

## MORPHOLOGICAL CHARACTERIZATION OF GEOGRAPHICAL INDICATION LITCHI CROPS AND RELEASED VARIETIES GROWN IN BANGLADESH

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### Abstract

Four Geographical Indication litchi genotypes (GIs) viz., Kadmi Lichu, Mongalbari Lichu, Deshi/Ati/Rajshahi Local (BARI Lichu-1) and Bedana Lichu, and three released varieties viz., BARI Lichu-2, 3 and 4) were characterized morphologically during July 2012 to June 2013 with a view to identifying the degree of morphological and genetic variation of litchi within cultivars, and to establish a permanent database for documentation of litchi. Morphological characterization data were recorded from standing trees of the most concentrated areas of cultivation for GIs and the respective stations from where the variety was released viz., Kadmi from Sonargaon, Narayanganj; Mongalbari from Pakundia, Kishoreganj; Rajshahi Local from Mohanpur village of Shyampur union under Rajshahi district; Bedana from Masimpur, Dinajpur; BARI Lichu-2 and BARI Lichu-3 from RARS, Akbarpur and BARI Lichu-4 from BSPC, Debiganj. Historical background of geographical indication crops of litchi as described by aged people of their most concentrated areas of cultivation indicated that the cultivars were originated naturally in those areas. The cultivars were very location specific. They do not perform well in respect of yield and quality outside their areas of origin indicating their very narrow adaptability range. It was another indication regarding location of origin of the GI crops. On the other hand, the exotic cultivars grown in the country such as BARI Lichu-2, BARI Lichu-3 etc. possess country wide adaptability. Wide variations were observed among the GI crops and released varieties included in this study for plant, leaf, inflorescence, flower and fruit characters. Variation was also recorded in respect of incidence of biotic and abiotic stresses like insect pests, mites, diseases, sunburn, fruit cracking and fruit drop. Each GI/released variety possesses some unique characters, which distinguish it from all other genotypes.

Keywords: Litchi, characterization, geographical indication, released varieties.

### Introduction

The litchi (*Litchi chinensis*) is one of the major fruit crops in Bangladesh. It is a member of the family Sapindaceae. Litchi fruit is famous for its excellent quality, characteristic pleasant flavour and for attractive red colour. Olfert Dapper (1670) wrote that the tree in fruit seems to be decorated with 'purple hearts' which melt like sugar in the mouth and that rightly the litchi should be called 'the queen of

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fruits'. In Bangladesh, it is liked very much as a table fruit and the fruits are in great demand during the season which, however, is rather too short, lasting about one month during May to June. It is also used as an excellent canned fruit. It is admitted that the litchi is a native of the South China (very close to Bangladesh). From China litchi reached Eastern India first via Burma by the end of 17<sup>th</sup> century and thereafter by the end of 18<sup>th</sup> century, it was introduced to Bengal (Goto, 1960; Knight, 1980 and Liang, 1981). From Bengal it spread to other parts of India (Pandey and Sharma, 1989). Hence, it can be said that Bangladesh (the then Bengal) is the secondary centre of diversity for this species.

It is grown all over the country sporadically especially in homesteads. In some areas like Dinajpur, Rajshahi, Pabna, Kustia and Chittagong Hill Tracts litchi is grown commercially in small to medium orchards. In some pocket areas of Narayanganj (Sonargaon) and Kishoreganj (Pakundia), it is cultivated in mini orchard form and in homesteads. Area under litchi cultivation in Bangladesh in orchard form is about 1725 hectare and total production in inside and outside orchard is 64995 metric tons (BBS, 2011). Several local and exotic cultivars are grown in the country. The cultivars are mostly location specific. Bangladesh Agricultural Research Institute (BARI) has developed five improved varieties through selection. Some cultivars have been originated in some localities and are being cultivated in those areas from more than several hundred years, which can be termed as geographical indication crops (GIs) for those locality. It is essential to characterize the GIs and released varieties of litchi both in morphological and molecular level for establishment of Intellectual Property Rights (IPR). A project was undertaken by Bangladesh Agricultural Research Council (BARC) to characterize GIs and released varieties of some crops grown in the country with the financial support of Sponsored Public Goods Research - National Agricultural Technology Project (SPGR-NATP) Phase-1. BARI has been assigned with 10 of its mandated crops and litchi is one of them. Four GIs and three released varieties of litchi have been included in this programme for characterization at their morphological level. The present study was, therefore, undertaken to identify the degree of morphological and genetic variation of litchi within cultivars, and to establish a permanent database for documentation of litchi, which will ultimately facilitate establishment of IPR for GI crops of litchi.

