasonal drought under different land situations

Group of rice (duration in days)	Land situations	Name of rice varieties	Duration (days)	Average yield (Kg ha^{-1})
Short duration (90–120)	Upland	Dishang	90–100	3200
		Lachit	120	3500
		Kolong	90–100	3000
		Luit	90–100	3000
Medium duration (125 to 140)	Medium land	Bashundhora	130–133	4500
		Mohan	126–130	4100
		Mulagabhoru	130–135	4600
		TTB-404	130–135	5000
Long duration (150 to 160 days)	Low land	Ranjit	150–155	5500 to 6000
		Gitesh	150–160	5000 to 5500
		Moniram	150–155	5400 to 6000

3 Results and discussion

3.1 Rainfall characteristics of the study area

The rainfall of Lakhimpur district of Assam was high, but its distribution over the time was not uniform. The district received 2848.5 mm rainfall annually with standard deviation (SD) of 522.5 mm and the coefficient of variation (CV) of 27.5% (Table 2). The monsoon season received 1968 mm of rainfall with a CV of 17.6% while post-monsoon season received 289.2 mm with a CV of 47.4%. During the *sali* rice growing period, July is the wettest month with rainfall of 556.1 mm followed by June (500.7 mm), August (467.6), September (382.9 mm), October (154.7 mm) and November (23.8 mm).

Though statistically not significant, coherent deceasing trends of monthly rainfall in all the months except November were observed during the period of cultivation of *sali* rice (Table 2). In case of seasonal rainfall, significant decreasing trend was found in monsoon season with the slope magnitude of – 15.9 mm yr^{-1}, while decreasing trend was not statistically significant in post-monsoon season. The annual rainfall decreased by a rate of 29 mm yr^{-1} during the study period.

In view of the fact that moving average is a powerful trend indicator, a 5-year moving average analysis of CV of monthly rainfall during the growing season of *sali* rice was carried out (Table 3). It was found that the coefficient of variation of a 5-year moving period in June, September and October increased significantly over the period from 1984 to 2016. The analysis revealed the presence of highly significant ($p < 0.01$) positive linear trend of CV of monthly rainfall for a 5-year moving period during June, September and October (Table 3).

The present study indicated significant decreasing trend of monsoon rainfall with significantly increasing rainfall variability in June, September and October, which might be linked to the observed increase in intermittent dry spells in recent years during rice growing period in the locality. The likelihood of increasing number of years with more number of dry spells due to irregularity in onset of monsoon (in June) and reducing rainfall activities during September and October is certainly going to affect the yield of *sali* rice. Similar results of negative trend of monsoon and annual rainfall with increasing frequency of dry and wet spells from different parts of North East India have been reported (Saikia et al. 2007; Patle and Libang 2014; Deka et al. 2015).

Table 2 General characteristics and trend analysis of monthly, seasonal and annual rainfall of Lakhimpur during *Sali* rice growing period for period from 1984 to 2016

Months/Season/ Annual	Average rainfall (mm)	Std Dev (mm)	Coefficient of variation (%)	M-K statistics (Z)	Sen's slope estimator (Q)	Trend
June	500.7	209.9	41.9	– 0.167	– 4.71	No trend
July	556.1	177.2	31.9	– 0.163	– 5.84	No trend
August	467.6	124.2	26.6	– 0.193	– 3.80	No trend
September	382.9	181.3	47.3	– 0.129	– 2.68	No trend
October	154.7	95.2	61.6	– 0.184	– 0.48	No trend
November	23.8	24.5	102.9	0.142	– 0.25	No trend
Monsoon	1968.0	347.3	17.6	– 0.267*	– 15.9	Decreasing trend
Post-monsoon	289.2	137.2	47.4	– 0.188	– 4.5	No trend
Annual	2848.5	522.5	27.5	– 0.36**	– 29.0	Decreasing trend

*represents 5% significance level and **represents 1% significance level

Table 3 Regression equations of trend of coefficient of variation of monthly rainfall for a 5-year moving period (Y) over the period of 1984 to 2016 in Lakhimpur district of Assam

Months	Regression equations	R^2	*p* value
June	Y = 0.948 X + 16.81	0.412	0.000171
September	Y = 1.405 X + 15.96	0.437	0.0000474
October	Y = 1.527 X + 31.75	0.485	0.0000133

3.2 Impact of dry spells on *sali* rice during 2011 to 2015

During the study period (2011 to 2015), daily rainfall data recorded in Chamua village were analyzed, and dry spells occurring during rice growing season (June to November) in the village were identified and presented in Table 4. During the study period, in three out of 5 years, the onset of monsoon in that village was delayed by 12 (2014) to 18 (2011) days. The village also experienced intermittent dry spells in all the years, which affected *sali* rice due to no or less rainfall in early part of June or during August to November.

