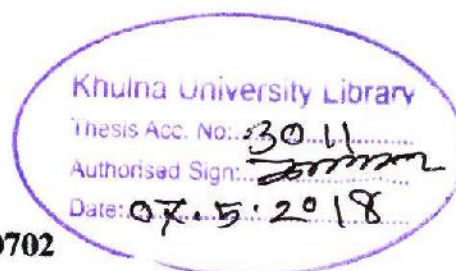


**EVALUATION OF PHYSICO-CHEMICAL AND GENETIC DIVERSITY OF
JACKFRUIT (*Artocarpus heterophyllus*) GERMPLASM AVAILABLE IN THE
SOUTH-WESTERN REGION OF BANGLADESH**



A Thesis By

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Examination Roll No: MS-090702
Session: 2008-2009



Submitted To

**Biotechnology and Genetic Engineering Discipline, Life Science School, Khulna
University, Khulna-9208, Bangladesh**
**in partial fulfillment of the requirement for the degree of Masters of Science
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**BIOTECHNOLOGY AND GENETIC ENGINEERING DISCIPLINE
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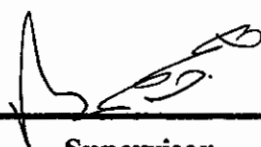
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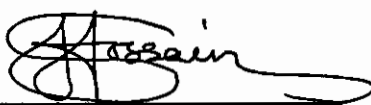
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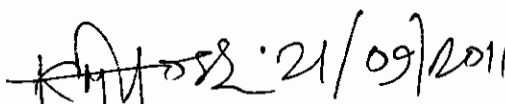
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JUNE 2011

DECLARATION

This thesis report is the original research work of the author, except as otherwise stated. The material presented has not submitted either in whole or in part for a degree for this or any other university. The findings of the research has not been/ will not be published anywhere without the concurrence of the concerned supervisor and co-supervisor.



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Student No: MS-090702

June 2011

*This thesis is dedicated to Khulna University and all its
happy student memories*

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EVALUATION OF PHYSICO-CHEMICAL AND GENETIC DIVERSITY OF JACKFRUIT (*Artocarpus heterophyllus*) GERMPLASM AVAILABLE IN THE SOUTH-WESTERN REGION OF BANGLADESH

Abstract

Jackfruit (*Artocarpus heterophyllus* Lam.) being highly cross pollinated crop possesses inestimable types with different fruit characteristics. The present study has attempted to account for the natural variability existing in physico-chemical and genetic characters of jackfruit germplasm (Gp) of the south-western region of Bangladesh. A significant variation in physico-chemical characters of jackfruit was observed among the 75 germplasm. In case of the physical traits, higher variability was observed for the characters like rachis weight (25.73 %), rachis length (11.65 %), skin weight (9.09 %), skin thickness (11.99 %) and spine length (8.13 %) while other parameters showed moderate variation. Of the biochemical characters, a high coefficient of variation was measured for ascorbic acid (13.86 %) and carotenoid (8.54 %) content. Moderate variation was observed for carbohydrate (5.27 %) and flavonoid (3.92 %) content while other parameters showed little variation. The highest (7.7 mg/100g) and the lowest (3.21 mg/100g) ascorbic acid content was recorded from Gp29 and Gp16, respectively while the highest and the lowest carotenoid was observed in Gp15 (0.787 mg/100g) and Gp35 (0.157 mg/100g), respectively. However, from the study of the genetic diversity of sixty jackfruit germplasm was measured by using four primers produced 33 unambiguous, readable and reproducible DNA bands. An average of 8.25 bands were obtained by using single primer, with the sizes ranging from 100 bp to 7.5k bp. Of the 33 bands, 21 (63.63 %) were polymorphic while 12 (36.63 %) were monomorphic in the sixty germplasm. The distance matrix data by UPGMA analysis and dendrogram showed the similarity between variants ranged from 60.4 to 98.3 % indicating their close relation. The lower genetic distance coefficient (<2 %) was found among Gp4, Gp5, Gp7, Gp20, Gp18, Gp19, Gp46 and Gp47, respectively. The dendrogram cluster analysis separated all the sixty germplasm into two clusters at 0.13 distance coefficient. The highest genetic distance coefficient (1.2 %) was between Gp24 and other germplasm under the multiple sub-clusters, indicating a diverse genetic relationship at a linkage distance of 1.0 %. Cluster 1 has only Gp24 while cluster 2 contained the remaining fifty nine germplasm separated into 2 sub clusters in which Gp53, Gp54 and Gp56 were in a clad. The lowest diversity value of 0.017 indicates high similarity between Gp7 and Gp20. The genetic distance index between Gp27 and Gp53 was highest with a value of 0.396. The present study showed high to moderate physico-chemical and low to moderate genetic diversity which are useful information to exert selection of jackfruit germplasm for crop improvement.

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1. INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* Lam.) belongs to the family Moraceae (Rowe-Dutton, 1985), is generally regarded as an underutilized fruit (Reddy *et al.* 2004) which is native to Western Ghats of India (Jagadeesh *et al.* 2007) and the rainforests of Malaysia (Elevitch and Harley, 2006). It grows in Bangladesh, India, many part of Southeast Asia (Odoemelam, 2005), in the evergreen forest zone of West Africa (Burkill, 1997), and in northern Australia as well (Azad *et al.* 2007). It is locally named Kathal, one of the most popular and indigenous fruit crop as well as national fruit of Bangladesh. It is cultivated in Bangladesh from time immemorial and grown through out the country; usually in high land and homestead areas where rain or floodwater does not stand (Karim *et al.* 2008). There are 24925 hectares of land under jackfruit farming and producing 254660 tons of fruits annually (BBS, 2006) and in terms of production it ranks second among the fruit crops of Bangladesh. Indeed Bangladesh is a rich source of variable germplasm of jackfruit; primarily due to universal practice of seed propagation employed with this fruit (Mannan *et al.* 2005). In Bangladesh, it is commonly referred to as “poor man’s food” (Rahman *et al.* 1995) as it is cheap and plentiful during the season. It is one of the most drought tolerant, hardy fruit crop and traditionally it is a farmer’s household fruit. Owing to its numerous culinary uses and its availability in plenty during heavy monsoon rains (Reddy *et al.* 2004).

Morphologically Jackfruit is a medium-sized evergreen tree, typically reaching 8-25 m in height, and producing heavier yields than any other tree species, and bears the largest known edible fruit. The fruits are big, 22 to 90 cm long with diameter reaching 13 to 50 cm, and their weight ranges between 3 and 60 kg, when ripe. The pulp represents about 30% of the jackfruit weight and, due to the carotenoids presence, shows cream color, while the external fruit color varies from soft green to yellow (Jagadeesh *et al.* 2007). Flakes of ripe fruits are high in nutritive value; every 100 g of ripe flakes contains 287-323 mg potassium, 30.0-73.2 mg calcium and 11-19 g carbohydrates, 30 IU vitamin A and 0.25 mg thiamine for every hundred gram (Samaddar, 1985). The nutritious seeds are boiled or roasted and eaten like chestnuts, added to flour for baking, or cooked in dishes (Shyamamma *et al.* 2008). The unripe fruit has a great demand for use as a vegetable, while the ripe fruit is a good source of vitamin A and C and minerals (phosphorus, iron

and calcium). Besides their colorant properties, carotenoids are related to important functions and physiological actions, pro-vitamin A activity is the most known one. In addition, a positive role is found in prevention of several chronic degenerative diseases, such as cancer, inflammation, cardiovascular disease, cataract, age-related macular degeneration, among others (Stahl and Sies, 2005). Most of the parts of the plant, including the bark, roots, leaves and fruits have medicinal properties (Hakim *et al.* 2005; Arung *et al.* 2006). Hot water extract of mature jack leaves is recommended by ayurvedic and traditional medical practitioners as a treatment for diabetes mellitus (Coyne *et al.* 2005). An extract of jack leaves improves the glucose tolerance in normal human subjects and diabetic patients. Photochemical screening has revealed that the hot water extract contains flavonoids, leucoanthocyanins, anthocyanins and tannins as components (Chandrika *et al.* 2005). The jackfruit latex is reported to possess bacteriolytic activity.

The trees have a significant role in the preservation of the environment. They can be very effective in the amelioration of soils and prevention of soil erosion and are therefore an important component of sustainable development (Ghosh, 2000). The tree is also known for its durable timber, which ages to an orange or reddish brown color, with anti-termite properties. The leaves and fruit waste provide valuable fodder for cattle, pigs and goats. Jackfruit wood chips yield a dye, which is used to give the famous orange-red color to the robes of Buddhist priests (Craig and Harley, 2006). Jackfruit is gaining popularity even in the United States due to emerging ethnic and mainstream marketing opportunities (Schnell *et al.* 2001). Being highly cross pollinated and mostly seed propagated, the jackfruit has innumerable types or forms with different fruit characteristics. Innumerable variations in sweetness, acidity, flavour and taste are observed in jackfruit growing areas (Jagadeesh *et al.* 2010). Singh and Srivastava (2000) identified 18 clones of jackfruit as superior in various parts of eastern Uttar Pradesh of India based on physico-chemical qualities of fruits, bearing, and yield and fruit maturity. Jackfruit types with TSS and total sugar more than 25°Brix and 20 %, respectively were found suitable for dessert purpose (Mitra and Mani, 2000). Of the qualitative characters studied, TSS recorded more variability in the clones identified and it ranged from 24.8 to 40.5°Brix (Reddy *et al.* 2004). The total acidity in jackfruit is low (0.13% as citric acid) at ripe stage and it showed little change during ripening (Bhatia *et al.* 1955). The low acidity level and high free sugars are responsible for the sweet taste of jackfruit.

Despite numerous advantages, the popularity of jackfruit as a commercial crop is very poor owing to wide variations in fruit quality, the long seed dormancy and the widespread belief that excessive consumption of jackfruit flakes leads to certain digestive ailments (Samaddar, 1985). Jackfruit is not easy to eat of hand owing to difficulty in separating fruit bulbs from rind (Jagadeesh *et al.* 2007). It gives more yields per tree than most of the fruit crops but is still not classified as a commercial fruit and is rarely grown on regular plantation scale. The popularity of jackfruit as a commercial crop is very meager due to wide variation in fruit quality. Jackfruit comprises innumerable trees differing from each other in fruit characteristics such as shape, size and quality. These types may be further divided depending on size of fruit, taste, odour of flesh, nature, shape and diversity of prickles on the rind for the maintenance of separate varieties (Singh, 1995).

However, several studies have reported diversity in jackfruit, but they were based mainly on morphological characteristics (Jagadeesh *et al.* 2007). There are no well-defined varieties in specific localities; local varieties have different names based on their variability in yield, fruit shape, flake color, total sugars, and so on. Cultivar identification and estimation of genetic diversity using morphological data are limited, as they are environmentally influenced, and there are few distinctive characters (Cavagnaro *et al.* 2006). Markers aided by polymorphisms in proteins and DNA structures have reduced the disadvantages of morphological markers to some extent (Sensoy *et al.* 2007), because they are unaffected by environmental factors (Dhanaraj *et al.* 2002). Jackfruit is a tetraploid; its somatic chromosome number is $(4n) 56$. Therefore, the basic chromosome number is 14 (Darlington and Wylie, 1956). Only two study until now by Schnell *et al.* (2001) and Shyamalamma *et al.* (2008) looked at the genetic diversity of 26 accessions from different parts of the world and 50 accessions from southern part of India, using amplified fragment length polymorphism (AFLP) markers, and provided an actual picture of diversity and genetic relatedness in jackfruit. The most recent study by Azad *et al.* (2007) looked at isozyme variation in jackfruit in Bangladesh. A total of 50 accessions were evaluated for four enzyme systems, and isozyme patterns were determined on the basis of number and position of bands. They discovered that morphological traits such as weight, length, girth of the fruits and percentage of pulp correlated poorly with environmental factors, suggesting that these characters are more likely genetically

controlled. However, isozyme markers are also known to be affected by both environment and post-translation modification, and their practical use is limited (Akashi *et al.* 2002).