## **Materials and Method**

### **Selection of trees for GI and released varieties**

Seven genotypes of litchi (four GI crops and three released varieties) were characterized morphologically under SPGR-NATP financed project entitled "Characterization of important plant genetic resources" during July 2012 to June 2013. Four GI crops viz., Kadmi Lichu, Mongalbari Lichu, Deshi/Ati/Rajshahi Local (BARI Lichu-1) and Bedana Lichu and three released varieties viz., BARI

Lichu-2, 3 and 4 was included in this programme. Morphological characterization data were recorded from standing trees. The centre of diversity or most concentrated area of cultivation of the respective GI was identified through discussion with experienced fruit scientists and Department of Agriculture Extension (DAE) Officials at district and upazila level. A team of scientists, involved in this programme, visited Sonargaon upazila of Narayanganj for Kadmi Lichu, Pakundia upazila of Kishoreganj for Mongalbari Lichu, Mohanpur village of Shyampur union under Rajshahi district for Deshi/Ati/Rajshahi Local (BARI Lichu-1), Masimpur village under Dinajpur Sadar upazila for Bedana Lichu, and located the targeted trees of selected GIs. Then three plants were selected in each location for each GI crop for data collection. Each plant was labeled with laminated paper sheet as plant number 1, 2 and 3 for each GI. For released varieties, the team visited Regional Agricultural Research Station, Akbarpur, Moulvibazar for BARI Lichu-2 and BARI Lichu-3; Breeder Seed Production Centre, Debiganj, Panchagarh for BARI Lichu-4 from where the varieties were developed. Discussing with the station heads and working scientific personnel, the original mother tree(s) (OMT) was identified and selected for data collection. In cases where there was only one OMT, daughter mother trees (DMT) were also selected for data collection. Each OMT and DMT was labeled as plant number 1, 2 and 3.

### **Recording historical background**

Scientists discussed with aged people of the growing areas to find out the historical background of the respective GIs of litchi. The team also located some very old trees (>100 years) as indicated by the nearby people and symptoms on the tree like canopy coverage, trunk circumference, extra-rough trunk surface and galls on trunk etc.

### **Management practices**

Farmers normally sell their crop as total plantation either in orchard or in homesteads just after harvest of the previous year's fruit. Then entire liability of the plantation goes to the traders. Management practices like pruning, weeding, irrigation, and fertilizer and pesticide application etc. were done by the traders. Chemical fertilizers like urea, TSP, MoP, gypsum etc. were applied at different rates. None of the traders used recommended doses of fertilizers. Pesticides as prescribed by the dealers or experienced traders were used indiscriminately even one or two days before harvesting especially for controlling fruit borer. All traders used to prune the mite infested top shoot during fruit harvesting. In the research stations application of fertilizers and other cultural practices like ploughing, weeding, irrigation, pruning etc. were done as per recommendation of BARI.

### **Observation, data collection and record keeping**

The selected trees were visited frequently at different stages of growth, flowering and fruiting. Passport information and morphological data in respect of plant, leaf, flower/inflorescence, fruit and stone characters were recorded following IPGRI Descriptors for Litchi (IPGRI, 2002) at appropriate time. A data collection book was prepared following IPGRI Descriptors prior to initiation of the programme. The photographs of the specific trait considered to be helpful for identification of the variety/cultivar were taken from each genotype at appropriate time of traits to compare the distinctness among them. Data related to distinctness in morphological traits were photographed on each of the seven litchi genotypes.

### **Results and Discussion**

#### **Historical background**

**1. Kadmi Lichu:** This cultivar of litchi is commercially cultivated in Sonargaon municipality area, and Mograpara and Bodyerbazar unions of Sonargaon upazila under Narayanganj district. It is also sporadically planted in homesteads of other areas of the upazila. A gentle man namely Amendra Sen planted the first plant of the cultivar in Panamgabtali village under Bodyerbazar union more than 120 years ago. Mr. Saroz Roy established an orchard more than 90 years ago in the same village taking air layerage from this plant. Later on this orchard got reputation in the name of his (Saroz Roy's) son as 'Sadhu's orchard'. The variety spread in other areas of the upazila from this orchard as 'Kadmi Lichu'. At present Hazi Abdul Latif Gazi, a resident of nearby village Haria Chaudhurypara is the owner of this orchard. His father bought this orchard in 1959. Hazi Md. Fazar Ali (more than 90 years old villager) described the history of Kadmi Lichu, which was supported by Hazi Abdul Latif Gazi (65 years).

**2. Mongalbari Lichu:** Cultivation of this variety was initiated from Mongalbaria village of Pakundia upazila under Kishoreganj district. Commercial cultivation of this variety is still concentrated in this village only. In recent days, some farmers of nearby villages started establishing orchard with this variety seeing its commercial potentiality. The variety was named as per name of the village, where it is commercially grown. There is a close relationship between initiation of cultivation of Mongalbari Lichu and establishment of Mongalbaria Kamil Madrasa. Moulvi Azim Khandaker established the Madrasa in 1802 a.c. and in the same year he planted the first plant of the variety in the Madrasa premises. Later on it has disseminated throughout the village at homestead level. Commercial cultivation was started about 40 years ago. Very large and aged plants were found during visiting the Mongalbaria village. Maulana Md. Toibuzzaman, Principal, Mongalbaria Kamil Madrasa described the history of Mongalbari Lichu. He also

mentioned that they are maintaining history of both Madrasa and Mongalbari Lichu.

**3. Rajshahi Local (Deshi) Lichu/BARI Lichu-1:** Rajshahi Local (Deshi) lichu is commercially cultivated in Rajshahi region (Rajshahi, Natore, Chapainawabganj and Pabna districts). Initiation of cultivation of the variety in this region could not be known. Some old plants (more than 100 years) were located in Mohanpur village of Shyampur union under Rajshahi district. Some old men of this area stated that they have been seeing the cultivation of the variety since childhood. Their father or grandfather planted those plants. Most of those plants died due to over age. Md. Shetar Uddin Mondal (about 90 years old) of Mohanpur village described the history of Rajshahi Local (Deshi/Ati) Lichu, which was supported by Md. Aizuddin (about 70 years old). It can be guessed from the statement of the old people that cultivation of Rajshahi Local (Deshi) Lichu has been initiated in this region more than 150 years ago. This cultivar has been released as BARI Lichu-1 in 1996.