The year 2011 was an exceptional year with multiple dry spells due to delayed onset of monsoon followed by substantial reduction of rainfall from mid-August. Sowing of the long-duration rice varieties could not be completed before third week of June which resulted in poor performance of these varieties. The occurrence of multiple dry spells, which coincided with tillering to maturity stage, caused substantial yield reduction of *sali* rice grown in the different land situations in the village. In some extreme cases, no panicle emergence was observed. The reduction of yield of farmers' varieties grown in upland situations of the village were observed to the extent of 1020 kg ha^{-1}, which was far below than average yield (1500 kg ha^{-1}) of these varieties grown under similar land situation. It was observed that yield of Ranjit, a popular long-duration high-yielding variety, was reduced to the extent of 40 to 100% when cultivated in upland and midland situations of the village.

During 2012, the village received a good amount of well distributed rainfall up to mid of October; however, no rainfall was received in remaining part of the growing season. The extent of damage due to the occurrence of terminal dry spell in different land situations was observed to be the least in 2012.

During 2013 and 2014, *sali* rice grown in the village was affected by occurrence of intermittent dry spells during September to November. Only three rainy days with monthly rainfall deficit of 89% was experienced during October 2014 and rainless condition continued up to the 10th of November. During 2015, the village was affected by midseason (26th of September to 7th of October 2015) and terminal (15th of October to end of November) dry spells which adversely affected the panicle initiation and grain filling stages of *sali* rice.

3.3 Dry spell management in upland and midland situations with alternate varieties

The grain yield of short-duration rice varieties evaluated for tolerance to intermittent dry spells in upland fields of Chamua village varied from 2255 to 4191 kg ha^{-1} during 2011-2015 (Table 5). Among the varieties, Dishang (3730 kg ha^{-1}) and Lachit (3449 kg ha^{-1}) recorded significantly higher grain yield as compared with Luit (2758 kg ha^{-1}) and Kolong (2882 kg ha^{-1}). During 2015, yield of the short-duration varieties was reduced significantly, which might be due to occurrence of dry spells (26th of Jul to 3rd of August 2015) during establishment and

Table 4 Intermittent dry spells affecting different growth stage (s) of *Sali* rice in Chamua village during 2011 to 2015

Year	Date of onset of monsoon (onset delayed)*	Rainfall (mm) during *Sali* rice growing season (June to Nov)	Dry spells Dates and month (duration)	Crop growth stages affected
2011	22 June (18 days)	1432	i. 01 to 21 June (21 days) ii. 03 to 11 July (7 days) iii. 25 Aug to 6 Sept (12 days) iv. 28 to 13 Oct (16 days) v. 27 Oct to 13 Nov (18 days) vi. 16 to 30 Nov (14 days)	Sowing, tillering, panicle initiation and grain filling
2012	4 June	1974	i. 13 to 21 Aug (9 days) ii. 15 Oct to 30 Nov (47 days)	Grain filling
2013	18 June (12 days)	1512	i. 01 to 16 June, (16 days) ii. 11 to 24 Sept (14 days) iii. 9 to 20 Oct (12 days) iv. 23 Oct to 30 Nov (39 days)	Sowing and grain filling
2014	20 June, 2014 (16 days)	1935	i. 01 June to 18 June (18 days) ii. 29 Aug to 06 Sept (9 days) iii. 29 Sept to 12 Nov (45 days)	Sowing and grain filling
2015	1 June, 2015	1976	i. 26 July to 3 Aug (11 days) ii. 26 Sept to 7 Oct (12 days) iii. 15 Oct to 30 Nov (45 days)	Transplanting, early tillering, PI, grain filling