To date, no one has made an attempt to estimate the genetic diversity of different jackfruit cultivars in Bangladesh. A comprehensive understanding of genetic diversity and molecular characterization of jackfruit cultivars is needed for formulating appropriate sampling and management strategies. A detailed analysis of a large number of genetic markers will provide us with useful gene conservation strategies and help in popularizing this species as a commercial crop. Cultivar identification and estimates of genetic diversity using phenotypic markers have several limitations, especially in perennial crops. Molecular differences, using DNA and protein-based markers are more authentic and unaffected by environmental factors. Hence, characterization of genotypes at the genetic level, supplemented by phenotypic characters, provides the first step towards more efficient conservation, maintenance, and utilization of existing genetic diversity. Among DNA based molecular markers, Random Amplified Polymorphic DNAs (RAPDs) provide an excellent tool for studying genetic diversity and genetic relationships (Simon *et al.* 2007).

Due to cross pollination and predominance of seed propagation over a long period of time, there is high degree of genetic diversity within the species as well as the jackfruit has innumerable types or forms with different fruit characteristics. Innumerable variations in sweetness, acidity, flavour and taste are observed in jackfruit growing areas. Such a wide diversity among jackfruit germplasm in the south-western region of Bangladesh, the home of jack in Bangladesh, offers tremendous scope for studying the variability and for improvement of this crop. This wide range of variation existing in nature aids in the selection of superior desirable types. In spite of its importance and possibilities of extended cultivation of this underutilized fruit in Bangladesh, not any work has been done so far on systematic characterization of the jackfruit quality of available genetic resources. In order to improvement the crop, it is imperative to study the physico-chemical and molecular variability in jackfruits. Therefore, the objectives of the present research are:

- I. to study the variability in physico-chemical properties of jackfruits available in south-western region of Bangladesh, and
- II. to estimate the genetic diversity in jackfruit germplasm using RAPD markers.

2. REVIEW OF LITERATURE

Jackfruit is a tropical fruit appears in the market in summer and consumed by all sector of community irrespective of age and gender. Though every portion of jackfruit is utilized at domestic level, scientific literature related to physico-chemical properties and molecular characterization and its utilization is limited. Hence, an attempt is made here to put together some of the closely related findings about the genetic diversity and physico-chemical analysis in general and has been reviewed in this chapter.

The domesticated jackfruit tree, *Artocarpus heterophyllus* Lam., is important in tropical and sub-tropical regions, particularly in South and Southeast Asia. The tree is a major component of subsistence and small farmers and the fruit often assumes the role of a secondary staple food as well as contributing to the livelihoods of the poor. Jackfruit has been in cultivation in India from ancient times. It was probably taken by Arab traders to the East African coast, and now it has spread through the tropics. It is thought that jackfruit originated in the Western Ghats region of India but whether it is found wild or not is still debatable. Some authorities think there are related wild materials in the Andaman Islands; others have proposed that jackfruit originated in Malaysia (Barräu, 1976). The lack of knowledge on a precise area of origin relates to inadequate taxonomic research having been carried out, although the work of Jarrett (1960) has substantially contributed to clarifying much confusion. More recently, molecular research has provided important pointers to which species might form the primary and secondary gene pools of jackfruit. However this recent work is preliminary because the research has been done only in Japan, Thailand and the USA and a limited number of accessions were available for analyses (Schnell *et al.* 2001).

Morphologically Jackfruit tree is an evergreen medium-sized to large tree, 10-20 m tall, occasionally reaching 30 m, with a long tap root and a dense crown. The crown is conical when the trees are young or grown under shaded conditions and reaches a diameter of 3.5-6.7 m at five years; becoming rounded and somewhat irregular when older. The trunk is unbuttressed and is usually about (80-120) cm in diameter but can be much wider in older trees. The bark is somewhat scaly and grayish brown or dark grey. Branches spread from low down the trunk and are inserted at angles ranging from 30-90°. Twigs are

cylindrical and mostly glabrous but sometimes with minute, short, white hairs, becoming glabrous later. Leaves are oblong, obovate or elliptic; leaves on upper mature branches tend to be more obovate and those on young shoot more oblong and narrower. Leaves are (2-25) cm long and (2-12) cm wide at or just above the middle where they are broadest. The lamina is coriaceous, stiff and dark shiny green above and pale green beneath, at first hispidous but becoming glabrous underneath. Venation is pinnate with (5-12) pairs of veins; midrib and main veins are greenish white to pale greenish yellow. Leaves are cuneate or obtuse at the base and entire but irregular shaped leaves can be seen in young plants. The lamina is flat, wrinkled or with upward sides. Leaf apices are blunt, rounded or with a short tip. From the widest point the leaves taper to the petiole which is dark green, (1-5) cm long and grooved on the side facing the stem. Leaves are inserted alternately on horizontal branches but tend to be spiral on ascending branches with a 2/5 phyllotaxis. Stipules are present, ovate, about (1-8) cm long and (0.5-3) cm wide, deciduous, leaving noticeable scars on the stem.

Jackfruit produces a large yellowish syncarp 30-100 cm long and 25-50 cm in diameter, round-cylindrical to pear-shaped hanging on a stout stalk. The fruit surface is warty with numerous protruding pyramidal sections. The perianths of the individual flowers become the fleshy pericarp and surround the seeds, each pericarp and seed being an individual fruit. The pericarp is yellow-white or yellow and waxy-firm (Corner, 1938). The fruit axis is the modified mature inflorescence axis and is somewhat dome shaped. It is rigid and slightly fleshy. The axis contains elongated broad parenchyma and vascular elements as well as numerous laticifers rendering this part of the fruit non-edible. The lower free part of the perianth becomes exclusively fleshy and edible; the middle fused part and the upper free region make up the rind of the fruit; it is the latter which forms the conical studs of the rind and this can differentiate into hairs, sclerenchymatous hypodermis, thick walled ground tissue, vascular elements and fibrous sheathes and laticifers making the conical regions of the fruit rigid and protective. The seed is firm and waxy, oval, oblong or oblong ellipsoid in shape. Each seed is 2-4 x 1-2 cm in size and 2.5-14 g in weight (Gunaseena *et al.* 1996) with a coriaceous testa. Many flowers on the inflorescence do not produce seeds; normally there are 100-500 seeds in each fruit syncarp. The testa is thin and leathery and is rather thick, tough, parchment-like and crinkly when dry. The inner seed coat is a thin, brownish membrane. The seed is thickened at the hilum, which is

situated with the micropyle in the distal end or near the reticular end of the seed. The fleshy cotyledons are very unequal, with one cotyledon only about one third to one-half the size of the other. The endosperm, if present, is very small. The embryo has a superficial radicle.

Several *Artocarpus* species bear edible fruits that are economically valuable (Wester, 1921). Breadfruit, *A. altilis* (Parkins.), widely grown in the Pacific islands, produces pulp which is cooked in various ways and used in numerous main and side dishes. Jackfruit is eaten fresh, as are fruits of *A. integer* (Thunb.), the chempedak, which is truly domesticated and locally important in Malaysia and Indonesia. Two other species are more minor domesticates: *A. odoratissimus* Blanco is well known in Borneo and selected wild forms from Indonesia and Malaysia have been cultivated for fruits in the Philippines; and *A. rigidus* Blume from the Malesian archipelago (covering Malaysia, Indonesia and extending to Papua New Guinea) is another locally important cultigen. There is also a range of wild species of *Artocarpus* whose fruits are gathered for fresh consumption such as *A. lakoocha* Roxb. which is mainly confined to peninsular India and Nepal. Jackfruit is regarded as a species worthy of research attention because of its wider potential use in nutrition and its potential to increase local incomes when grown in agro-forestry and home garden systems. It is locally sometimes of high value (Rehm and Espig, 1991) and has proved valuable when introduced to other parts of the world where it is fairly widely cultivated in suitable climates (Morton, 1965).

Jagadeesh *et al.* (2010) attempted to account for the natural variability existing in physico-chemical qualities of jackfruit bulbs through an extensive survey of coastal zone of Karnataka (situated in the Western Ghats of India), where the jackfruit diversity exists. A significant variation in physico-chemical characters of jackfruit bulbs was observed among the 30 jackfruit selections surveyed and studied in this zone. A high coefficient of variation was observed for bulb parameters such as flake mass (74.79%), bulb mass (71.17%) and single bulb mass (50.11%). Among the biochemical parameters starch content (67.30%), TSS: Acid ratio (34.69%) and titratable acidity (31.76%) exhibited a wide variation.

Karim *et al.* (2008) studied the physico-chemical characteristics of jackfruit at three different harvesting times. Physical characteristics of fruit such as weight of fruit, bulb, seed, rind and axis; skin color, number of bulbs per fruit; nature, flavor and sweetness of bulbs, and chemical characteristics such total soluble solid (TSS), pH, sugar, vitamin C, moisture, dry matter, ash contents of jackfruit bulbs were determined. Matured jackfruits were harvested at three different times, namely early harvesting, mid harvesting and late harvesting and observed that texture, fibrousness, juiciness, flavor and sweetness of bulbs were changed at different harvesting time. Weight of fruit, weight of edible and non-edible portions were also varied at three different harvesting times. Dry matter, ash and non-reducing sugar contents of bulbs were gradually increased with the harvesting times from early to late in the season. At early harvesting time dry matter, ash and non reducing sugar contents were found to be the lowest and the highest at late harvesting time. On the other hand, they found TSS, vitamin C, moisture, total sugar, reducing sugar, contents of jackfruit bulbs decreased during the time. Again TSS, vitamin C, moisture, total sugar, reducing sugar, non-reducing sugar contents were found to be the highest at early harvesting time and the lowest at late harvesting time.

Mannan *et al.* (2005) reported the qualitative and chemical characteristics of 28 selected off-season jackfruit germplasm of South Western region of Bangladesh. There was found a significant variation among the germplasms in relation to fruit characteristics. It was observed from the data of chemical analysis of off-season jackfruits that germplasm No. 1 showed better performance in respect of pH and moisture content of fruit pulp, germplasm No. 10 in total soluble solids content of pulp, germplasm No. 9 in dry matter content of pulp, germplasm No. 22 in titratable acidity of pulp and germplasm No. 8 in vitamin C content of fruit pulp. On the other hand, germplasm No. 5, 18, and 24 produced very sweet, juicy and agreeable flavored bulb.

Ten open pollinated fruits of jackfruit collected from elite clones of South Karnataka were evaluated by Reddy *et al.* (2004) for different qualitative and quantitative traits of the fruit based on descriptors developed by International Plant Genetic Research Institute (IPGRI) for jackfruit. Among the quantitative traits, maximum variability was observed for the characters like fruit weight, fruit shape, carpel number, and carpel colour and carpel size. Different accessions were identified for these fruit characters. Of the

qualitative characters studied, TSS recorded more variability in the clones identified and ranged from 24.8 - 40.5° brix. Highest TSS (40.5° brix) and lowest acidity (0.18%) was noticed in Acc.No.18 and Acc.No.7, respectively. Reducing sugar was more in Acc.No.15 (8.62%). Chemical properties such as pH, total acidity, total Soluble Solid (TSS) and sugar content changes during ripening of jackfruit cultivar J33 were evaluated by Shamsudin *et al.* (2009) at ambient temperature ($\pm 27^{\circ}\text{C}$; 70-80% RH). They found a significant changes pH, total soluble solids, total acidity and sugar content at different ripening days. They reported that the ripening process of jackfruit cultivar J33 was at its optimum at day 9 after harvest at ambient temperature.

Kumar and Jayapradha (2010) reported the total polyphenol content of the extracts ranged from 97.33 to 117.75mg gallic acid equivalent (GAE)/g extract depending on the solvent used and extraction time applied. Among the three solvent extracts, methanol extract showed maximum polyphenol content at 2 hr extraction time followed by ethanol and butanol respectively. Chemical composition of bulbs from 24 different firm-type jackfruit clones was analyzed by Jagadeesh *et al.* (2007) to study the variability. A wide variation in the TSS, acidity, TSS: A ratio, sugars, starch and carotenoid contents was observed in the bulbs of jackfruit types considered in the present investigation. Jagtap *et al.* (2010) analyzed jackfruit pulp (JFP) for total phenolic content (TPC) and total flavonoids content (TFC). The ethanol and water are the best solvents for the extracting phenols and flavonoids from the JFP. The antioxidant activities of JFP extracts were correlated with the total phenolic and flavonoids content. The results indicated that the jackfruit pulp is one natural source of antioxidant compounds.