**4. Bedana Lichu:** The general people of the locality confidently stated that cultivation of Bedana Lichu was initiated in Masimpur village under Dinajpur Sadar upazila. A 65 years old villager Md. Azhar Ali claimed that the first plant of the variety was planted by his father in the vicinity of his house more than 100 years ago. About 80 years old villager Md. Asim Uddin told that he has been observing this litchi since his childhood. Some aged plants were found in the village, which were seemed to be over 100 years old. The villagers stated that earlier the variety was called as Kancha Mitha Lichu as it was less sour at green stage. According to their statement, the variety was not much popular before 1980s because of poor bearing. Virtually the variety needs intensive care and nourishment. When litchi attained commercial importance, traders started applying fertilizer and irrigation to litchi orchards. Then it flourished as a quality variety having high yield and its demand increased rapidly, and the price went sky-high within very short time during early 1980s (from Tk.150 to 2000 per 1000 fruits). Based on its colour, seed size and high price someone compared it with pomegranate (which is termed as 'Bedana' in Bangla), and spontaneously the variety was named as 'Bedana Lichu.'

**5. BARI Lichu-2:** The variety has been selected from exotic germplasm and released in 1996 for cultivation in Bangladesh after a long time evaluation at the Regional Agricultural Research Station, Akbarpur, Moulvibazar. It is a late variety and is suitable for cultivation in eastern and north eastern region of the country.

**6. BARI Lichu-3:** The variety has been selected from exotic germplasm and released in 1996 for cultivation in Bangladesh after a long time evaluation at the Regional Agricultural Research Station, Akbarpur, Moulvibazar. It is a mid season variety and is suitable for cultivation all over the country.

**7. BARI Lichu-4:** The variety has been selected from several locally collected germplasm planted at the Breeder Seed Production Centre (BSPC), Debiganj, Panchagarh and released in 2008 as BARI Lichu-4 for cultivation in the north-western region of Bangladesh after a long time evaluation. Mr. Md. Abdul Quadir, the then Assistant Agronomist of the centre collected several local germplasm of litchi and planted in the farm during 1960s. Parentage and origin of the variety is unknown. It is assumed that this variety was evolved from chance seedling more than 100 years ago. Md. Asimuddin (100 years old), resident of nearby village Khaturia under Domar upazila of Nilfamari district (former master roll labour of the centre) described the history of BARI Lichu-4. It is a mid season variety and is adapted only in the north-western region of the country. Source of collection, name of collector and actual date of planting of original mother tree (OMT) could not be traced out.

Passport data, plant, leaf, inflorescence/flower, fruit and seed characteristics and incidence of pest and diseases recorded for the geographical indications and released varieties of litchi are presented in tables 1 to 7.

### **Plant characters**

Results presented in Table 2 revealed that litchi genotypes included in this study varied widely in respect of plant characters like tree vigour, trunk surface, crown shape, growth habit, branching density, branching pattern and young shoot pubescence. Tree vigour was high for GI crops and low or medium in exotic genotypes (BARI Lichu-2, 3). Rajshahi Local/BARI Lichu-1 had the maximum tree height (12.12 m) and trunk circumference (278 cm) while BARI Lichu-4 had the minimum tree height (5.50m) and BARI Lichu-3 had the minimum trunk circumference (82 cm). Crown diameter and tree volume were also maximum (16.56 m and 979.25 m<sup>3</sup>) in Rajshahi Local/BARI Lichu-1 and minimum (7.30 m and 99.70 m<sup>3</sup>) in BARI Lichu-3. Variations in quantitative plant characters (tree height, trunk circumference, crown diameter and tree volume) might be due to both genetic behaviour of the genotypes and tree age. Trunk surface was rough in all the genotypes except BARI Lichu-2, which possesses smooth trunk surface. Rajshahi Local/BARI Lichu-1 had distinct crown shape (irregular) as against semi-circular crown shape in other genotypes. Tree growth habit was semi-erect in five genotypes while that in Mongalbari and Bedana was erect. Branching was dense in four genotypes and medium dense in the remaining three genotypes. Branching pattern was irregular in all the genotypes. This might be due to vegetative propagation of the trees through air layering. Only BARI Lichu-2 had glabrous young shoot. That of other genotypes was pubescent. Khurshid *et al.* (2004) recorded wide variation among litchi cultivars for canopy spread and tree shape, Miao *et al.* (1998) and Rai *et al.* (2001) recorded wide variation for tree height. The results are in accordance with the findings of present investigation.

