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Heritable variation and trait relatedness in smooth gourd (*Luffa cylindrica* L.) genetic resources of Assam

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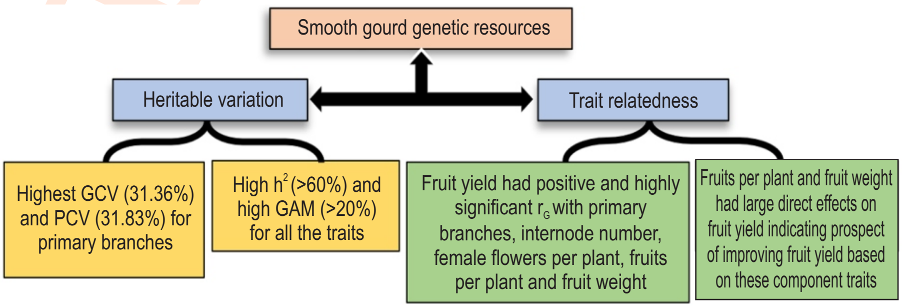
Abstract

Aim: The North-Eastern Region (NER) of India is endowed with enormous variability in genetic resources of smooth gourd. The present investigation was carried out to assess the hereditary variation and determine the trait relatedness in a collection of smooth gourd germplasm.

Methodology: The experiment was conducted in a Randomized Complete Block Design with thirty-three smooth gourd germplasm consisting of thirty germplasm collected from Assam, two collected from Nagaland while another (Pusa Sneha) collected from IARI, New Delhi. Genetic variability parameters were estimated using standard statistical methodology.

Results: The percent estimates of both genotypic coefficient of variability (31.36) and phenotypic coefficient of variability (31.83) were found to be the largest in respect of primary branches per plant. Higher estimates of both heritability in broad sense (>60%) and genetic advance as per cent of mean (>20%) were observed for the traits. Marketable fruit yield per plant had highly significant positive correlation with the number of primary branches, internodes, female flowers and fruits per plant and the weight of fruit. At genotypic level, path analysis revealed large direct effects of fruits per plant and fruit weight on marketable fruit yield.



Interpretation: High h^2 coupled with high GAM observed for the characters substantiates that inheritance of these characters could largely be due to genes with additive effects. Simple selection methods such as mass selection without progeny testing would be efficient for improving the population with respect to such characters. Selecting plants having higher mean values for genetically correlated traits would enhance the marketable fruit yield.

Key words: Correlation, Heritability, Smooth gourd, Variability

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Introduction

Smooth gourd, also called sponge gourd or loofah [*Luffa cylindrica* L. (Roem.)], is a highly nutritive and appetizing vegetable. It is a monoecious cross-pollinated annual vine of family Cucurbitaceae with a slender stem and large yellow flowers. This crop has been cultivated for centuries in China, Japan, India, Indonesia and the Middle East. It is an important vegetable crop of tropical and subtropical regions of the world with its origin within these regions (Swarup, 2006; Zhang *et al.,* 2019; Wu *et al.,* 2020). The cultivation of smooth gourd has not yet gained success at commercial scale in India and is still considered an underutilized vegetable. In addition to its edible young and tender fruits with nutritional and medicinal attributes, the fibrous endocarp of matured fruit (rubbing loofah) is used by the people in USA, Japan, Korea and some other Asian countries (Dhillon *et al.,* 2020). Various studies have revealed that smooth gourd as a good source of carbohydrates, ascorbic acid and minerals like Mg, Ca, Na, K, Fe, Cu, Zn, and Mn (Oboh and Aluyor, 2009; Azeez *et al.*, 2013). Furthermore, the leaves, seeds, and fruits of sponge gourd have been used for the treatment of various diseases including inflammatory diseases, diarrhoea, and viral infections (Muthumani *et al.,* 2010; Khan, *et al.,* 2013; El-gengaihi *et al.,* 2015; Salam *et al.,* 2019).