Research from Faria *et al.* (2009) confirmed the carotenoid composition of jackfruit by high-performance liquid chromatography connected to photodiode array and mass spectrometry detectors (HPLC-PDA-MS/MS). The main carotenoids were all-trans-lutein (24–44%), all-trans- β -carotene (24–30%), all-trans-neoxanthin (4–19%), 9-cis-neoxanthin (4–9%) and 9-cis-violaxanthin (4–10%). Either qualitative or quantitative differences, mainly related to the lutein proportion, were found among three batches of jackfruit. Since the fruits from batch A showed significantly lower contents for almost all carotenoids, it also had the lowest total carotenoid content (34.1 $\mu\text{g}/100\text{ g}$) and provitamin A value, whereas the total carotenoid ranged from 129.0 to 150.3 $\mu\text{g}/100\text{ g}$ in the other

batches. The provitamin A values from batches B and C were 3.3 and 4.3 $\mu\text{g RAE}/100\text{ g}$, respectively. The carotenoid composition of jackfruit was successfully determined, where 14 of the 18 identified carotenoids were reported for first time. Differences among batches may be due to genetic and/or agricultural factors.

Because the flowers are open-pollinated, there is usually great variation in seedlings. Variation is exhibited in a wide range of characteristics such as tree size and structure, leaf and fruit form, age to bearing, and fruit quality. Fruit size, shape, and color of the fruit and texture, odor, and taste of the edible pulp vary tremendously. There are numerous cultivars of each type in regions where jackfruit is a significant food crop, including South India, Bangladesh, Thailand, Malaysia, the Philippines, and Ceylon. And there exists a huge genetic diversity among and within the varieties. However, the genetic diversity and genetic relatedness of 50 jackfruit accessions were studied by Shyamamma *et al.* (2008) using amplified fragment length polymorphism markers. Of 16 primer pairs evaluated, eight were selected for screening of genotypes based on the number and quality of polymorphic fragments produced. These primer combinations produced 5976 bands, 1267 (22%) of which were polymorphic. Among the jackfruit accessions, the similarity coefficient ranged from 0.137 to 0.978; the accessions also shared a large number of monomorphic fragments (78%). Cluster analysis and principal component analysis grouped all jackfruit genotypes into three major clusters. Cluster I included the genotypes grown in a jackfruit region of Karnataka, called Tamaka, with very dry conditions; cluster II contained the genotypes collected from locations having medium to heavy rainfall in Karnataka; cluster III grouped the genotypes in distant locations with different environmental conditions. Strong coincidence of these amplified fragment length polymorphism-based groupings with geographical localities as well as morphological characters was observed. They found moderate genetic diversity in these jackfruit accessions.

Anburaj and Sudarmani (2010) stated that Random Amplified Polymorphic DNAs (RAPDs) provide an excellent tool for studying genetic relationships. Investigation on DNA fingerprinting to estimate the genetic diversity in jackfruit using D19 primer (OPD19 – CTGGGGACTT) was used by them to estimate genetic diversity in five high yielding jackfruits accessions obtained from different location in GKVK campus. Good

quality of DNA was extracted from five different varieties of young tender leaves of *Artocarpus heterophyllus* by CTAB method with minor modification of high detergent concentration of 2 % PVP and 3 % CTAB. The quality of DNA was checked by Agarose Gel Electrophoresis. The isolated DNA was quantified using UV spectrophotometer at 260 nm and 280 nm. And Quantified DNA was subjected for PCR amplification. 67 unambiguous, readable and reproducible RAPD markers were produced using the selected primer (OPD19 – CTGGGGACTT). The number of bands obtained the average of 13.4 bands using single primer, with the sizes ranging from 250 bp to 10000 bp. Of the 67 bands, 18 (21.1%) were polymorphic and shared between five individuals, while 45 (52.9%) were monomorphic in five individuals. Finally they showed low to moderate genetic diversity among the 5 jackfruit accessions.

Schnell *et al.* (2001) did research on twenty-six jackfruit accession; one inter-specific hybrid, champedak, and one breadfruit accession were analyzed using amplified fragment length polymorphic (AFLP) markers to determine the degree of genetic diversity within the Fairchild Tropical Garden (FTG) germplasm collection. Of the 30 primer pairs evaluated, 12 were identified for collection screening based on number and quality of polymorphic fragments. A total of 187 AFLP markers were scored using the 12 primer pairs, 92 (49.2%) being polymorphic. All accessions could be uniquely identified using the 12 primer pairs. Among the jackfruit accessions, similarity coefficients ranged from 0.567 to 0.950; the accessions also shared a large number of monomorphic fragments (54.9%). Cluster analysis and principal component analysis (PCA) grouped all of the jackfruit accessions with south-east Asian origins into one major cluster with little bootstrap support for groupings within the cluster. The Indian accessions were grouped in a different cluster, as did the hybrid and the breadfruit accession. The AFLP marker based analysis indicates that limited genetic diversity exists within this collection. These observations are in agreement with the phenotypic evaluation and suggest that new accessions be obtained from the center of origin for the species.

In the study from Ying-zhi *et al.* (2010), genetic diversity of 50 jackfruit accessions from three provinces in China was analyzed based on amplified fragment length polymorphic (AFLP) markers. A total of 320 unambiguous bands were produced by eight primer combinations, and 65 (20.3%) of them were polymorphic. Genetic similarity coefficients

ranged from 0 to 0.9841, with an average of 0.5000, indicating a moderate genetic diversity in this collection. The dendrogram derived by unweighted pair group method with arithmetic mean algorithm (UPGMA) analysis revealed five groups, and no correlation between genetic relationship and geographical origin were found. Accessions of soft and firm flesh type were not clustered into distinct groups; neither could yearly bearing once, or twice fruit accessions. This study has provided useful information for collection and preservation of jackfruit germplasm worldwide. Jackfruit is cross-pollinated and mostly seed propagated, a wide range of variation exists in fruit quality. With the development of efficient vegetative propagation methods, excellent genotypes selected from these seed propagated seedlings will gradually replace other genotypes in jackfruit producing areas.

3. MATERIALS AND METHODS

The study “Evaluation of Physico-chemical and Genetic Diversity of Jackfruit Germplasm available in the south-western region of Bangladesh” was carried out during the period of November 2009 to May 2011 in the laboratory of Molecular Horticulture, Agrotechnology Discipline, Khulna University, Khulna-9208, Bangladesh. In the present study, 75 jackfruit germplasm were selected from south-western part of Bangladesh where as the south-western region covered for the study included Jessore, Khulna and Sathkhira district falling in coastal zone, and enjoying an agro-climatic condition of the state. The trees were marked to facilitate frequent visits if fruits of desired stage were not available during the initial trip. The fruits were harvested at mature unripe stage and then the collected fruits were brought to the laboratory and kept in ambient condition for ripening to study the physico-chemical characters of bulbs. The survey was made by frequent visit to different jackfruit growing areas of south-western part and enquiries were made from the villagers to identify the superior germplasm (Table 1). Physical properties were recorded i.e; fruit weight, fruit length, fruit breadth, bulb number, bulb including seed weight, bulb length, weight of non-edible portion, seed number, weight of seed, length and breadth of seed, skin thickness, rachis length, spine length and spine number. Biochemical characteristics of jackfruits were estimated viz. pH, total soluble solids (TSS), titratable acidity (TA), TSS: TA, ascorbic acid (Vit-C), flavonoid, anthocyanin and carbohydrate content of fruit pulp. In addition, at the time of collection of the fruit, young green leaves also collected about 5 gm from each of 1-60 germplasm of jackfruit and stored in -80°C ultra low freezers for molecular characterization.

Table 1. Location wise distribution of collected germplasm of jackfruit from south-western region of Bangladesh

SI	Germplasm number	Name of the farmer	Location of collection/ Address
01	Gp01	M. M. Molla	Bughdanga, Bashubari, Ghuni, Bugharpara, Jessore
02	Gp02	M. S. Islam	Bughdanga, Bashubari, Ghuni, Bugharpara, Jessore
03	Gp03	M. K. Molla	Ghoshnagar, Ghuni, Bugharpara, Jessore
04	Gp04	M. S. Molla	Jangalbadal, Jangalbada, Katuali, Jessore
05	Gp05	R. C. Mondal	Ghoshnagar, Ghuni, Bugharpara, Jessore
06	Gp06	D. Shankar	Ghoshnagar, Ghuni, Bugharpara, Jessore
07	Gp07	B. K. Bishwas	Ghoshnagar, Ghuni, Bugharpara, Jessore
08	Gp08	S. Rahman	Bashundia, Bashundia, Jessore
09	Gp09	M. Molla	Bughdanga, Bashubari, Ghuni, Bugharpara, Jessore
10	Gp10	S. Molla	Bashundia, Bashundia, Jessore
11	Gp11	V. Sarker	Jangalbadal, Jangalbada, Katuali, Jessore
12	Gp12	V. Sarker	Jangalbadal, Jangalbada, Katuali, Jessore
13	Gp13	I. Ali	Jangalbadal, Jangalbada, Katuali, Jessore
14	Gp14	A. Ali	Jangalbadal, Jangalbada, Katuali, Jessore
15	Gp15	M. H. Rahman	Jangalbadal, Jangalbada, Katuali, Jessore
16	Gp16	M. A. Hossain	Jangalbadal, Jangalbada, Katuali, Jessore
17	Gp17	A. R. Gazi	Jangalbadal, Jangalbada, Katuali, Jessore
18	Gp18	J. Uddin	Jangalbadal, Jangalbada, Katuali, Jessore

19	Gp19	A. Hossain	Jangalbadal, Jangalbadal, Katuali, Jessore
20	Gp20	M. R. Islam	Jangalbadal, Jangalbadal, Katuali, Jessore
21	Gp21	S. Molla	Jangalbadal, Jangalbadal, Jessore Sodor, Jessore
22	Gp22	Mobbashar	Jangalbadal, Jangalbadal, Jessore Sodor, Jessore
23	Gp23	Mobbashar	Jangalbadal, Jangalbadal, Jessore Sodor, Jessore
24	Gp24	D. C. Dev	Jangalbadal, Jangalbadal, Jessore Sodor, Jessore
25	Gp25	A. Taher	Jangalbadal, Jangalbadal, Jessore Sodor, Jessore
26	Gp26	A. Taher	Jangalbadal, Jangalbadal, Jessore Sodor, Jessore
27	Gp27	M. I. Moral	Jangalbadal, Jangalbadal, Jessore Sodor, Jessore
28	Gp28	M. M. Beig	Bashundia, Bashundia, Jessore
29	Gp29	M. E. Beig	Bashundia, Bashundia, Jessore
30	Gp30	M. A. Khan	Bashundia, Bashundia, Jessore
31	Gp31	T. Islam	Kafayathnagar, Bashundia, Jessore
32	Gp32	Y. Biswash	Kafayathnagar, Bashundia, Jessore
33	Gp33	J. H. Khan	Shudullopur, Katuali, Bashundia, Jessore
34	Gp34	T. H. Khan	Shudullopur, Katuali, Bashundia, Jessore
35	Gp35	L. J. Khan	Shudullopur, Katuali, Bashundia, Jessore
36	Gp36	M. F. Khan	Shudullopur, Katuali, Bashundia, Jessore
37	Gp37	M. M. Khan	Shudullopur, Katuali, Bashundia, Jessore
38	Gp38	S. Khan	Shudullopur, Katuali, Bashundia, Jessore
39	Gp39	M. M. Khan	Shudullopur, Katuali, Bashundia, Jessore
40	Gp40	N. K. Sarker	Shudullopur, Katuali, Bashundia, Jessore
41	Gp41	M. M. Ali	Shudullopur, Katuali, Bashundia, Jessore
42	Gp42	M. M. Ali	Shudullopur, Katuali, Bashundia, Jessore
43	Gp43	L. M. Box	Shudullopur, Katuali, Bashundia, Jessore
44	Gp44	M. S. Khan	Botiaghata, Khulna
45	Gp45	M. Sorkar	Tala, Satkhira
46	Gp46	H. Mondol	Kolaroa, Satkhira
47	Gp47	R. K. Datta	Noapara, Jessore
48	Gp48	M. A. Mannan	Germplasm Centre, Khulna University
49	Gp49	K. Ghotok	Keshobpur, Jessore
50	Gp50	M. M. Molla	Khalishpur, Khulna
51	Gp51	P. K. Saha	Keshobpur, Jessore
52	Gp52	S. Islam	Islamnagar, Khulna
53	Gp53	M. Tiwari	Keshobpur, Jessore
54	Gp54	Ashraf	Colonybari, Bashundia, Jessore
55	Gp55	A. A. Khan	Khanpara, Bashundia, Jessore
56	Gp56	N. M. Molla	Bashundia Bazar, Bashundia, Jessore
57	Gp57	N. I. Khan	Bashundia Bazar, Bashundia, Jessore
58	Gp58	A. Dacktar	Bashuria, Bugharpara, Jessore
59	Gp59	M. Molla	Bashundia, Jessore
60	Gp60	Y. Mridha	Bashundia, Jessore
61	Gp61	R. Molla	Schoolpara, Bashundia, Jessore
62	Gp62	H. Molla	Bashundia, Jessore
63	Gp63	M. Ali	Bashundia, Jessore
64	Gp64	Acklush	Katuali, Bashundia, Jessore
65	Gp65	H. A. Mridha	Katuali, Bashundia, Jessore
66	Gp66	N. Batul	Ghoshnagar, Ghuni, Bugharpara, Jessore
67	Gp67	F. Rahman	Kafayathnagar, Bashundia, Jessore
68	Gp68	R. M. Molla	Kafayathnagar, Bashundia, Jessore
69	Gp69	S. A. Mir	Bashundia, Jessore
70	Gp70	Solimullah Khan	Islamnagar, Khulna
71	Gp71	R. Rayhan	Khalishpur, Khulna
72	Gp72	T. Kaji	Mohammadnagar, Khulna
73	Gp73	R. Ali	Halimnagar, Khulna
74	Gp74	M. Khondokar	Mohammadnagar, Khulna
75	Gp75	F. Rahman	Mohammadnagar, Khulna