Table 1. Passport data of geographical indications and released varieties of litchi grown in Bangladesh

Character	Cultivar	Kadmi Lichu	Mongalbari Lichu	Rajshahi Local	Bedana Lichu	BARI Lichu-2	BARI Lichu-3	BARI Lichu-4
Collecting Institute	BARI	BARI	BARI	BARI	BARI	BARI	BARI	BARI
Country of origin	Bangladesh	Bangladesh	Bangladesh	Bangladesh	Bangladesh	-	-	Bangladesh
Name of farmer	Hazi A. Latif Gazi	Mukhlesur Rahman	Md. Alaluddin	Mohammed Azhar Ali	CSO, RARS, Akbarpur, Moulvibazar	CSO, RARS, Akbarpur, Moulvibazar	CSO, RARS, Akbarpur, Moulvibazar	CSO, BSPP, Debiganj, Panchagarh
Location of collecting site	Vill: Panamgabtali UP: Bodyerbazar, Uz: Sonargaon Dist: N'ganj	Vill: Mongalbaria UP: Pakundia, Uz: Pakundia, Dist: K'ganj	Vill: Mohanpur, UP: Harian, Uz: Motihar, Dist: Rajshahi	Vill: Masimpur, UP: Auliapur, Upazila: Sadar Dist: Dinajpur	RARS, Akbarpur, Moulvibazar	RARS, Akbarpur, Moulvibazar	RARS, Akbarpur, Moulvibazar	BSPP, Debiganj, Panchagarh
Latitude of the site	23°39.660'N	24°19.428'N	24°21.096'N	25°34.46'N	24°25.892'N	24°25.892'N	24°25.892'N	26°15.270'N
Longitude of the site	90°37.077'E	90°41.244'E	88°48.675'E	88°37.55'E	91°45.692'E	91°45.692'E	91°45.692'E	88°51.311'E
Commercial value	High	High	High	High	High	High	Very high	Very High
Cultivation practices	Homestead & commercial orchard	Homestead & commercial orchard	Homestead & commercial orchard	Homestead & commercial orchard	Homestead & commercial orchard	Homestead & commercial orchard	Homestead & commercial orchard	Homestead & commercial orchard
Area coverage	30 ha	40 ha	328 ha	-	-	-	-	-

Table 2. Plant characters of geographical indications and released varieties of litchi grown in Bangladesh

Character	Cultivar	Kadmi Lichu	Mongalbari Lichu	Rajshahi Local	Bedana Lichu	BARI Lichu-2	BARI Lichu-3	BARI Lichu-4
Tree age		90 yrs	42 years	> 80 years	>100 years	> 50 years	> 50 years	50 years
Tree vigour		High	High	High	High	Medium	Low	High
Tree height		7.20 m	11.41 m.	12.12 m	10.26 m	6.67 m	6.35 m	5.50 m
Trunk circumference		189 cm	197 cm	278 cm	156 cm	110 cm	82 cm	170 cm
Trunk surface		Rough	Rough	Rough	Rough	Smooth	Rough	Rough
Crown diameter		9.13 m	12.03 m	16.56 m	9.83 m	8.24 m	7.30 m	11.0 m
Tree volume		176.84 m <sup>3</sup>	486.50 m <sup>3</sup>	979.25 m <sup>3</sup>	292.09 m <sup>3</sup>	133.43 m <sup>3</sup>	99.70 m <sup>3</sup>	195.91 m <sup>3</sup>
Crown shape		Semi-circular	Semi-circular	Irregular	Semi-circular	Semi-circular	Semi-circular	Semi-circular
Tree growth habit		Semi-erect	Erect	Semi-erect	Erect	Semi-erect	Semi-erect	Semi-erect
Branching density		Medium	Dense	Dense	Medium	Medium	Dense	Dense
Branching pattern		Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular
Young shoot pubescence		Pubescent	Pubescent	Pubescent	Pubescent	Glabrous	Pubescent	Pubescent

Table 3. Leaf characters of geographical indications and released varieties of litchi grown in Bangladesh

Character	Cultivar	Kadmi Lichu	Mongalbari Lichu	Rajshahi Local	Bedana Lichu	BARI Lichu-2	BARI Lichu-3	BARI Lichu-4
Young leaf colour		Pinkish green	Yellowish green	Yellowish green	Purple	Purple	Purple	Pinkish green
Mature leaf colour		Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green
No. of leaflet per leaf		6.00	7.00	6.50	7.00	6.33	4.33	6.00
Arrangement of leaflets		Opposite	Alternate	Both alternate and opposite	Both alternate and opposite	Both alternate and opposite	Opposite	Both alternate and opposite
Rachis length		8.48 cm	10.23 cm	13.93 cm	7.8 cm	7.17 cm	6.47 cm	6.90 cm
Petiole length		0.65 cm	0.73 cm	0.70 cm	0.43 cm	0.93 cm	0.67 cm	0.63 cm
Leaf blade length		13.90 cm	10.39 cm	15.13 cm	12.73 cm	11.03 cm	14.57 cm	9.73 cm
Leaf blade width		4.45 cm	3.83 cm	4.33 cm	2.64 cm	5.33 cm	4.73 cm	2.63 cm
Leaflet blade shape		Elliptic	Elliptic	Elliptic	Elliptic	Elliptic	Elliptic	Oblong
Leaflet apex shape		Acuminate	Acuminate	Acuminate	Acute	Acuminate	Acute	Acute
Leaflet base shape		Cuneate	Attenuate	Cuneate	Attenuate	Cuneate	Cuneate	Attenuate
Leaflet upper surface pubescence		Absent	Absent	Absent	Absent	Absent	Absent	Absent
Leaflet lower surface pubescence		Absent	Absent	Absent	Absent	Absent	Absent	Absent
Leaflet midrib appearance		Prominent	Prominent	Prominent	Slightly prominent	Slightly prominent	Prominent	Prominent
Leaflet venation appearance		Slightly prominent	Slightly prominent	Slightly prominent	Not prominent	Slightly prominent	Slightly prominent	Not prominent
Leaflet curvature		Curve down slightly at top	Curve upward from midrib	Curve upward from midrib	Curve down slightly at top	Curve upward from midrib	Curve upward from midrib	Curve down slightly at top
Date of initiation of new flushes		Oct.-Nov.	Oct.-Nov.	Sep.- Oct.	Oct.-Nov.	Sep.-Oct.	Sep.-Oct., Dec.-Jan.	Oct.-Nov.
Protuberance on petiole		Present	Present	Present	Absent	Absent	Absent	Present