*normal date 4th June

Table 5 Yield of short duration improved varieties grown in the uplands of village Chamua during 2011 to 2015

Varieties (No of participant farmers)	Yield (kg ha^{-1})					
	2011	2012	2013	2014	2015	Mean
Disang (16)	4008	3703	4191	3708	3047	3730
Lachit (12)	3815	3229	3160	3590	-	3449
Kolong (12)	3558	2556	2756	2660	-	2882
Luit (18)	3170	2688	2815	2738	2255	2758
Mean	3602	3044	3231	3151	2651	3195
CD(p = 0.05)	372	438	903	813	756	609
Average yield of farmers' varieties						1500

early tillering stage of these varieties. In spite of absence of dry spells during 2012, comparatively lower grain yield (3044 kg ha^{-1}) of short-duration varieties might be attributed to continuous rainfall as well as cloudy days up to mid of October. However, varieties evaluated for upland situation consistently performed better with average grain yield of 3194.8 kg ha^{-1} as compared with farmers' varieties (1500 kg ha^{-1}) grown in similar land situation.

The grain yield of medium-duration high-yielding varieties evaluated for medium land situations varied from 3701 kg ha^{-1} (Mohan) to 5008 kg ha^{-1} (TTB-404) with mean value of 3947 kg ha^{-1} (Table 6). A perusal of data revealed that grain yield of medium-duration varieties was influenced by both cultivars and crop seasons. Among the varieties, TTB-404 (4523 kg ha^{-1}) and Mulagabhoru (4344 kg ha^{-1}) recorded significantly higher yield, while among the crop seasons, the lowest (3701 kg ha^{-1}) and highest (4107 kg ha^{-1}) average grain yield was recorded during 2012 and 2013, respectively. In spite of variation in grain yield, medium-duration high-yielding varieties were observed to be significantly superior with average grain yield of 3947 kg ha^{-1} to the farmers' varieties (2250 kg ha^{-1}) cultivated in the similar land situation.

Plant's response to abiotic stresses is crop and cultivar specific. Generally, short-duration high-yielding varieties can escape the terminal drought as well as other impending abiotic and biotic stresses. In the present study, short-duration high-yielding rice varieties reached physiological maturity by the end of September and therefore, could escape dry spells occurring after mid-September. Similarly, high-yielding medium-duration varieties grown in the medium lands could escape terminal dry spells, while reproductive stages of farmers' varieties grown in similar land situation were exposed to dry spells in the months of October and November resulted in substantial reduction of their yield. The observations showed that in upland and medium land

Table 6 Yield of medium duration improved rice varieties grown in the medium lands of village Chamua during 2011 to 2015

Varieties (No of farmers)	Mean yield (kg ha^{-1})					
	2011	2012	2013	2014	2015	Pooled
Basundhara (9)	3820	3850	3931	-	-	3867
Mohan (12)	-	3367	4020	3619	3800	3701
Mulagabhoru (15)	-	4175	4565	4593	4001	4344
TTB404(14)	-	3885	5008	4716	4353	4523
Pooled	3932	3701	4107	4053	3882	3947
CD (p = 0.05)	393.2	1662.3	748.3	975.3	1230.3	649.3
Farmers' varieties (mean)						2250

situations adverse effect of midseason or terminal dry spell can be avoided by replacing farmers' varieties with the short-duration and medium-duration high-yielding varieties, respectively.

3.4 Cope up with the delayed onset of monsoon through manipulation of sowing time

Though onset of monsoon in the village was delayed, the village received pre-monsoon rainfall to the tune of 544, 447, and 482 mm during 2011, 2012, and 2014, respectively. During pre-monsoon months, a good quantity of that rainfall was harvested in farm ponds of the village and was utilized for sowing of long-duration *sali* paddy varieties before third week of June.