3.1 Study of Physical Properties

Physical properties were recorded as i.e.; the weight of fruit; bulb including seed, only bulb, non-edible portion, seed, skin and rachis were taken in Kg by electric balance. Fruit length, fruit breadth, seed length, seed breadth, skin thickness, rachis length, spine length and bulb length were estimated in centimeter by using scale and slide calipers. Finally spine number per square centimeter and total bulb and seed number were counted.

3.2 Study of Biochemical Properties

The methods for the estimation of pH, TSS, titrable acidity (TA), ascorbic acid (Vit-C), carotenoid, anthocyanin, carbohydrate and flavonoid content of fruit pulp were followed as described by Mazumdar and Majumdar (2001); Saini *et al.* (2006).

pH: The pH of fruit pulp was measured by a desktop pH meter (pHep Hanna, Italy). The methods for the estimation of the parameters were followed as described by Anonymous (1965).

Total soluble solids (TSS): Total soluble solids (TSS) content was determined by hand refractometer (ATAGO, Japan). A drop of juice squeezed from the jackfruit bulb was placed on the prism of the refractometer and percent total soluble solid was obtained from the direct reading. The methods for the estimation of the parameters were followed as described by Anonymous (1965); Lane and Eynon (1923). Temperature correction was made as described by Ranganna (1979).

Ascorbic acid (Vit-C): Ascorbic acid quantified according to the method of Sadasivam and Manickam (1996). Twenty grams of the bulb of jackfruit were blended in a warming blender containing 100 ml. of 3% HPO_3 (metaphosphoric acid solution) for 5 minutes. The dilute sample was filtrated through Whatman No. 40 and final volume was recorded. Ten ml aliquot of the filtrate was pipeted into a small Elenmeyer flask. It was titrated immediately with the solution of 2,6-dichlorophenol indophenol dye as outlined in the A.O.A.C. (1965). The dye had earlier has been standardized with vitamin C solution to find an equilibrium factor for dye. The ascorbic acid content of the samples was calculated from the following formula:

mg of ascorbic acid per 100 g bulbs = $T \times D \times V_1 \times 100 / V_2 \times W$,

Where,

T = Titre,

D = Dye factor,

V₁ = Volume made up,

V₂ = Aliquot of extract taken for estimation,

W = Weight of sample taken for estimation.

Determination of carotenoid: Carotenoids content determined according to the methods of Saini *et al.* (2001). 1 g of finely cut fruit sample was weighed by an electric balance and then the fruit sample was mixed well into a clean mortar. The tissue sample was grinded to a fine pulp with addition of 20 ml of 80 % acetone. It was centrifuged at 5000 rpm for 5 minutes and transferred the supernant to a 100 ml of volumetric flask. The residue was grinded with 20 ml of 80 % acetone, centrifuged and transferred the supernant to the same flask. The procedure was repeated until the residue was colourless. The pestle and mortar were washed thoroughly with 80 % acetone and the clear washing was collected in the flask. The volume was made to 100 ml with 80% acetone. The absorbance was read at 510 nm and 480 nm against blank by using T 60 UV visible spectrophotometer. The carotenoid content of the samples was calculated from the following formula:

mg carotenoid s/g tissue = $7.6 (A. 480) - 1.49 (A. 510) \times V / (1000 \times 10)$,

Where,

A= Absorbance of the specific wave length,

V=Final Volume of the carotenoids in 80% acetone,

W= Fresh weight of the tissue extracted.

Determination of anthocyanin: Anthocyanin was measured according to the methods of Mazumdar and Majumdar (2001). 5 g of tissue sample by weight was taken and extracted with ethanol hydrochloric acid mixture. It was allowed to stand overnight at a temperature of about 4°C. After extraction, the mixture was filtered through filter paper (Whatman No.1). The extraction was repeated for maximum recovery of the pigment. The extract was then made up to 15 ml with the solvent. 15 ml of aliquot from the above extract was taken. It was filtered through fine (milli-pore) filter paper. The filtered aliquot was

maintained in darkness for about 2 hours with cover of the container. This was then made up to 25 ml with the solvent (for colour measurement). The optical density (O.D.) value of the solution was then measured through 535 nm wavelength in a colorimeter (T 60 UV visible Spectrophotometer) against blank. The anthocyanin content of the samples was measured and calculated from the following formulas:

$$\text{Total absorbance value of the sample (per 100 g)} = \{(e \times b \times c) / (d \times a)\} \times 100$$

Where,

a = weight of sample,

b = volume made for colour measurement,

c = total volume made,

d = volume of aliquot taken for estimation,

e = Volume for 535 nm,

$$\text{Anthocyanin (mg/100g)} = \text{Total absorbance} / 98.2$$

Determination of flavonoids: Flavonoid was estimated by following the method of Boham and kocipai (1994). 10 g sample was taken and crushed finely. Then 100 ml of 80 % methanol was added and kept it in a water bath for 10 hours at 40°C. The whole solution was filtered through a filter paper. The filtrate was transferred to a crucible and then evaporated to dryness over a water bath at room temperature. The final finding was weighed as flavonoid.

Determination of carbohydrate: 100 mg of the sample was taken into a boiling tube. Then hydrolyzed by keeping it in boiling water bath for three hours with 5 ml of 2.5 N HCl and cold to room temperature and neutralized it with solid sodium carbonate until the effervescence ceases. Made up the volume to 100 ml and centrifuged. After then collected the supernatant and took 0.5 and 1 ml aliquots for analysis. For estimation of carbohydrate content, prepared the standard curve by taking 0, 0.2, 0.4, 0.6, 0.8 and 1 ml of the working standard in which zero serves as blank. Further more made up the volume to 1 ml in all the tubes including the sample tubes by adding DW. Then added 4 ml of anthrone reagent and heated for eight minutes in a boiling water bath. Cold rapidly and read the green color at 630 nm by spectrophotometer. Drown a standard graph by plotting concentration of the standard on the X-axis and absorbance on the Y-axis. From the graph calculated the amount of carbohydrate present the sample tube (Ranganna, 1986).

Titration acidity (%): 30 g of tissue sample by weight was taken. This was extracted with distilled water by through crushing in blender. Extract was filtered and the filtrate was made up to 100 ml with distilled water. Then, 15 ml of aliquot was taken into a conical flask. Three to four drops of phenolphthalein solution were added to this aliquot and shaken well. A burette was filled with the sodium hydroxide solution after washing and rinsing. Titration was done and end point was determined by the appearance of pink colour and its persistence for at least 10 to 15 seconds. In term of citric acid 1 ml of 0.1N NaOH solution can neutralize 0.064 g of citric acid. Finally TA was estimated by the following formula of (Anon 1984):

$$\% \text{ Titration acidity} = \{(d \times 0.064 \times c) / (a \times b)\} \times 100$$

Where,

a = Weight of sample,

b = Volume of aliquot taken for examination,

c = Volume made with distilled water,

d = Average burette reading for sample



Experimental design and analysis of data: The experiment was laid out in Completely Randomized Design (CRD) with three replications. The collected data from physical and biochemical properties were statistically analyzed by Analysis of Variance (ANOVA). Duncan's Multiple Range Test (DMRT) was used to compare the mean of different parameters and the means were calculated by using "MSTAT-C".

3.3 Estimation of Genetic Diversity

Sample Collection and Preparation: In the present study, young tender leaves from 60 jackfruit germplasm were collected from the south-western part of Bangladesh. The fruits of different germplasm exhibited morphological and biochemical variation in some characters, such as fruit wt., length and bulb number as well as their nutrient quantity, however, the morphological and biochemical characteristics of the fruits of each germplasm were recorded (Table 3; Table 4a; Table 4b and Table 5). Approximately 5 g of recently matured and tender leaves (10-15 days old) was collected, washed by using distilled water, wiped with 70% (v/v) ethanol and then air dried, of which 1 g was weighed out and stored in sealed plastic bags at -80°C for further use.

DNA Extraction and Purification: The DNAzol protocol which is based on the use of a novel guanidine detergent lysing solution that allows the selective precipitation of DNA from the lysate (Chomczynski *et al.* 1997) was fast and permits efficient isolation of genomic DNA from a variety of plant tissues that why the study followed the methods of Chomczynski *et al.* (1998). 0.5 to 1 g leaf samples were ground into powder with mortar and pestle and 1-1.5 ml of DNAzol (Invitrogen, USA) was added and then homogenized properly. The mixture was centrifuged at 12,000 rpm for 10 minutes and transferred the supernatant to another 1.5 ml centrifuge tube. DNA was precipitated from the lysate/homogenate by the addition of 0.5-0.75 ml of 100 % ethanol and then mixed gently by inverting tubes 3-5 times and stored at room temperature for 2-3 minutes to form a well mixed homogenous solution. As DNA became visible as a cloudy precipitate and then the mixer was centrifuged at 12,000 rpm for 10 minutes again. The DNA precipitated was found and needed to discard supernatant and there after precipitated DNA was washed with 75 % of ethanol about 2-3 times. After addition of ethanol, inverting the tubes 8-10 times and were stored the tubes vertically for 0.5 – 1 minute to allow the DNA to settle to the bottom of the tubes and were removed ethanol through decanting and pepeting. Finally air dried the DNA pellet.

DNA Solubilization and Quantification: The air dried pellet was dissolved in 300 µl of 8 mM NaOH was stored at -20°C. The DNA was checked in 1 % agarose gel electrophoresis and quantified using UV spectrophotometer (T 60 UV-Visible, PG

instrument Ltd). 2 µl of isolated DNA sample from each germplasm of Jackfruits were taken and made up to 2000 µl or 2 ml with 8 mM NaOH. The entire isolated DNA samples were quantified using UV spectrophotometer at 260 nm. The concentrations of absorbance were calculated by using the following formula:

$$\text{DNA concentration } (\mu\text{g/ml}) = (\text{OD}_{260}) \times (\text{dilution factor}) \times (50 \mu\text{g DNA/ml}) / (100 \text{OD}_{260}).$$

The DNA solution was expressed in ng/mL (Hoisington *et al.* 1994). The final concentrations of jackfruit DNA stock solutions were adjusted to 1.00 ng/mL for PCR.