### **Leaf characters**

Wide variation was observed among the genotypes in respect of all the leaf characters recorded except mature leaf colour, leaflet upper surface pubescence and leaflet lower surface pubescence (Table 3). Young leaf colour was yellowish green in Mongalbari and Rajshahi Local, and purple in other genotypes except Kadmi and BARI Lichu-4 having pinkish green leaf. Singh *et al.* (1999) noted that litchi cultivars can be distinguished on the basis of young leaf colour. Number of leaflets per leaf ranged from 4.33 in BARI Lichu-3 to 7.00 in Mongalbari and Bedana. Leaflets were arranged in opposite, alternate or both opposite and alternate modes. Rachis length was maximum (13.93 cm) in Rajshahi Local and minimum (6.47 cm) in BARI Lichu-3. BARI Lichu-2 had maximum (0.93 cm) and Bedana had minimum (0.43 cm) petiole length. Leaf blade length varied from 9.73 cm in BARI Lichu-4 to 15.13 cm in Rajshahi Local while leaf blade width varied from 2.63 cm in BARI Lichu-4 to 5.33 cm in BARI Lichu-2. BARI Lichu-4 showed distinctness in leaflet blade shape (oblong). Leaf blade shape was elliptic in other genotypes. Leaflet apex shape was acute or acuminate while Leaflet base shape was Cuneate or Attenuate. Protuberance on petiole was present in four genotypes (Kadmi, Mongalbari, Rajshahi Local and BARI Lichu-4) and absent in the remaining three genotypes. Wide variation among litchi cultivars for leaf length, leaf shape, young leaf colour and number of leaflets per leaf was also reported by Khurshid *et al.* (2004).

### **Inflorescence and flower characters**

As per opinion of farmers and scientific staff engaged in farm management, first flowering occurred 3-4 years after planting in most of the genotypes (Table 4). Only BARI Lichu-2 flowered earlier (1-2 years). Panicle emerged during mid to late January in four genotypes but in Bedana, BARI Lichu-2 and BARI Lichu-4 it emerged in early February. Panicle emergence continued up to mid or late February, and in some cases (BARI Lichu-2, 3, 4) up to early March. According to Khurshid *et al.* (2004) environment profoundly influenced cultivar characteristics. So, variation in the time of panicle emergence might be due to varietal character or variation in weather condition among the locations. Mainly three types of flowers were observed in all the genotypes viz. male, functional male and functional female (Pandey and Sharma, 1989). Male or staminate flowers can easily be distinguished by the absence of pistil. The filaments in this type of flower varied in length. The functional female flowers strongly resembled the hermaphrodite flowers with 5-8 contabescent stamens and one bicarpeliate pistil. In functional male flower both pistil and stamens were present but the pistil was non-functional as the lobes of the stigma did not open to permit the entrance of the pollen. These three types of flowers were observed in all the seven genotypes studied.

Table 4. Inflorescence and flower characters of geographical indications and released varieties of litchi grown in Bangladesh

Character	Cultivar	Kadmi Lichu	Mongalbari Lichu	Rajshahi Local	Bedana Lichu	BARI Lichu-2	BARI Lichu-3	BARI Lichu-4
Flowering precocity		3-4 yrs	3-4 yrs	3-4 yrs	3-4 yrs	1-2	3-4 yrs	3-4 yrs
Panicle duration		Late Jan. to late Feb.	3 <sup>rd</sup> week of Jan. to 3 <sup>rd</sup> week of Feb	Mid Jan. to mid Feb.	Early Feb. to late Feb.	2 <sup>nd</sup> week of Feb. to 2 <sup>nd</sup> week of Mar.	Late Jan. to 1 <sup>st</sup> week of Mar.	Early Feb. to early Mar
Flowering duration (male)		Mid Feb. to late Feb.	3 <sup>rd</sup> week of Feb. to early Mar.	Early Feb. to mid Feb.	Late Feb. to Early Mar.	1 <sup>st</sup> week of Mar. to 3 <sup>rd</sup> week of Mar.	Late Feb. to early Mar.	Late Feb. to mid Mar.
Flowering duration (functional male)		Late Feb. to Late Mar.	Late Feb. to mid Mar.	Mid Feb. to mid Mar.	Early Mar. to Late Mar.	3 <sup>rd</sup> week of Mar. to 1 <sup>st</sup> week of Apr.	1 <sup>st</sup> week of Mar. to Late Mar.	Mid Mar. to early Apr
Flowering duration (functional female)		Early Mar. to Late Mar.	Early Mar. to Mid Mar.	Late Feb. to mid Mar.	Mid Mar. to Late Mar.	3 <sup>rd</sup> week of Mar. to 2 <sup>nd</sup> week of Apr.	1 <sup>st</sup> week of Mar. to late Mar.	Mid Mar. to early Apr
Position of inflorescence		Both terminal and axillary	Both terminal and axillary	Both terminal and axillary	Both terminal and axillary	Both terminal and axillary	Both terminal and axillary	Both terminal and axillary
Panicle stalk colour		Green	Light green	Light green	Light green	Green	Green	Green
Flower disk colour		Light yellow	Light cream	Yellow	Light cream	Light yellow	Light cream	Yellow
Flower size		Medium	Medium	Medium	Small	Small	Small	Medium
Inflorescence length		29.00 cm	37.00 cm	32.00 cm	29.00 cm	20.00 cm	21.00 cm	30.50 cm
Width of inflorescence		27.00 cm	24.00 cm	19.00 cm	15.00 cm	15.00 cm	14.00 cm	17.00 cm
Abundance of flower		Profuse	Profuse	Profuse	Moderate	Profuse	Moderate	Moderate