Irrespective of interventions and farmers' practice, the grain yield of long-duration varieties cultivated in the village varied from 1050 to 5474, 3205 to 4858, and 3352 to 4351 kg ha^{-1} in Ranjit, Gitesh, and Moniram, respectively (Table 7). Irrespective of varieties and sowing times, highest and lowest grain yield of long-duration varieties were recorded during 2013 (4804 kg ha^{-1}) and 2011 (3562 kg ha^{-1}), respectively as in case of medium-duration varieties. Perusal of data revealed that the average grain yield of the varieties sown before third week of June was the highest in Ranjit (4958 kg ha^{-1}), followed by Gitesh (4508 kg ha^{-1}) and Moniram (4236 kg ha^{-1}). Grain yield in all the varieties reduced substantially when sowing was delayed beyond third week of June and percent reduction of grain yield as compared with normal sowing were 18.99, 24.81, and 43.07% in Moniram, Gitesh, and Ranjit, respectively. The net income was also decreased in all varieties if sowing was delayed beyond third week of June and the reduction in net income was the highest in Ranjit (70.6%) followed by Gitesh (41.1%), and Moniram (31.5%) as compared with the normal practice. The benefit-cost ratio of these long-duration varieties varied from 2.00 to 2.32 and 1.42 to 1.72 when they were sown before and after the third week of June, respectively.

The exceptionally poor grain yield of Ranjit (1050 kg ha^{-1}) during 2011, when sowing was forced to be delayed beyond 23 June, was probably due to exposure of tillering and reproductive growth stages of the variety as the rainfall activities in the village was greatly reduced from mid of August to the end of crop season. Moreover, in the same year, flowering stage of the variety under delayed sown condition was exposed to low daily minimum temperature (15.4 to 18.2 °C) which was detrimental as reported by Medhi (2016). Thus, during first crop season (2011), long-duration variety transplanted in the village were not only affected by multiple dry spells, but also affected by low temperature stress.

Table 7 Performance of long-duration high-yielding varieties of rice under improved practice (IP) and farmers' practice (FP) at Chamua village during 2011, 2013, and 2014

Varieties	Yield (kg ha^{-1})								Decrease in yield (mean of 3 years) (%)	Net returns (mean of 3 years) (Rs ha^{-1})		B:C ratio	
	Sowing within 3rd week of June (IP)				Sowing after 3rd week of June (FP)								
	2011	2013	2014	Mean	2011	2013	2014	Mean		IP	FP	IP	FP
Ranjit	4810	5474	4589	4958	1050	3971	3445	2822	43.07	28,241	8312	2.32	1.42
Gitesh	4080	4587	4858	4508	-	3206	3574	3390	24.81	23,741	13,992	2.11	1.70
Moniram	-	4351	4120	4236	-	3510	3352	3431	18.99	21,021	14,402	2.00	1.72
Mean (kg ha^{-1})	4445	4804	4522	4590	1050	3562	3457	3214	41.41	24,561	12,232	2.15	1.61

It is obvious that grain yield of long-duration varieties was reduced considerably due to delay in sowing beyond third week of June. In addition to it, adverse impact of delayed sowing was further amplified by the additive impact of midseason or terminal dry spells. However, the adverse effect of delayed sowing on long-duration varieties could be overcome by making interventions of utilizing harvested pre-monsoon rainfall in farm ponds for sowing of these varieties on time within third week of June. Alternatively, if sowing is not possible in time, long-duration varieties may be replaced with medium or short-duration varieties as the case may be.

4 Conclusion

The increased frequency of intermittent dry spells during *sali* rice growing season is the major weather risk causing extensive damage to *sali* rice in the NBPZ of Assam. The significant decreasing trends of annual and monsoon rainfall, coherent decreasing trends of monthly rainfall from June to October and significant increasing rainfall variability in June, September and October are the reflection of shift in rainfall behavior during the crop growing period. However, impact of such dry spells can be reduced through contingency planning of selecting appropriate varieties suitable to prevailing land situations. Intermittent dry spell can be effectively managed by replacing long-duration high-yielding or traditional rice cultivars with high-yielding short and medium-duration varieties for upland and medium lands, respectively. Though intermittent dry spells did not affect long-duration varieties of rice under low land situation, grain yield of these cultivars reduced substantially when sowing was delayed beyond third week of June. The adverse impact of delayed onset of monsoon on these varieties could be ameliorated either by completing sowing within third week of June by utilizing rain water harvested during pre-monsoon months or growing alternate varieties.

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