PCR of DNA

Selection of Primer: Primers were selected mainly based on GC content, intensity of bands, presence of smearing, consistency within individuals and potential for population discrimination. Primers that have GC content more than 60% are suitable for RAPD analysis. Five subsets of primers selected (supplied by Bioneer Corporation, South Korea) (Table 2) and among them four (A02, A03, S7 and S18) were exhibited good quality banding patterns and sufficient variability. Annealing temperature was calculated by the following formula:

$$\text{Annealing temperature} = 0.3 \times T_m (\text{primer}) + 0.7 \times T_m (\text{product}) - 25$$

Table 2. List of Random Primers

Primer code	Sequence (5' – 3')	GC content (%)	*T _m ; T _a
OP A00	ATC AGC GCA CCA	58%	38°C; 36.8°C
OP A02	GCC AGC TGT ACG	66.7%	40°C; 37.4°C
OP A03	TGC CTC GCA CCA	66.7%	40°C; 37.4°C
OP S7	GGT GAC GCA G	70%	34°C; 35.6°C
OP S18	CCA CAG CAG T	60%	32°C; 35°C

*T_m: Melting Temperature; T_a: Annealing Temperature

PCR reaction: PCR was carried out in MyGenie 96 Thermal Block, Bioneer Corporation, South Korea. PCR amplification was preceded according to the method of Simon *et al.* (2007). The PCR reaction was carried at in a final volume of 20 µl reaction mixture contained PCR stock DNA (2 µl), top polymerase (2 µl), DNTPs (2 µl), 10X reaction buffer (2 µl), 5 Pmoles primers (1 µl), sterile water (11 µl). The chemical was supplied by Bioneer Corporation, South Korea. The Mixture was over layered with a drop of mineral oil. This reaction mixture involved in PCR amplification conditions (PCR lead at 105°C, hot start at 94°C for 4 min's, denaturation at 94°C for 1 min, annealing at 35°C

for 1min, extension at 72°C for 2 min's, 35 cycles, final extension at 72°C for 10 min's, holding at 4°C for 10 min's and end).

Electrophoresis of the amplified products and documentation: Amplified PCR products were electrophoresed (Agarose-power system, Bioneer Corporation, South Korea) on an agarose gel (2 %) in TAE buffer and visualized by staining with ethidium bromide solution. Polymorphic band was observed by high performance UV trans-illuminator (UVP-UK) and picture was taken by the GEL DOC/Bio-Imaging System affiliated digital canon camera.

PCR product analysis: Study of genetic diversity, each germplasm was scored manually for presence or absence of a particular amplification product. Data was analyzed by the software GelQuest and MEGA5.05 for phylogenic analysis. RAPD matrix of the 60 germplasm of jackfruit using A02, A03, S7 and S18 primer were assembled for statistical analysis and the sizes of the DNA fragments were estimated using 1 kb and 100 bp ladders by co-electrophoresis with the PCR product DNA. The unweighted pair group method with arithmetic averages (UPGMA) based dendrogram was constructed using the MEGA5.05. Numerical value was considered to construct the dendrogram and presence of band (1) and absence of band (0) value consider for these RAPD analysis.

4. RESULTS AND DISCUSSION

4.1 Physical Properties Analysis

Fruit weight, length and breadth: The maximum fruit weight was observed in Gp25 (11.067 kg) while it was minimum (3.217 kg) in Gp42 (Table 3; Table 4a). Azad (1989) recorded 7.1 kg as larger fruit and Karim *et al.* (2008) stated 8.67 kg as biggest fruit. More interestingly, Jagadeesh *et al.* (2010) reported maximum (18.74 kg) and minimum (2.15 kg) jackfruit in India with mean value of 6.54. Again, Reddy *et al.* (2004) reported in his paper that 20 kg highest and minimum (6.5 kg) jackfruit available in south Karnataka. Thus, it is assumed that fruit weight is greatly influenced by agro-climatic condition and germplasm variation. Fruit length and breadth was also significantly affected by germplasm variation that the maximum fruit length was recorded from Gp17 (48.667 cm), while Gp59 was minimum (23.00 cm) with mean value of (32.827), CV % (3.97) and SD (6.28), respectively. Fruit breadth maximum (29.333 cm) recorded from Gp23, minimum (17.00 cm) from Gp49 with the mean, CV %, SD values of 22.336, 6.67 and 2.97, respectively (Table 3; Table 4a). However, no other writer reported about the fruit length and breadth.

Skin weight and thickness: The highest 4.665 kg recorded from Gp5 and lowest in Gp42 (0.97 kg) with mean (2.336), CV % (9.09) and SD (0.87) (Table 3; Table 4a). Karim *et al.* (2008) recorded maximum (3.02 kg) and minimum (2.37 kg) skin weight of jackfruit clones. Jagadeesh *et al.* (2010) stated mean, CV% and SD values were 2.42, 74.79 and 1.81 while minimum and maximum skin weight 0.40 kg and 7.84 kg. Though skin weight is significantly affected by germplasm variation and location but our results is more or less similar with other researcher. Skin thickness is one of the important properties of jackfruits and it can be significantly influenced by genotype variation. Maximum skin thickness (1.833 cm) found in Gp49 and minimum in Gp3 (0.680 cm) with mean value of 1.279, CV % of 11.99 and SD of 0.29 (Table 3; Table 4a). Jagadeesh *et al.* (2010) showed mean, CV %, SD, minimum and maximum values of jack fruits skin thickness were 0.39, 28.21, 0.11, 0.17 cm and 0.63 cm, respectively. According to the results and other researcher it is proved that skin thickness is varied region to region as well germplasm to germplasm.

Table 3. Physico-chemical properties of the collected jackfruit germplasm

SN	Character/parameter	Mean	CV %	SD	Minimum	Maximum
01	Fruit wt. (kg)	6.214	3.97	1.69/0.25	3.217	11.067
02	Fruit length (cm)	32.827	7.51	6.28/2.47	23.000	48.667
03	Fruit breadth (cm)	22.336	6.67	2.97/1.49	17.000	29.333
04	Bulb number	129.307	5.06	55.77/6.55	33.000	324.667
05	Bulb including seed wt. (kg)	3.561	5.25	1.16/0.19	2.017	7.233
06	Bulb length (cm)	5.983	3.10	1.03/0.19	4.413	9.100
07	Bulb breadth (cm)	3.431	3.56	0.74/0.12	1.950	6.880
08	Only bulb wt. (kg)	2.88	5.53	1.03/0.16	1.082	6.545
09	Wt. of non-edible portion (kg)	2.653	7.38	0.94/0.20	1.233	5.153
10	Seed number	123.169	5.86	52.26/7.22	30.667	313.000
11	Seed wt. (Kg)	0.682	7.72	0.33/0.05	0.227	1.733
12	Seed length (cm)	2.983	4.93	0.44/0.15	1.667	4.017
13	Seed breadth (cm)	1.931	6.60	0.30/0.13	1.300	2.710
14	Skin wt. (Kg)	2.336	9.09	0.87/0.21	0.970	4.665
15	Skin thickness (cm)	1.279	11.99	0.29/0.15	0.680	1.833
16	Rachis length (cm)	23.783	11.65	5.72/2.77	14.667	39.000
17	Rachis wt. (kg)	0.317	25.73	0.18/0.08	0.850	1.060
18	Spine length (cm)	0.374	8.13	0.13/0.03	0.110	0.803
19	Spine number/cm ²	3.792	7.60	1.46/0.29	0.767	8.733
20	pH	5.516	3.47	0.36/0.19	4.827	5.907
21	TSS	20.180	1.74	3.59/0.35	11.100	29.200
22	Carotenoid (mg/100 g)	0.435	8.54	0.16/0.04	0.157	0.787
23	Anthocyanin (mg/100 g)	0.128	2.19	0.05/0.01	0.057	0.247
24	Ascorbic Acid (mg/ 100 g)	5.574	13.86	1.10/0.77	3.210	7.700
25	Flavonoid (mg/ 100 g)	18.576	3.92	3.39/0.73	11.463	37.547
26	T – acidity (TA)	0.331	2.47	0.12/0.01	0.117	0.593
27	Carbohydrate (mg/ 100 g)	22.874	5.27	1.99/1.20	18.960	28.333
28	TSS: TA	72.006	3.31	34.23/2.38	27.227	160.989

CV=Coefficient of variance, SD = Standard deviation (among Gp/within Gp)

Rachis weight and length: The highest rachis weight (1.060 kg) was recorded from Gp14 and the lowest (0.108 kg) from Gp70 with the mean value of 0.317, CV % (25.73) and SD (0.18) (Table 3; Table 4a). Karim *et al.* (2008) stated that jackfruit rachis exhibited significant variation and was observed maximum weight of rachis (0.55 kg) and minimum (0.40 kg), fruit rachis length of the jackfruit exhibited significant variation and was observed that of Gp14 had maximum length of rachis (39 cm) while Gp66 showed the minimum (14.667 cm). The mean, CV % and SD values were 23.783, 11.65 and 5.72, respectively (Table 3; Table 4a).

Spine length and spine number/cm²: The length and number of spine per square cm was varied significantly among the germplasm variation. The highest length of spine (0.803 cm) was noted from Gp25, while it was lowest (0.110 cm) in Gp29. The mean value, CV % and SD were 0.374, 8.13 and 0.13, respectively. The interaction effect of germplasm variation in respect of spine length and no. was statistically significant. The highest spine number (8.733/cm²) was found in Gp70 and the lowest (0.767/cm²) in Gp51. The mean value, CV % and SD were 3.792, 7.60 and 1.46, respectively (Table 3; Table 4a).

Weight of non- edible portion (rachis and skin): Variation in germplasm had significant influence on the weight of non-edible portion i.e. rachis and skin weight of jackfruit. The maximum non-edible portion (5.153 kg) was found in Gp5, while the lowest (1.233 kg) was noted from Gp31 with mean value (2.653), CV % (7.38) and SD (0.94) (Table 3; Table 4a). Karim *et al.* (2008) stated the weight of non-edible portion was varied significantly among the germplasm and he noted the maximum weight of non-edible portion (3.65 kg) and minimum (2.58 kg). The interaction effect of germplasm variation in respect of weight of non-edible portion was statistically significant. Jagadeesh *et al.* (2010) reported highest (6.545 kg) and lowest (0.89 kg) of non edible portion.

Table 4a. Physical properties of collected jackfruit germplasm from south-western region of Bangladesh