Male flowers opened and dried prior to opening of functional male and female flowers in all the genotypes. Synchronization was observed in anthesis of functional male and functional female flowers resulting successful pollination for fruit setting. Inflorescences were basically terminal in all the genotypes but simultaneously axillary inflorescences were also found. Inflorescence stalk colour was green or light green. Flower disk colour was light yellow in Kadmi and BARI Lichu-2, light cream in Mongalbari, Bedana and BARI Lichu-3. While that of Rajshahi Local and BARI Lichu-4 was yellow. Length of inflorescence ranged from 20.00 cm in BARI Lichu-2 to 37.00 cm in Mongalbari. Widest inflorescence (27.00 cm) was observed in Kadmi and the narrowest (14.00 cm) in BARI Lichu-3. Profuse flowers were borne by the local cultivars except Bedana while abundance of flowers was moderate in the released varieties except BARI Lichu-2 (profuse).

According to Menzel (1984), and Menzel and Simpson (1992), the flowers are in order of appearance, functionally male, functionally female and functionally male. Menzel (1983) reported that panicles were normally produced terminally in clusters, but in some trees a high percentage of axillary panicles may also be produced. Robbertse *et al.* (1995) observed that the apical bud of a modular branch produced one inflorescence. One or more of the lateral buds directly below the apical bud were also produced resulting in more than one inflorescence at the tip of a module. All the above results are in conformity with the results of present study.

### **Fruit characters**

Geographical Indications and released varieties included in this study showed wide variation for almost all the characters recorded in respect of fruits (Table 5). All the genotypes took 4-5 years for fruiting from planting except BARI Lichu-3 which took little longer time (5-6 years). Fruit setting was completed within March in all the genotypes. Kadmi took minimum time (60-65 days) from fruit set to maturity closely preceded by Mongalbari (60-70 days). Maximum time (75 days) was taken by Bedana and BARI Lichu-2. Harvesting duration was also very short for all the genotypes. Narrower variation in fruit set duration and time taken for maturity from fruit set with shorter harvesting duration resulted very short harvesting season for this fruit. As per opinion of the farmers and researchers all the genotypes are regular in bearing. Local cultivars (GIs) except Bedana are heavy bearer while released varieties are medium in bearing intensity. Rajshahi Local had maximum fruits per cluster (17.6) and BARI Lichu-3 had the minimum (3.5).

Fruit shape was oval in Kadmi; oblong in Mongalbari and Rajshahi Local; cordate in Bedana and BARI Lichu-3 and round in BARI Lichu-2 and BARI Lichu-4. Kadmi and BARI Lichu-3 had even fruit shoulder while the shoulder of the remaining genotypes was protruding. Shape of fruit tip was obtuse only in BARI Lichu-3, which distinguished it from other genotypes having round fruit

tip. Fruit segment was smooth in Kadmi and BARI Lichu-4. That of other genotypes was swelling type. Length of fruit ranged from 3.10 cm in BARI Lichu-3 to 3.67 cm in Mongalbari. BARI Lichu-4 produced the widest fruit (3.77 cm) and Rajshahi Local produced the narrowest (3.10 cm). Mongalbari, Bedana and BARI Lichu-4 were not prone to fruit cracking while in other genotypes fruit cracking was observed at various level. Colour of mature fruit was partially reddish yellow in Kadmi, BARI Lichu-2 and BARI Lichu-3; uniformly rosy red in Mongalbari; partially pinkish red in Rajshahi Local, and uniformly dark red in Bedana and BARI Lichu-4. The genotypes differed from each other in respect of shape and density of tubercles. Fruit suture was prominent in Kadmi, BARI Lichu-2 and BARI Lichu-4 while other genotypes had weak suture. BARI Lichu-4 had the maximum fruit (26.6 g) and aril (20.6 g) weight, and edible portion (77.44%). Fruit weight (18.0 g), aril weight (12.30 g) and edible portion (68.33%) was minimum in BARI Lichu-2. Total soluble solids content in fruit juice varied from 19.78% in Kadmi to 22.00% in BARI Lichu-4. Aril flavour was strong in Rajshahi Local and BARI Lichu-4, and intermediate in the other genotypes. Aril quality was very sweet for BARI Lichu-4, sour sweet for Kadmi and sweet for the remaining genotypes. Juicy aril was found in Kadmi, Rajshahi Local and BARI Lichu-2 while the aril of other genotypes was very juicy. Overall taste (eating quality) of Bedana and BARI Lichu-4 was excellent, and that of other genotypes was good to very good.