Smooth gourd germplasm of India bear fruits of varying sizes ranging from few centimetres to one metre. Large variation in this crop is apparent for various qualitative and quantitative characters, *viz.,* number of lobes in leaves, fruit colour, fruit shape, flesh taste, fruit length, fruit diameter, vine length, fruits per plant and fruit yield. The exploitation of hybrid vigour in smooth gourd is meagre despite the availability of a wide spectrum of genetic variation in plant and fruit characters (Reddy *et al.,* 2019). Phenotypically diverse types are common in farmstead gardens and local markets of Assam reflecting a wide-ranging variability among the smooth gourd genetic resources of Assam. The published literature lacks variability and diversity analysis in the local smooth gourd germplasm of Assam. Assessing genetic variation in a crop is a prerequisite for improving the crop for a region. The evaluation of already available hereditary variation in a crop is important for formulating effective improvement strategies as the existing variability can be utilized to augment the productivity level of cultivars or germplasm (Khan *et al.,* 2016).

The coefficient of variation gives an idea of the extent of variability in the germplasm and helps to gauge and compare variation for different traits irrespective of units of measurement. Heritability in broad sense is the proportion of observed variation that is attributable to the genotype(s) and it is, thus, a degree of resemblance between parents and offspring. Genetic advance is deviation of mean phenotypic value between the progeny of selected parental plants and the entire parental generation before selection. Expected genetic advance expressed as percent of grand mean becomes independent of unit of measurement and is, thus, helpful to compare the expected response to selection for two different traits. Fruit yield is a complex polygenic trait which is highly influenced by environmental modifications. Selecting plants with higher number and size of fruits, higher primary branches and higher mean values of many component traits will give high yielding progenies if fruit yield is correlated to all these secondary traits. It is also possible that selection may be exerted on secondary traits that have greater heritability than the primary trait of importance (Hallauer and Miranda, 1988). Thus, a picture on nature and extent of relatedness of fruit yield with a number of other corollary component traits is necessary in smooth gourd improvement programme. Correlation coefficient reflects the degree of relatedness between any two traits while the path coefficient analysis partitions a correlation coefficient into one direct effect and various indirect effects of independent traits on the dependent variable (Diz *et al.,* 1994; Mihretu *et al.,* 2014).

Magnitude and direction of direct and indirect effects of independent variables guide the researchers to decide which out of several possible interrelationships matter the most, and which might turn out to be not desirable at all. Thus, magnitude and nature of various biometrical parameters, *viz.,* genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense (h^2), expected genetic advance as percent of mean (GAM), genotypic correlation coefficient (r_G) and phenotypic correlation coefficient (r_P) and direct as well as indirect influences of independent traits are all important in a breeding programme designed to improve fruit yield in smooth gourd. Considering the view points specified above, the present investigation was undertaken to assess the heritable variation in indigenous smooth gourd genetic resources of Assam and to determine the relatedness among various productivity traits, including marketable fruit yield.

Materials and Methods

The present investigation was conducted at the Krishi Vigyan Kendra, Jorhat Farm of Assam Agricultural University during *Kharif* 2018. The smooth gourd experimental materials consisted of 30 germplasm collected from various districts of Assam, 2 germplasm from Phek districts of Nagaland and an improved variety, Pusa Sneha, from IARI, New Delhi. Ploughing, harrowing and leveling operations were performed to bring the experimental land to a fine tilth. The experiment was laid with two replications in a Randomized Complete Block Design (RCBD). In each replication, individual plot size for each germplasm was represented by single row accommodating seven plants with a planting distance of 2.0 m x 1.2 m. Mounds 15-20 cm high were prepared and, on each mound, 4-6 seeds were sown at a depth of 2-3 cm during March. One vine was retained in each mound by thinning when the seedlings reached a height of 10-15 cm. All the vines were provided support with bamboo poles for climbing. Observations on quantitative as well as qualitative traits *viz.,* number of primary branches, internode length (cm), days to appearance of first male flower, days to appearance of first female flower, internode number, vine length (m), number of nodes at which first female flower appears, days to first fruit harvest, fruit length (cm), fruit diameter (cm), female flowers per plant, fruits per plant, fruit weight (g), male-female flower ratio and marketable fruit yield per plant (kg) were noted by sampling four plants in each germplasm in each replication and the plants were tagged. The variable values of four plants for a particular character for a germplasm in a replication were used to work out the average for the character for that germplasm in that replication. Genetic variability parameters *viz.,* GCV, PCV, h^2, GAM, r_G and r_P were all estimated by standard statistical procedures from replicated data in RCBD. Path coefficient analysis was performed by the procedure given by Dewey and Lu (1959). Each of the estimates of aforementioned parameters were categorized into various classes using the classification suggested by Sivasubramanian and Madhavamenon (1973) for GCV and PCV, Johnson *et al.* (1955) for h^2 and GAM, and Lenka and Mishra (1973) for direct and indirect effects.