GP no	Fruit wt. (Kg)	Fruit length (cm)	Fruit breadth (cm)	Wt. of non-edible portion (kg)	Skin wt. (kg)	Skin thickness (cm)	Rachis length (cm)	Rachis wt. (kg)	Spine length (cm)	Spine no./cm ²
01	5.533	30.000	23.667	2.063	1.714	1.057	20.000	0.349	0.437	3.167
02	8.300	44.667	26.333	4.810	4.231	1.637	34.667	0.579	0.277	2.817
03	4.950	27.333	21.333	2.597	2.397	0.680	20.667	0.200	0.260	2.353
04	5.767	29.000	25.667	3.560	3.233	0.987	23.000	0.327	0.310	1.057
05	8.300	34.667	26.000	5.153	4.665	1.020	25.000	0.489	0.320	3.500
06	6.067	36.333	24.000	3.783	3.405	0.967	27.000	0.378	0.283	1.100
07	6.733	36.667	22.667	3.267	2.987	1.400	25.667	0.280	0.400	3.717
08	8.033	47.667	22.000	3.417	3.067	1.700	37.333	0.350	0.397	3.100
09	8.133	32.333	25.000	3.793	3.375	1.173	22.000	0.418	0.393	3.000
10	5.800	29.000	21.000	1.800	1.611	1.033	19.667	0.189	0.480	3.000
11	4.900	28.333	19.333	2.217	1.780	1.033	19.667	0.437	0.200	3.483
12	6.317	30.000	21.333	1.667	1.470	1.200	20.333	0.197	0.210	2.550
13	8.400	39.667	19.333	2.903	2.471	1.233	31.333	0.432	0.407	3.550
14	10.250	48.667	24.667	3.900	2.840	1.450	39.000	1.060	0.303	3.467
15	6.367	28.333	23.667	2.287	2.065	0.830	21.000	0.222	0.307	3.100
16	5.900	32.000	20.667	2.497	2.145	1.067	22.667	0.352	0.207	4.500
17	10.767	48.667	25.000	4.403	3.970	1.450	37.667	0.434	0.497	2.857
18	6.033	30.333	20.000	3.100	2.909	0.720	20.667	0.191	0.380	3.060
19	7.200	33.667	26.333	2.167	1.862	1.300	26.667	0.304	0.607	4.400
20	6.433	35.333	23.333	2.613	2.278	1.100	26.667	0.335	0.303	3.233
21	7.050	35.333	24.667	2.500	2.205	1.100	26.000	0.295	0.323	2.600
22	5.000	26.667	21.333	1.610	1.428	1.400	18.333	0.182	0.193	7.333
23	7.800	33.333	29.333	3.020	2.770	1.000	23.000	0.250	0.293	5.283
24	3.700	32.000	19.667	1.300	1.115	1.200	23.000	0.185	0.327	4.267
25	11.067	38.333	27.667	3.833	3.455	1.500	26.667	0.378	0.803	1.560
26	5.600	37.000	21.667	2.567	2.244	1.000	27.667	0.322	0.497	3.200
27	4.800	30.333	22.333	1.273	1.119	1.033	21.333	0.154	0.303	2.483
28	8.233	42.000	24.000	2.467	2.026	1.550	33.000	0.440	0.310	3.980
29	7.933	40.667	22.667	3.533	3.223	1.400	31.333	0.310	0.110	3.233
30	6.333	27.667	26.000	2.333	2.170	2.013	16.000	0.164	0.480	4.480
31	4.233	29.667	19.667	1.233	1.031	1.213	16.667	0.203	0.490	3.423
32	6.000	33.333	19.333	2.727	2.427	1.233	24.000	0.300	0.397	3.217
33	4.867	31.000	23.000	2.047	1.721	1.367	22.667	0.326	0.497	4.310
34	7.100	33.333	27.000	3.900	3.613	1.593	23.333	0.287	0.303	3.457
35	5.550	33.000	23.000	2.383	2.215	1.550	22.000	0.168	0.497	3.610
36	5.667	29.000	24.667	1.893	1.428	1.027	20.000	0.465	0.303	4.427
37	4.967	30.667	21.333	2.920	2.712	1.517	21.000	0.208	0.500	7.367
38	5.400	27.333	24.333	1.843	1.439	1.460	19.667	0.404	0.293	2.760

39	3.800	27.333	18.667	1.610	1.346	1.333	22.000	0.264	0.307	3.897
40	6.567	33.333	25.000	4.100	3.250	1.500	22.333	0.850	0.723	2.330
41	8.367	45.000	24.667	4.733	4.237	1.650	30.667	0.497	0.490	5.283
42	3.217	26.667	20.333	1.193	0.970	1.317	19.167	0.223	0.393	6.587
43	4.933	31.000	17.667	2.277	1.517	1.233	20.667	0.760	0.400	5.533
44	4.900	28.333	23.000	1.883	1.380	1.267	22.333	0.503	0.347	4.100
45	7.600	35.000	20.667	2.567	2.186	1.200	27.667	0.381	0.397	4.167
46	7.700	41.667	21.667	3.950	3.314	1.500	32.333	0.636	0.503	3.100
47	6.767	38.667	21.000	2.633	2.323	1.533	31.333	0.310	0.310	4.500
48	10.033	36.667	25.667	4.433	4.172	1.500	27.667	0.261	0.207	1.843
49	3.567	24.667	17.000	1.300	1.095	1.833	19.333	0.205	0.210	4.557
50	8.533	38.333	25.000	2.867	2.450	1.500	26.667	0.417	0.203	2.810
51	4.667	31.667	20.333	2.533	2.160	1.333	22.333	0.373	0.573	0.767
52	5.500	29.667	21.667	2.200	2.036	1.100	19.667	0.164	0.193	4.317
53	5.533	33.000	22.000	1.847	1.700	0.960	23.333	0.147	0.203	5.033
54	6.100	40.333	23.333	3.203	2.912	1.467	29.167	0.291	0.503	3.960
55	5.433	27.667	20.667	1.817	1.524	1.167	20.000	0.292	0.403	2.033
56	6.267	40.667	23.333	2.900	2.553	1.600	30.233	0.347	0.397	3.967
57	6.333	29.000	24.000	2.877	2.472	0.967	21.667	0.405	0.407	2.923
58	5.167	30.000	20.333	1.753	1.579	1.000	21.000	0.174	0.297	5.993
59	5.500	23.000	18.000	2.947	2.747	1.700	18.833	0.199	0.307	6.963
60	6.100	24.000	23.000	2.210	1.746	1.200	20.000	0.464	0.430	4.023
61	6.733	25.333	23.000	2.037	1.879	1.200	16.000	0.158	0.283	4.367
62	5.967	28.000	23.000	2.100	1.897	0.723	20.000	0.203	0.133	1.500
63	4.000	25.000	19.000	1.533	1.418	1.400	18.333	0.115	0.283	4.797
64	4.833	28.333	20.000	2.023	1.907	1.033	22.000	0.116	0.437	5.700
65	4.033	28.000	17.333	1.650	1.257	1.267	20.000	0.393	0.227	4.333
66	4.200	24.000	23.333	1.940	1.796	1.433	14.667	0.144	0.510	4.433
67	5.533	34.667	20.333	2.167	1.942	1.133	26.333	0.225	0.400	4.000
68	5.667	25.000	26.000	2.590	2.408	1.567	15.667	0.182	0.503	2.800
69	9.067	33.667	26.333	3.820	3.555	1.400	21.000	0.265	0.633	2.250
70	5.000	29.000	20.533	2.960	2.852	1.600	22.000	0.108	0.527	8.733
71	5.500	36.333	21.000	2.423	2.065	1.200	27.333	0.358	0.383	4.483
72	5.700	38.667	20.000	3.583	3.312	1.433	29.500	0.272	0.500	3.967
73	6.833	28.667	20.333	3.100	2.881	1.100	19.000	0.219	0.313	4.183
74	4.567	33.333	17.667	2.333	1.334	1.200	23.333	0.166	0.427	4.100
75	4.350	35.000	17.333	2.063	2.185	1.200	23.833	0.149	0.413	4.063

Number of bulbs per fruits: In the present study, variation was found in number of bulbs among the different germplasm of jackfruit. The highest of bulbs per fruit (324.667) was found in Gp28 while in Gp40 had the lowest (33) bulbs with the mean, CV % and SD values of 129.307, 5.06 and 55.77, respectively (Table 3; Table 4b). Karim *et al.* (2008) reported the average of 115.00, 109.78 and 88.42 bulbs per fruit was found in early, mid and late harvesting times, respectively. Again, he stated that there was difference in respect of number of bulbs per fruit among the selection. It appeared that the selection-1 had maximum bulbs (119.00) which are significantly higher than the selection-2 (106.67) and selection-3 (94.89). Reddy *et al.* (2008) showed maximum 208 and minimum 68 bulbs per fruit in respect of genotype.

Weight of bulb, Bulb length and breadth: The results showed that the bulb weight of jackfruit also varied significantly among the germplasm. Gp25 had maximum bulb weight (6.545 kg), while Gp75 had the minimum (1.082 kg) with the mean, CV % and SD values of

2.88, 5.53 and 1.03, respectively (Table 3; Table 4b). Karim *et al.* (2008) reported 4.42 kg as maximum and minimum (1.33 kg) bulb weight from a single jackfruit. Jagadeesh *et al.* (2010) accounted highest 10.03 kg and lowest 0.59 kg bulb weight per fruits with the mean (3.40), CV % (71.17), SD (2.42). In other study of Reddy *et al.* (2004) revealed that the highest and the lowest bulb weight 6.656 kg and 1.52 kg. The results from the study were similar to other author. Bulb length and breadth was significantly affected by variation in germplasm that the maximum bulb length was obtained from Gp40 (9.10 cm), while Gp66 was minimum (4.413 cm) with mean value of (5.983), CV % (3.10) and SD (1.16), respectively. Whereas, maximum bulb breadth showed by Gp73 (29.33 cm), minimum (1.950 cm) by Gp28 and their mean value, CV, SD is 3.431, 3.56, and 0.74, respectively (Table 3; Table 4b). Jagadeesh *et al.* (2010) reported bulb lengths mean (5.71), CV (19.09), SD (1.09), minimum (4.23) cm and maximum 7.83 cm while breadth mean (3.32), CV % (7.51), SD (0.55), minimum (2.38 cm) and maximum (5.03 cm), respectively.

Number and weight of seed: Seed quantity had significantly varied from germplasm to germplasm. The highest number of seed (313) produced by Gp28 per fruit while the lowest (30.667 pieces) seed was found in the Gp40 with the mean, CV % and SD values of 123.169, 5.86 and 52.26, respectively (Table 3; Table 4b). Jagadeesh *et al.* (2010) reported maximum (445) and minimum (19) seed producing jackfruit with the mean (141.86), CV % (65.82) and SD (93.37). The results of the present study was almost similar to other researcher. The weight of seed had significantly influenced by germplasm variation. The maximum weight of seed (1.733 kg) was obtained from Gp17 while the minimum weight (0.227 kg) was noted from Gp66. The mean, CV % and SD were also recorded as 0.682, 7.72 and 0.33, respectively (Table 3 and Table 4b). Karim *et al.* (2008) noted minimum (0.59 kg) and maximum (0.79 kg) seed producing germplasm. Reddy *et al.* (2004) also reported the highest (12.30 kg) and the lowest (5.00 kg) seed producing jackfruit clone in their study. Results are highly varied with other researcher due to germplasm variation, study location and harvesting time.

Seed length and breadth: From the table 3 and 4b, it was clear that the seed length and breadth was varied significantly among the germplasm. The maximum seed length (4.017 cm) was recorded from Gp40, minimum (1.667 cm) from Gp3 while the mean (2.983), CV % (4.93), SD (0.44), respectively. On the other hand seed breadth was the highest (2.71 cm) in Gp47 and the lowest (1.30 cm) in Gp61 with the mean values of 1.931, CV % (6.60) and SD of 0.30 (Table 3; Table 4b).

Table 4b. Physical properties of collected jackfruit germplasm from the south-western region of Bangladesh