Pandey and Sharma (1989) reported that litchi fruits are produced in loose clusters of 2 to 20 or even more. The results are in consonance with the findings of the present study. Siddiqui (2002) categorized Rajshahi Local/BARI Lichu-1 as early, BARI Lichu-2 as late and BARI Lichu-3 as mid season variety. He also reported 19.5 g, 15.2 g and 18.4 g fruit weight, and 18.4 to 20.5%, 16.1 to 20.5% and 18.9 % total soluble solids content for BARI Lichu-1, BARI Lichu-2 and BARI Lichu-3, respectively which are in line with the results of present study.

### **Seed characters**

Variation was also noticed for shape, size and colour of seed (Table 6). Mongalbari produced the longest (2.49 cm) and widest (1.57 cm) seed while BARI Lichu-3 had the shortest (1.82 cm) and BARI lichu-2 had the narrowest (1.30 cm) seed. Individual seed weight was minimum (2.30 g) in BARI Lichu-3 closely preceded by BARI Lichu-2 (2.70 g) and BARI Lichu-4 (2.78 g). Maximum seed weight (4.00 g) was recorded in Mongalbari. Oval shaped seed was found only in BARI Lichu-3 while seed shape of other genotypes was oblong. Seed coat colour was dark brown in Kadmi and Mongalbari, dull brown in BARI Lichu-4 and brown in the remaining genotypes.

Table 5. Fruit characters of geographical indications and released varieties of litchi grown in Bangladesh

Character	Cultivar	Kadmi Lichu	Mongalbari Lichu	Rajshahi Local	Bedana Lichu	BARI Lichu-2	BARI Lichu-3	BARI Lichu-4
No. of yrs to 1 <sup>st</sup> fruiting from planting		4-5	4-5	4-5	4-5	4-5	5-6	4-5
Fruit set duration		2 <sup>nd</sup> week of Mar. to 3 <sup>rd</sup> week of Mar.	Early Mar. to 3 <sup>rd</sup> week of Mar.	Early Mar. to 3 <sup>rd</sup> week of Mar.	Mid Mar. to end of Mar.	Second week of Mar. to 3 <sup>rd</sup> week of Mar.	Second week of Mar. to 3 <sup>rd</sup> week of Mar.	Last week of Mar. to 1 <sup>st</sup> week of Apr.
No. of days from fruit set to maturity		60-65 days	60-70 days	65-75 days	75 days	75 days	70 days	65 to 75 days
Fruit maturity group		Early	Early	Early	Medium	Late	Medium	Medium
Fruit availability period		1 <sup>st</sup> week of May to 3 <sup>rd</sup> week of May	1 <sup>st</sup> week of May to 3 <sup>rd</sup> week of May	3 <sup>rd</sup> week of May to end of May	Last week of May to 1 <sup>st</sup> week of Jun.	1 <sup>st</sup> week of June to 3 <sup>rd</sup> week of Jun.	4 <sup>th</sup> week of May to end of May	1 <sup>st</sup> week of Jun. to 2 <sup>nd</sup> week of Jun.
Harvesting duration		2-3 weeks	2-3 weeks	2 weeks	2 weeks	1-2 weeks	1-2 weeks	2 weeks
Fruit ripening		Synchronous	Synchronous	Synchronous	Synchronous	Synchronous	Synchronous	Synchronous
Fruit bearing habit		Regular	Regular	Regular	Regular	Regular	Regular	Regular
Fruit bearing intensity		Heavy	Heavy	Heavy	Medium	Medium	Medium	Medium
Fruit clustering habit		Clusters	Clusters	Clusters	Clusters	Clusters	Clusters	Clusters
No. of fruits per cluster		10.5	12.3	17.6	9.0	4.5	3.5	6.0
Fruit shape		Oval	Oblong	Oblong	Cordate	Round	Cordate	Round
Fruit shoulder		Even	Protruding	Protruding	Protruding	Protruding	Even	Protruding
Shape of fruit tip		Round	Round	Round	Round	Round	Obtuse	Round
Fruit segment		Smooth	Swelling type	Swelling type	Swelling type	Swelling type	Swelling type	Smooth
Fruit length		3.63 cm	3.67 cm	3.52 cm	3.53 cm	3.41 cm	3.10 cm	3.56 cm
Fruit diameter		3.39 cm	3.15 cm	3.10 cm	3.48 cm	3.11 cm	3.24 cm	3.77 cm
Fruit cracking		Prone	Not prone	Prone	Not prone	Prone	Prone	Not prone