Results and Discussion

Analysis of variance revealed highly significant genotype mean square for each of the characters under study. This indicated that there was significant variation among the entries and it substantiated good scope for selection of agronomically superior germplasm. The grand means and ranges (shown within parentheses) for various growth characters *viz.,* primary branches per plant, internode length, internode number, vine length, node number at which first female flower appeared and female flowers per plant were 4.3 (1.8-8.4),16.2 cm (10.6-23.2 cm), 41.2 (31.0-54.0), 6.5 m (4.6-8.1 m), 13.3 (10.1-17.7) and 12.5 (8.7-16.0), respectively (Table 1).The mean values observed for three phenological characters *viz.,* days to appearance of first male flower, days to appearance of first female flower and days to first fruit harvest were 58.0, 63.0 and 79.0 with ranges 41-73 days, 45-78 days and 60-95 days, respectively. Similar study was conducted by Truong *et al.* (2017) in sponge gourd inbred lines in Vietnam and worked out the mean performances and ranges for various growth and fruit traits. In the present study, the mean values along with the ranges (within parentheses) for fruit length, fruit diameter, fruits per plant, individual fruit weight, male-female flower ratio and marketable fruit yield per plant were 29.6 cm (14.3-48.6), 6.0 cm (4.6-8.6), 8.0 (5.3-11.0), 338 g (256-492), 7.33 (6.0-9.5) and 2.69 kg (1.40-5.00), respectively. Phan *et al.* (2015) and Choudhary *et al.* (2016) also reported wide range of mean performances for few sponge gourd traits.

The magnitude of genotypic coefficient of variability (GCV) was smaller than the corresponding phenotypic coefficient of variability (PCV) for all the characters under study. It indicated that the expression of genotypes for each character was influenced by the environmental factors. Similar observations were also reported for fruit yield, fruit length, vine length, fruits per plant and fruit weight in sponge gourd by Som *et al.* (2020b). High estimates of GCV (>20%) were exhibited by three characters namely, primary branches (31.36%), fruit length (28.92%) and marketable fruit yield per plant (26.41%). It indicated that considerable improvement on smooth gourd could be made through selection for these characters in positive direction. For PCV, high values (>20%) were observed for four characters, *viz.,* primary branches (31.83%), fruit length (29.01%), marketable fruit yield (28.79%) and internode length (21.83%). High GCV and PCV values reported by Pandey *et al.* (2012) for fruit length in sponge gourd supports the above results. Further, Ananthan and Krishnamoorthy (2017) obtained high GCV and PCV in ridge gourd for fruit yield per plant and fruit length. Higher magnitude of GCV revealed a greater extent of heritable variability among the genotypes for these characters suggesting enough room for improvement through selection.

In the present investigation, all the characters under study exhibited high h^2 values (>60%). Heritability estimate was the highest (99.4%) in case of both days to appearance of first male flower and fruit length and it was the lowest (66.8 %) in case of vine length. High heritability indicates that phenotype of progeny is a direct reflection of the genotype of the parent and that

Table 1: Coefficients of variation, heritability and genetic advance for different quantitative traits in smooth gourd of Assam

Traits	Grand Mean	Range	GCV (%)	PCV (%)	h^2 (%)	GAM (%)
Primary branches	4.3	1.8 - 8.4	31.36	31.83	97.10	63.65
Internode length (cm)	16.2	10.6 – 23.2	19.18	21.83	77.10	34.70
Days to appearance of first male flower	58.0	41-73	16.04	16.09	99.40	32.94
Days to appearance of first female flower	63.0	45-78	14.34	14.44	98.60	29.33
Internode number	41.2	31.0-54.0	15.88	16.90	88.30	30.73
Vine length (m)	6.5	4.6-8.1	12.04	14.72	66.80	20.27
Node number at which first female flower appears	13.3	10.1-17.7	17.54	17.79	97.20	35.62
Days to first fruit harvest	79.0	60-95	11.83	11.93	98.20	24.14
Fruit length (cm)	29.6	14.3-48.6	28.92	29.01	99.40	59.39
Fruit diameter (cm)	6.0	4.6-8.6	12.57	13.14	91.60	24.79
Female flowers per plant	12.5	8.7-16.0	13.88	14.52	91.40	27.35
Fruits per plant	8.0	5.3-11.0	16.28	17.39	87.70	31.41
Fruit weight (g)	338	256-492	15.52	18.98	66.90	26.15
Male-female flower ratio	7.33	6.0-9.5	10.96	12.21	80.50	20.25
Marketable fruit yield per plant (kg)	2.69	1.40-5.00	26.41	28.79	84.20	49.92