GP no.	Bulb number	Bulb including seed wt. (kg)	Bulb length (cm)	Bulb breadth (cm)	Bulb wt. excluding seed wt. (kg)	Seed number	Seed wt. (kg)	Seed length (cm)	Seed breadth (cm)
01	273.667	3.470	4.493	2.133	2.753	268.000	0.717	3.167	1.383
02	137.000	3.490	4.753	3.173	2.777	134.667	0.713	2.920	1.723
03	208.667	2.353	6.180	2.667	1.742	203.000	0.611	1.667	1.977
04	207.667	2.207	4.900	2.850	1.230	205.000	0.977	3.497	1.427
05	192.000	3.147	6.100	2.533	1.387	190.667	1.760	3.883	1.560
06	186.667	2.283	4.787	2.600	1.353	181.667	0.930	2.850	1.367
07	92.333	3.467	6.167	3.100	2.961	88.667	0.506	3.100	2.100
08	188.667	4.617	4.133	3.100	3.830	182.333	0.787	2.850	1.850
09	220.667	4.340	5.750	2.800	3.222	215.333	1.118	3.000	2.027
10	128.000	4.000	4.900	4.400	3.097	123.000	0.903	3.433	2.300
11	115.333	2.683	5.683	3.333	2.038	109.667	0.645	2.500	2.083
12	146.333	4.650	6.850	3.267	3.823	138.667	0.827	3.300	2.000
13	160.667	5.497	5.760	3.267	4.710	154.667	0.787	2.833	2.100
14	161.000	6.350	6.033	3.833	5.583	152.333	0.767	2.727	1.950
15	183.000	4.080	2.973	2.570	3.571	179.333	0.509	2.000	1.533
16	134.333	3.403	5.593	4.117	3.005	130.000	0.399	2.723	1.813
17	282.667	6.363	7.750	2.800	4.630	173.000	1.733	3.200	2.000
18	69.667	2.933	6.060	4.117	2.430	66.000	0.503	3.317	2.233
19	153.333	5.033	6.067	3.100	4.100	151.000	0.933	2.000	1.390
20	117.000	3.820	5.433	3.817	3.297	115.000	0.523	3.117	2.633
21	182.333	4.550	6.500	3.583	3.817	176.000	0.733	2.633	1.817
22	116.000	3.390	6.000	3.067	2.994	113.667	0.396	2.567	1.820
23	156.667	4.780	7.117	3.183	4.127	151.333	0.653	3.083	1.797
24	84.000	2.400	5.050	3.050	2.077	80.000	0.323	2.667	1.793
25	143.000	7.233	7.267	3.867	6.545	139.667	0.688	3.100	2.100
26	143.667	3.033	5.620	2.700	2.231	137.000	0.803	3.100	1.820
27	132.667	3.527	5.903	3.083	2.797	127.333	0.729	3.550	1.900
28	324.667	5.767	5.747	1.950	4.164	313.000	1.603	3.133	1.850
29	201.333	4.400	5.967	3.300	3.533	194.000	0.867	2.777	1.850
30	125.667	4.000	7.217	3.400	3.301	120.667	0.699	3.110	2.083
31	100.667	3.000	5.500	3.367	2.179	95.667	0.821	3.083	2.000
32	122.333	3.273	5.800	3.517	2.407	120.667	0.867	3.283	2.117
33	105.667	2.820	5.833	3.400	2.150	100.333	0.670	3.033	2.200
34	91.333	3.200	7.200	3.883	2.687	87.333	0.513	3.383	1.717
35	75.000	3.167	6.707	4.017	2.888	73.667	0.279	2.917	1.797
36	151.000	3.773	6.147	2.817	3.073	147.333	0.700	3.117	1.850
37	45.333	2.047	5.733	3.317	1.593	45.333	0.454	3.267	1.890
38	81.333	3.557	6.367	4.600	3.118	78.000	0.439	3.083	2.083
39	81.667	2.190	4.900	3.050	1.660	77.333	0.530	3.400	1.873
40	33.000	2.467	9.100	4.500	2.181	30.667	0.286	4.017	2.167
41	113.333	3.633	7.400	4.100	2.910	104.667	0.723	3.517	2.503
42	105.667	2.023	5.670	3.317	1.531	102.000	0.493	2.510	1.817
43	41.667	2.657	6.617	4.783	2.423	41.333	0.233	2.740	1.753
44	91.333	3.017	5.150	4.300	2.260	85.000	0.757	2.900	2.183
45	141.333	5.033	6.367	3.017	4.617	135.667	0.417	2.903	1.893
46	199.333	3.750	5.023	3.100	2.427	190.667	1.323	3.643	2.493
47	140.000	4.133	5.150	3.883	3.151	132.333	0.982	3.810	2.710
48	209.667	5.600	7.083	2.517	4.074	199.333	1.526	3.527	1.790
49	64.333	2.267	4.880	3.450	1.930	62.667	0.337	2.450	1.743
50	148.000	5.667	7.267	3.883	4.210	143.667	1.457	3.283	2.080
51	90.333	2.133	7.087	2.900	1.243	88.000	0.890	2.567	1.867
52	105.000	3.300	6.017	2.750	2.738	99.333	0.562	2.737	1.947

53	71.000	3.687	6.717	5.217	3.188	68.000	0.499	3.150	2.037
54	154.667	2.897	5.727	3.817	2.333	150.333	0.563	3.433	1.867
55	157.000	3.617	6.167	3.133	3.017	152.667	0.600	2.477	2.033
56	149.667	3.367	5.983	3.233	2.749	147.333	0.617	3.000	1.913
57	167.333	3.457	5.200	2.917	2.703	163.000	0.753	3.150	2.360
58	94.000	3.413	6.530	3.500	2.948	91.667	0.465	3.123	1.723
59	81.000	2.553	6.033	3.067	2.138	76.667	0.415	3.050	1.550
60	90.000	3.890	4.650	4.050	3.462	85.000	0.428	2.373	2.017
61	124.333	4.697	8.000	2.483	4.129	118.667	0.568	3.350	1.300
62	118.667	3.867	6.667	2.767	3.418	115.667	0.448	2.810	1.907
63	59.667	2.467	5.767	4.017	2.164	57.333	0.303	2.567	1.667
64	116.333	2.810	5.467	3.183	2.367	111.333	0.443	3.000	1.800
65	63.000	2.383	7.020	3.483	1.993	59.000	0.390	3.073	1.837
66	61.667	2.260	4.413	3.550	2.033	56.333	0.227	3.040	2.277
67	120.667	3.367	4.900	3.717	2.912	114.667	0.454	2.570	2.190
68	88.333	3.077	7.217	3.550	2.717	84.000	0.360	3.260	1.630
69	118.333	5.247	6.500	4.000	4.417	115.667	0.830	3.400	1.743
70	72.333	2.040	6.517	4.117	1.639	66.000	0.401	3.167	1.820
71	126.333	3.077	5.283	3.083	2.610	119.000	0.467	2.827	2.413
72	96.000	2.117	6.000	2.683	1.648	91.000	0.468	2.677	1.807
73	74.000	3.733	8.317	6.880	3.080	63.333	0.653	2.510	1.980
74	107.667	3.067	4.577	3.543	2.640	101.333	0.427	2.460	2.283
75	80.000	2.017	5.333	4.100	1.082	74.000	0.935	2.250	1.953

Weight of edible portion (bulb and seed): The maximum weight of edible portion (7.233 kg) was obtained from Gp25 while the minimum weight (2.017 kg) was noted from Gp75 with the mean, CV % and SD values of 3.561, 5.25 and 1.16, respectively (Table 3; Table 4b). It was revealed that the results on the weight of edible portion that had significantly affected by genotype variation. Karim *et al.* (2008) stated that when they considered the selection, it was found that the weight significantly affected. And he recorded the maximum (4.25 kg) weight of edible portion while minimum (2.56 kg). According to Jagadeesh *et al.* (2010), the highest (12.195 kg) and the lowest (1.445 kg) edible portion was estimated from each jackfruit.

4.2 Biochemical Properties Analysis

pH of fruit pulp: There was a significant variation in the germplasm in respect of pH of fruit pulp. The highest pH (5.907) was estimated from Gp54 and the lowest (4.827) from Gp17 with the mean, CV % and SD values of 5.516, 3.47 and 0.36, respectively (Table 3; Table 5). Mannan *et al.* (2005) reported that the highest pH of fruit pulp was 5.82 and the lowest pH content of fruit pulp was 5.25. Karim *et al.* (2008) showed no significant difference in pH due to the harvesting times which were in the range from 5.60 to 5.65. But, he also stated that selections had effect of insignificant variation in pH.

Total soluble solids (brix %) of fruit pulp: Total soluble solid content observed the highest (29.200 %) in Gp1 while the lowest (11.10 %) was recorded from Gp57 with the mean, CV %, SD values of 20.180, 1.74 and 3.59, respectively (Table 3; Table 5). Jagadeesh *et al.* (2010) reported the highest TSS (35 %) and the lowest (16.13 %), SD (4.14), CV % (17.15) and mean

(24.14) from a study of some genotypes of jackfruits. Karim *et al.* (2008) stated no significant difference in total soluble solid content of bulb due to the harvesting times. Haque (1993) found that the total soluble solids in green jackfruit were 18 % and 20 % in ripe jackfruit bulb. Total soluble solid content observed in the present study agree with the above report. Mannan *et al.* (2005) observed the highest TSS of fruit pulp 18.47 % and the least (13.05 %). Similar results were also reported by Haque (1991 and 2005).

Titrateable acidity of fruit pulp: The highest (0.593 %) TA was recorded from Gp56 while the lowest (0.117 %) in Gp69 with the mean, CV % and SD values of 0.331, 2.47 and 0.12, respectively (Table 3; Table 5). Jagadeesh *et al.* (2010) reported the highest TA (0.552%), the lowest TA (0.160%), SD (0.094), CV% (31.76) and mean (0.296), respectively. Mannan *et al.* (2005) reported the maximum amount of TA content 0.80 % and minimum amount 0.50 %. Similar results were also repeated by Ranganna (1979). Reddy *et al.* (2004) estimated highest (0.68 %) and lowest (0.18 %) of TA content of fruit pulp. However, the variation in titrateable acidity among the germplasm was significant.

Table 5. Biochemical properties of collected jackfruit germplasm from the south-western region of Bangladesh

GP No.	pH	TSS	TSS: T A	Carbohydrate mg/100 g	Flavonoid mg/100 g	Ascorbic acid mg/100 g	Anthocyanin mg/100 g	Carotenoid mg/100 g	T A
01	5.623	29.200	125.334	25.217	19.133	6.177	0.101	0.557	0.233
02	5.547	27.400	119.825	24.760	16.167	6.377	0.101	0.663	0.229
03	5.807	24.167	95.147	24.000	14.483	5.220	0.102	0.418	0.254
04	5.767	20.900	73.681	23.000	20.177	6.243	0.100	0.263	0.284
05	5.560	22.200	78.723	23.217	22.587	5.840	0.101	0.445	0.282
06	5.680	22.167	87.273	23.263	17.727	4.857	0.130	0.383	0.254
07	5.707	21.633	48.869	22.467	18.450	6.243	0.148	0.203	0.443
08	5.607	24.267	123.403	23.993	16.573	6.610	0.118	0.282	0.197
09	5.627	20.200	115.890	20.407	18.187	5.053	0.203	0.170	0.174
10	5.547	22.467	60.020	23.333	20.100	6.473	0.133	0.440	0.374
11	4.943	16.133	43.871	18.960	21.410	6.610	0.160	0.486	0.368
12	5.890	21.200	58.297	22.713	13.270	5.797	0.178	0.184	0.364
13	5.563	19.000	115.879	21.553	11.463	5.033	0.183	0.435	0.164
14	5.720	17.133	138.256	22.367	18.753	5.210	0.122	0.504	0.124
15	4.917	22.600	123.957	26.000	18.520	3.427	0.140	0.787	0.182
16	5.707	20.200	96.804	22.300	20.790	3.210	0.180	0.470	0.209
17	4.827	24.800	87.530	26.500	17.667	5.077	0.165	0.358	0.283
18	4.897	26.033	71.524	23.133	17.793	5.477	0.143	0.497	0.364
19	5.430	19.033	50.376	23.033	19.243	5.067	0.142	0.419	0.378
20	5.363	23.400	64.433	23.960	14.660	7.433	0.130	0.613	0.364
21	5.730	21.100	107.286	23.533	15.127	5.490	0.182	0.366	0.197
22	4.920	22.000	65.609	23.167	16.713	5.233	0.150	0.249	0.335
23	5.790	19.000	49.309	22.517	18.333	5.707	0.153	0.249	0.385
24	5.850	23.733	51.157	25.707	17.790	5.010	0.099	0.174	0.464
25	4.923	16.933	41.777	21.500	17.657	5.943	0.101	0.687	0.405
26	5.750	16.000	47.624	22.627	18.960	7.530	0.120	0.672	0.336
27	4.913	27.867	90.381	25.893	19.073	5.150	0.095	0.516	0.308
28	4.967	22.900	68.630	23.967	18.707	6.753	0.214	0.319	0.334
29	5.670	19.000	35.292	22.580	17.430	7.700	0.093	0.238	0.538
30	5.800	15.100	38.360	19.300	16.917	4.500	0.247	0.389	0.394
31	5.763	19.167	73.234	20.267	15.627	4.500	0.089	0.293	0.263
32	4.923	16.167	61.609	23.067	16.413	6.103	0.085	0.360	0.263
33	5.820	24.400	85.623	26.500	22.613	5.823	0.089	0.527	0.285
34	5.780	21.000	70.526	23.200	18.320	5.223	0.091	0.421	0.299
35	5.820	13.033	39.319	21.533	15.533	6.670	0.098	0.157	0.333