<b>Cultivar Character</b>	<b>Kadmi Lichu</b>	<b>Mongalbari Lichu</b>	<b>Rajshahi Local</b>	<b>Bedana Lichu</b>	<b>BARI Lichu-2</b>	<b>BARI Lichu-3</b>	<b>BARI Lichu-4</b>
Fruit skin thickness	Medium	Thin	Medium	Medium	Thick	Medium	Medium
Mature fruit colour	Reddish yellow	Rosy red	Pinkish red	Dark red	Reddish yellow	Reddish yellow	Dark red
Distribution of colour on fruit	Partial	Uniform	Partial	Uniform	Partial	Partial	Uniform
Shape of tubercles	Sharp pointed	Slightly pointed	Sharp pointed	Smooth	Obtuse	Smooth	Smooth
Tubercle density	Dense	Medium	Medium	Sparse	Medium	Sparse	Sparse
Presence of suture	Prominent	Weak	Weak	Weak	Prominent	Weak	Prominent
Fruit attractiveness	Good	Good	Good	Excellent	Good	Good	Excellent
Fruit weight	23.0 g	22.0 g	20.0 g	24.6 g	18.0 g	22.0 g	26.6 g
Aril weight	16.0 g	15.4 g	14.0 g	18.6 g	12.3 g	16.8 g	20.6 g
Skin weight	3.60 g	2.6 g	2.60 g	3.20 g	3.00 g	2.90 g	3.22 g
Seed weight	3.40 g	4.0 g	3.40 g	2.80 g	2.70 g	2.30 g	2.78 g
Skin content	15.65 %	11.82 %	13.00 %	13.01 %	16.67 %	13.18 %	12.11 %
Seed content	14.78 %	18.18 %	17.00 %	11.38 %	15.00 %	10.45 %	10.45 %
Edible portion	69.57 %	70.00 %	70.00 %	75.61 %	68.33 %	76.36 %	77.44 %
Aril thickness	Medium	Medium	Medium	Thick	Medium	Thick	Very thick
Aril texture	Fibrous	Soft	Crisp	Soft	Soft	Soft	Soft
Aril TSS	19.78 %	20.85 %	20.88 %	21.00 %	20.69 %	21.78 %	22.00 %
Aril flavour	Intermediate	Intermediate	Strong	Intermediate	Intermediate	Intermediate	Strong
Aril quality	Sour sweet	Sweet	Sweet	Sweet	Sweet	Sweet	Very sweet
Aril juiciness	Juicy	Very juicy	Juicy	Very juicy	Juicy	Very juicy	Very juicy
Aril colour	Dull white	Waxy white	Waxy white	Waxy white	Waxy white	Dull white	Dull white
Eating quality	Good	Good	Good	Excellent	Very good	Very good	Excellent

Table 6. Seed characters of geographical indications and released varieties of litchi grown in Bangladesh

Character	Cultivar	Kadmi Lichu	Mongalbari Lichu	Rajshahi Local	Bedana Lichu	BARI Lichu-2	BARI Lichu-3	BARI Lichu-4
Seed length		2.19 cm	2.49 cm	2.40 cm	2.09 cm	2.13 cm	1.82 cm	2.08 cm
Seed width		1.53 cm	1.57 cm	1.49 cm	1.43 cm	1.30 cm	1.47 cm	1.36 cm
Seed weight		3.40 g	4.00 g	3.40 g	2.80 g	2.70 g	2.30 g	2.78 g
Seed shape		Oblong	Oblong	Oblong	Oblong	Oblong	Oval	Oblong
Seed coat colour		Dark brown	Dark brown	Brown	Brown	Brown	Brown	Dull brown

Table 7. Incidence of biotic and abiotic stresses in GIs and released varieties of litchi grown in Bangladesh

Character	Cultivar	Kadmi Lichu	Mongalbari Lichu	Rajshahi Local	Bedana Lichu	BARI Lichu-2	BARI Lichu-3	BARI Lichu-4
<b>Biotic and Abiotic Stress Susceptibility</b>								
<b>Insect Pests/Mites</b>								
Fruit borer		Low	Low	Low	Low	Low	Low	Low
Bark eating caterpillar		Very low	Nil	Low	Low	Low	Low	Low
Trunk borer		Nil	Nil	Nil	Nil	Nil	Nil	Nil
Litchi mite		Very low	Very low	Very low	Low	Low	Medium	Medium
<b>Fungal Disease</b>								
Leaf spot		Low	Very low	Very low	Nil	Medium	Medium	Nil
Flower blight		Nil	Nil	Nil	Nil	High	Low	Nil
Fruit rot		Very low	Nil	Very low	Nil	Low	High	Nil
<b>Abiotic stress</b>								
Sunburn		Low	Very low	Very low	Very low	Low	Very low	Very low
Fruit cracking		Low	Very low	Very low	Very low	Low	Low	Very low
Fruit drop due to wind		Low	Low	Low	Low	Low	Very low	Very low

### **Incidence of biotic and abiotic stresses**

Incidence of biotic and abiotic stresses was recorded at varying level among the genotypes (Table 7). All the GIs and BARI Lichu-4 showed highly resistant to resistant reaction against all the stresses recorded under natural epiphytotic condition. But medium to high incidence of leaf spot, flower blight and fruit rot was recorded in BARI Lichu-2 and BARI Lichu-3.

### **Conclusion**

Historical background of geographical indications of litchi as described by aged people of their most concentrated areas of cultivation indicated that the cultivars have been originated naturally in those areas. The cultivars possess high commercial value and are being cultivated widely around their areas of origin. Every GI possesses some special characters, which it might gain from its habitat. Each genotype had some unique characters, which distinguished it from all other genotypes. Considering all characteristics, BARI Lichu-4 can be ranked as the best among the genotypes studied. Some of the GIs viz. Bedana and Rajshahi Local are located along the periphery of the country. Both Bangladesh and India can claim them as their own property. It is essential to give proper attention to establish legal rights on these invaluable wealth of the country. For identification of the degree of morphological and genetic variation of litchi within cultivars and establishment of Intellectual Property Rights (IPR), characterization at molecular level is essential. Immediate action should be undertaken to perform molecular characterization of the geographical indications and released varieties of litchi with ultimate goal to provide necessary information for establishment of IPR on the same.

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