Table 2: Genotypic and phenotypic correlation coefficients among fruit yield and its component traits in smooth gourd of Assam

Traits	Correlation coefficients	Internode length	Days to appearance of first male flower	Days to appearance of first female flower	Internode number	Vine length	Node number at which first female flower appears	Days to first fruit harvest	Fruit length	Fruit diameter	Female flowers per plant	Fruits per plant	Fruit weight	Male-female flower ratio	Marketable fruit yield per plant
		2	3	4	5	6	7	8	9	10	11	12	13	14	15
1[£]	r_P	-0.330	-0.222	-0.267	0.507**	0.094	-0.283	-0.254	0.437*	-0.233	0.426*	0.655**	0.238	-0.137	0.565**
	r_G	-0.411*	-0.224	-0.270	0.557**	0.077	-0.286	-0.258	0.445**	-0.272	0.443*	0.704**	0.255	-0.153	0.601**
2	r_P		0.061	0.114	-0.727**	0.637**	-0.056	0.115	-0.115	0.020	-0.536**	-0.497**	-0.408*	0.299	-0.622**
	r_G		0.066	0.113	-0.759**	0.588**	-0.082	0.137	-0.129	-0.040	-0.640**	-0.660**	-0.591**	0.368*	-0.768**
3	r_P			0.983**	-0.338	-0.240	0.629**	0.967**	0.147	0.176	-0.028	-0.078	-0.456**	-0.034	-0.369*
	r_G			0.992**	-0.356*	-0.295	0.639**	0.979**	0.148	0.186	-0.034	-0.082	-0.560**	-0.025	-0.405*
4	r_P				-0.399*	-0.236	0.656**	0.988**	0.117	0.207	-0.052	-0.112	-0.508**	-0.031	-0.425*
	r_G				-0.409*	-0.295	0.670**	0.996**	0.120	0.214	-0.057	-0.132	-0.629**	-0.058	-0.476**
5	r_P					0.039	-0.195	-0.408*	0.017	-0.089	0.656**	0.676**	0.609**	-0.385*	0.859**
	r_G					0.062	-0.198	-0.435*	0.017	-0.056	0.704**	0.821**	0.835**	-0.412*	1.044**
6	r_P						-0.312	-0.245	-0.117	-0.145	0.002	0.040	0.034	-0.048	0.016
	r_G						-0.402*	-0.287	-0.143	-0.224	-0.046	0.050	0.065	-0.009	0.075
7	r_P							0.675**	0.118	0.153	-0.089	-0.070	-0.298	0.161	-0.265
	r_G							0.690**	0.120	0.151	-0.090	-0.084	-0.381*	0.190	-0.302
8	r_P								0.108	0.189	-0.077	-0.128	-0.505**	0.008	-0.438*
	r_G								0.109	0.199	-0.072	-0.148	-0.649**	-0.032	-0.501**
9	r_P									-0.517**	0.253	0.305	-0.132	-0.045	0.066
	r_G									-0.539**	0.267	0.331	-0.160	-0.054	0.074
10	r_P										-0.238	-0.231	0.082	0.065	-0.052
	r_G										-0.247	-0.295	0.054	0.065	-0.084
11	r_P											0.705**	0.197	-0.745**	0.572**
	r_G	-										0.840**	0.225	-0.818**	0.645**
12	r_P												0.152	-0.401*	0.683**
	r_G												0.148	-0.484**	0.746**
13	r_P													-0.108	0.787**
	r_G													-0.153	0.773**
14	r_P														-0.312
	r_G														-0.394*

£, primary branches, r_P, phenotypic correlation coefficient, rG, genotypic correlation coefficient, ** 1% level of significance, * 5% level of significance the environmental influence on the genes is relatively small or negligible as the environmental variance (σ_e^2) is less than 0.66 times the genetic variance (σ_g^2) for high heritability (>60%) estimates.. Estimates of heritability throw light for resolving many issues which arise in a plant selection programmes. High h^2 was reported by Singh *et al.* (2019b) for primary branches, days to blooming of staminate flower, node number to blooming of first pistillate flower, vine length, fruit length, fruit diameter, fruits per plant, fruit weight and fruit yield in smooth gourd. All the characters under study showed high (>20%) GAM values as the genes for these traits were less influenced by environmental factors. The trait with the highest GAM (63.65%) was the primary branches per plant while the trait with the lowest GAM (20.25%) was the male-female flower ratio. The results of Singh *et al.* (2019b) corroborated these findings. All the quantitative traits under the investigation had both high h^2 and high GAM. It indicated that these traits were governed largely by genes with additive gene action. A genetically variable population could be improved with simple selection methods such as mass selection if such characters are chosen for selecting superior plants from a population. No progeny testing is suggested for improvement of population with respect to such characters. Singh *et al.* (2019b) reported high heritability and high genetic advance for node number at which first female flower appears, days to appearance of first male flower, vine length, primary branches, fruit diameter, fruit length, fruits per plant, fruit weight and marketable fruit yield per plant.

Phenotypic correlation coefficient (r_P) and genotypic correlation coefficient (r_G) (both being presented within parenthesis in a sequence below) were found highly significant between the marketable fruit yield per plant and the following traits: primary branches (0.565**, 0.601**), internode number (0.859**, 1.044**), female flowers per plant (0.572**, 0.645**), fruits per plant (0.683**, 0.746**) and fruit weight (0.787**, 0.773**) (Table 2). Selecting plants with higher values for number of primary branches, number of internodes, number of female flowers, number of fruits and weight of fruit would enhance the fruit yield of the progeny population. Truong *et al.* (2019) observed positive correlation of marketable fruit yield per plant with fruits per plant and fruit weight in sponge gourd. Strong positive correlations of fruit yield with both fruits per plant and fruit weight were observed in sponge gourd by Yadav *et al.* (2017) and Singh and Tiwari (2018). At phenotypic and genotypic levels, marketable fruit yield had significant to highly significant negative correlation coefficients with internode length (-0.622**, -0.768**), days to appearance of first male flower (-0.369*, -0.405*), days to appearance of first female flower (-0.425*, -0.476**) and days to first fruit harvest (-0.438*, -0.501**). Selecting plants with earliness in respect of anthesis of both male and female flowers and harvesting time of first fruit would improve the population for fruit yield. Previous studies have also supported that marketable fruit yield per plant had strong negative correlation with days to appearance of first pistillate flower (Khule *et al.,* 2011) and days to blooming of first staminate flower (Yadav *et al.,* 2017). At both phenotypic and genotypic levels, fruits per plant showed highly significant positive association with primary branches (0.655**, 0.704**), internode number (0.676**, 0.821**) and female flowers per plant (0.705**, 0.840**). Highly significant values of negative phenotypic and genotypic association of fruits per plant were observed with internode length ((-0.497**, -0.660**) and male-female flower ratio (-0.401*, -0.484**). These results (-0.497**, -0.660**) indicated that the plants having higher number of primary branches, higher number of shorter internodes, more number of female flowers and lower value of male-female flower ratio would also be high yielders. Kumar *et al.* (2019) reported that fruit yield had highly significant positive association with number of primary branches in sponge gourd. Fruit diameter showed highly significant negative correlation coefficients of -0.517** and -0.539** with fruit length at phenotypic and genotypic level, respectively. Days to first fruit harvest had highly significant positive phenotypic and genotypic correlations with days to appearance of first male flower (0.967**, 0.979**), days to appearance of first female flower (0.988**, 0.996**) and node number at which first female flower appears (0.675**, 0.690**). These results conform to the findings of Mahapatra *et al*. (2019) who reported that days to first fruit harvest had strong positive correlation with days to anthesis of first pistillate flowers in bottle gourd.

Node number at which first female flower appears exhibited highly significant positive correlation with days to appearance of first female flower at both phenotypic and genotypic levels with values of 0.656** and 0.670**, respectively. Highly significant positive correlation was found between days to appearance of first male flower and days to appearance of first female flower at both phenotypic (0.983**) and genotypic (0.992**) levels and these results were corroborated by Singh *et al.* (2019a). Internode number had highly significant positive phenotypic (0.507**) and genotypic correlation (0.557**) with primary branches while it had highly significant negative correlation with internode length at phenotypic (-0.727**) and genotypic (-0.759**) level. Highly significant positive phenotypic and genotypic correlations were observed between vine length and internode length with coefficients of 0.637** and 0.588**, respectively. Genetic correlation between any two traits results under any of the following conditions: (i) some, if not all, genes governing a quantitative trait are linked to some genes responsible for the inheritance of another quantitative trait, or (ii) some genes show pleiotropic effects for the both the traits or (iii) both the phenomena of genetic linkage and pleiotropy are involved (Falconer and Mackay, 1996). The role of both genotypic variability and environmental modification is, however, involved in the phenotypic correlation.

The characters which exhibited significant to highly significant positive genotypic correlation with marketable fruit yield per plant in the present investigation were subjected to genotypic path coefficient analysis. The results of path analysis revealed that fruits per plant and fruit weight were the two most important component characters of marketable fruit yield per plant as they showed large and positive direct effects. Fruit weight showed a positive and large direct effect of 0.472 on marketable fruit yield per plant. The highest positive direct effect of fruit weight on fruit yield was also reported by Singh and Tiwari (2018) and Kumar *et al.* (2013) in sponge gourd. The indirect effect of fruit weight on fruit yield via internode number was positive and moderate with a value of 0.245. Fruits per plant exhibited the highest and positive direct effect on marketable fruit yield with a value of 0.510 while it showed moderate value (0.240) of indirect effect on fruit yield via internode number. Khule *et al.* (2011) and Som *et al.* (2020a) reported that fruits per plant had positive direct effect on fruit yield in sponge gourd genotypes and it indicated that if the breeder selects plants with higher number of fruits the progeny would be high yielder.

The direct effect of female flowers per plant on fruit yield was low and negative (- 0.100) although fruit yield had highly significant positive correlation with female flowers per plant. This necessitated looking for the role of indirect effects of female flowers per plant via some other traits. It was observed that female flowers per plant had high and positive indirect effect via fruits per plant (0.429) while it had moderate and positive indirect effect via internode number (0.206). Partitioning of significant positive genetic correlation between internode number and marketable fruit yield revealed that the internode number had a positive and moderate direct effect (0.293). The indirect effects of internode number on fruit yield via fruits per plant and fruit weight were large and positive with values 0.419 and 0.394, respectively. Further, indirect effect of primary branches on fruit yield via fruits per plant was positive and high (0.359). The residual of genotypic path analysis was 0.009 which amounted to 0.90%. This indicated that five independent variables considered in the genotypic path analysis *viz.,* primary branches, internode number, female flowers per plant, fruits per plant and fruit weight sufficiently covered 99.10% of total genetic variability observed in respect of marketable fruit yield. Genotypic path analysis revealed the importance of two most important secondary traits *viz.,* fruit weight and fruits per plant based on both their direct effects and indirect effects on marketable fruit yield per plant. High heritability of these two traits would also augment the correlated response in respect of fruit yield from selection. Thus, breeding work designed to effect improvement of fruit yield in smooth gourd will be rapid and comparatively simple if plants with higher number of fruits and large fruits are selected from population of variable genotypes.

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Add-on Information

Authors' contribution: I. Sarma, D.B. Phookan, L. Saikia and J. Saikia: Conceptualization of research; **I. Sarma, D.B. Phookan and L. Saikia:** Designing experiments; **I. Sarma, D.B. Phookan and R. Borgohain:** Contribution of experimental materials; **I. Sarma, R. Borgohain, D.B. Phookan and P. Kalita:** Execution of field/laboratory experiments and data collection; **I. Sarma, D.B. Phookan, N. Sarma Barua and A. Sarma:** Analysis of data and interpretation; **I. Sarma, D.B. Phookan and N. Sarma Barua:** Preparation of manuscript.

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