36	5.807	15.000	31.570	22.400	37.547	4.490	0.068	0.222	0.475
37	5.860	25.000	70.041	24.000	12.560	5.253	0.099	0.375	0.357
38	4.940	23.000	61.553	24.000	17.657	5.000	0.238	0.459	0.374
39	5.043	22.000	51.212	23.190	18.273	5.637	0.078	0.559	0.430
40	5.000	20.000	37.038	22.500	19.120	5.433	0.121	0.364	0.540
41	5.667	21.467	59.961	22.767	22.817	6.370	0.121	0.652	0.358
42	5.693	25.000	99.875	25.217	18.033	5.753	0.234	0.539	0.250
43	5.850	25.000	95.274	25.333	22.483	5.687	0.081	0.619	0.263
44	5.613	15.567	54.623	23.067	17.000	5.153	0.148	0.465	0.285
45	5.690	18.800	65.008	22.700	23.333	5.750	0.132	0.361	0.289
46	4.920	21.067	65.367	23.033	15.557	5.397	0.102	0.672	0.323
47	5.180	22.400	47.666	24.000	18.333	4.927	0.098	0.576	0.470
48	5.683	16.000	44.929	21.033	18.597	4.693	0.091	0.479	0.357
49	5.257	15.000	40.183	23.000	17.070	5.557	0.094	0.256	0.373
50	5.770	15.200	35.619	22.890	22.130	5.043	0.164	0.591	0.427
51	5.717	16.267	34.755	20.223	21.100	4.033	0.102	0.387	0.468
52	5.263	22.000	45.115	23.800	17.977	4.787	0.088	0.443	0.488
53	5.633	16.533	35.200	22.300	15.743	4.537	0.088	0.625	0.470
54	5.907	20.767	49.767	22.433	19.853	5.013	0.100	0.346	0.417
55	5.660	16.200	39.447	22.000	19.730	4.290	0.164	0.310	0.411
56	5.570	16.400	27.678	21.143	19.073	5.797	0.162	0.233	0.593
57	5.823	11.100	43.435	19.867	19.067	5.787	0.103	0.247	0.256
58	5.267	21.233	94.120	23.110	18.233	5.310	0.234	0.294	0.226
59	5.220	19.500	55.721	20.667	18.147	6.617	0.099	0.250	0.350
60	5.540	14.600	40.632	22.113	19.683	7.453	0.099	0.365	0.359
61	5.850	22.500	156.252	23.700	21.117	5.437	0.122	0.492	0.144
62	5.743	21.467	75.144	21.333	18.607	5.440	0.215	0.571	0.286
63	5.413	23.567	42.084	28.333	21.127	6.757	0.057	0.358	0.560
64	5.283	16.000	27.227	20.333	15.557	5.290	0.129	0.320	0.588
65	5.507	20.167	36.447	22.833	19.383	5.987	0.142	0.373	0.553
66	5.643	18.500	32.843	20.333	21.150	5.680	0.090	0.460	0.563
67	5.683	21.333	150.223	23.333	19.377	7.197	0.233	0.445	0.142
68	5.603	19.233	132.948	22.190	18.000	5.080	0.077	0.244	0.145
69	5.660	18.833	160.989	19.650	13.233	4.487	0.058	0.711	0.117
70	5.747	16.733	131.776	22.260	18.900	5.327	0.100	0.744	0.127
71	5.830	20.400	85.127	22.667	18.077	7.533	0.097	0.725	0.240
72	5.833	21.000	113.474	24.377	23.377	5.517	0.099	0.725	0.185
73	5.070	19.600	43.110	21.433	21.227	5.453	0.098	0.575	0.455
74	5.553	18.267	73.277	23.000	18.743	4.947	0.095	0.449	0.249
75	5.567	19.233	108.888	23.447	13.827	5.373	0.198	0.554	0.177

Ascorbic Acid (Vit-C) content of fruit pulp: The present study showed that ascorbic acid content was the highest (7.70 mg/100 g) ascorbic acid in Gp29 followed by Gp71 (7.533 mg/100 g) while the lowest (3.21 mg/100 g) from Gp16 with the mean, CV % and SD values of 5.574, 13.86 and 1.10, respectively (Table 3; Table 5). Mannan *et al.* (2005) recorded the highest vitamin C content of fruit pulp 5.08 mg/100 g and the lowest amount of ascorbic acid content was observed 4.81 mg. Similar results in respect of vitamin C content were also reported by Hossain *et al.* (1979). According to Karim *et al.* (2004), analysis of variance showed that the harvesting time had significant influence on the vitamin C where the maximum vitamin C content (5.06 mg/ 100 g) was obtained from the early harvesting time and the minimum (4.09 mg /100 g) late harvesting. Hossain and Haque (1979) stated that average ascorbic acid content of the bulb was 5.56 mg/100g. Thus, the present result was found to be close to that of the above authors. There is significant variation in vitamin C content among the

germplasm.

Carotenoid content: The highest (0.787 mg/100g) carotenoid was presented in Gp15 followed by Gp70 (0.744 mg/100g) while the lowest (0.157 mg/100g) in Gp35 with the mean, CV % and SD values of 0.435, 8.54 and 0.16, respectively (Table 3; Table 5). Jagadeesh *et al.* (2010) reported the highest (0.701 mg/100g) and the lowest (0.251 mg/100g) carotenoid, SD (0.093), CV % (17.35) and mean (0.536). The present study results are almost similar to other authors.

Flavonoid content: It was recorded from this study that flavonoid content was the highest (37.547 mg/100g) in Gp36, followed by (23.377 mg/100 g) flavonoid from Gp41, (23.333 mg/100g) in Gp45 while the lowest was (11.463 mg/100g) from Gp13 with the mean, CV % and SD values of 18.576, 3.92 and 3.39/0.73, respectively (Table 3; Table 5). The data of the present study shows that flavonoid contents were significantly influenced by germplasm variation.

Anthocyanin content: The highest (0.247 mg/100g) anthocyanin was estimated from Gp30 while the lowest (0.057 mg/100g) was recorded from Gp63 followed by Gp69 (0.058 mg/100g) with the mean, CV % and SD values of 0.128, 2.19 and 0.05, respectively (Table 3; Table 5). The data of the present study shows that anthocyanin contents were significantly influenced by germplasm variation.

Carbohydrate content: Total carbohydrate content was found the highest (28.333 mg/100 g) in Gp63 followed by Gp17 (26.5 mg/100 g) while the lowest in Gp11 (18.96 mg/100g) followed by Gp30 (19.3 mg/100g) with the mean, CV % and SD values of 22.874, 5.27 and 1.99, respectively (Table 3; Table 5). Jagadeesh *et al.* (2010) reported starch content the highest (8.68 %) and the lowest (0.87 %), SD (1.50), CV % (67.30) and mean (2.23). Rahman *et al.* (1999) also observed a wide variation in the starch content of jackfruits collected from different locations of Bangladesh.

TSS and TA ratio: It was calculated that the maximum TSS: TA was 160.989 in Gp69 while the lowest was 27.227 in Gp64 with the mean, CV % and SD values of 72.006, 3.31 and 34.23, respectively (Table 3; Table 5). Jagadeesh *et al.* (2010) reported the highest TSS: TA was 165.82 and the lowest was 43.17 with SD (32.64), CV % (36.49) and mean (89.46). However, TSS: TA was similar to other author.

A significant variation in physico-chemical characters of jackfruit and its bulbs was observed among the 75 jackfruit germplasm collected and studied from the south-western part of Bangladesh. The information related to these parameters enables to select the best germplasm for crop improvement. However, a very few studies were carried out with respect to survey and characterization of suitable jackfruit types for dessert purpose (Guruprasad 1981; Muralidharan *et al.* 1997; Mitra and Mani, 2000; Reddy *et al.* 2004; Mannan *et al.* 2005). Bulb characters depicted appreciably high coefficient of variation for edible portion weight. Bulb is the economically important part of jackfruit as it comprises the edible part. Bulbs with higher single bulb wt. and low skin thickness, low rachis wt. are attractive and commercially important especially when jackfruit is sold in minimally processed form. Hence, fruit wt. bulb wt. and rachis wt. can be considered for selection of elite jackfruit types. Bulb length and bulb breadth exhibited lower coefficient of variation than the other bulb parameters discussed. Few published reports indicated the variation for bulb characters in jackfruit clones (Muralidharan *et al.* 1997; Mitra and Mani, 2000; and Reddy *et al.* 2004). Seed related traits namely seed wt. and seed number also showed greater variation. Mitra and Mani (2000) and Reddy *et al.* (2004) made similar observations in jackfruit selections. More the number of seeds per fruit indicate more number of bulbs per fruit, although it may not guarantee the quantity and quality of edible portion. Hypothetically, between the two different jackfruits of equal mass, being rind and cylinder parameters and seed size constant, the fruit with less number of bold seeds will have more flake thickness and vice-versa. Higher seed percentage in total fruit mass will reduce the net edible portion. Hence selection may be carefully exerted for these traits taking thickness of bulbs also into account. TSS, pH, anthocyanin, flavonoid in the germplasm explored elicited a comparatively low variation signifying that these traits are conserved in nature while ascorbic acid, carotenoid and carbohydrate explored a higher diversity which need to account for selection. Nevertheless, a slight variation in these parameters can cause considerable impact on taste and nutrition. According to Mitra and Mani (2000), TSS (>25°B) and total sugars (>20 %) are important for dessert purpose jackfruits. Rahman *et al.* (1999) also observed a wide variation in the starch content of jackfruits collected from different locations of Bangladesh.

4.3 Genetic Diversity by RAPD analysis

Jackfruit is the most wide spread species of the *Artocarpus* genus. It forms forest associations with homesteads, tropical rain forests, dry evergreen forests, and the montane vegetation of mountain groups (Hossain and Nath, 1995). However, healthy, fresh tender leaves of 60 different Gps were collected for the isolation of good quality DNA. Matured leaves were avoided because they are rich in phenol, secondary metabolites and polysaccharides. Extraction and purification of DNA from fresh leaf tissues was done by using DNAzol protocol (Chomczynski *et al.* 1998). On the other hand, Puchooa, (2004) and some other author used the CTAB method of plant DNA extraction with or without modification. The quality of DNA was confirmed by 1 percent Agarose Gel Electrophoresis (Figure 1).

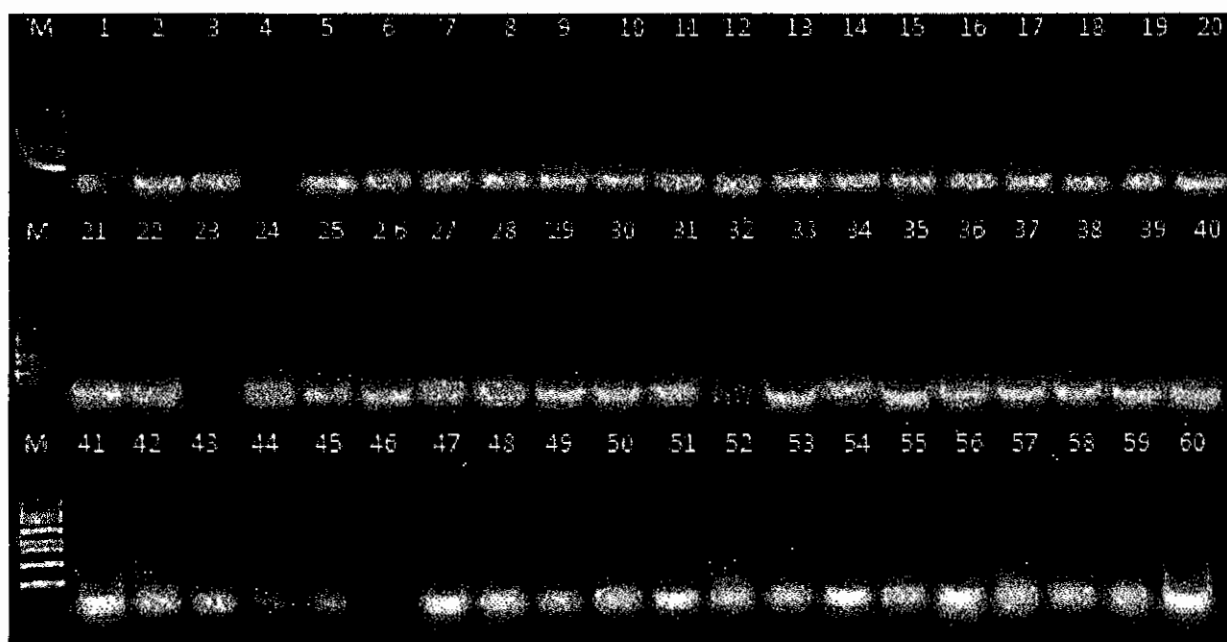


Figure 1. The gel profile of *Artocarpus heterophyllus* DNA extraction

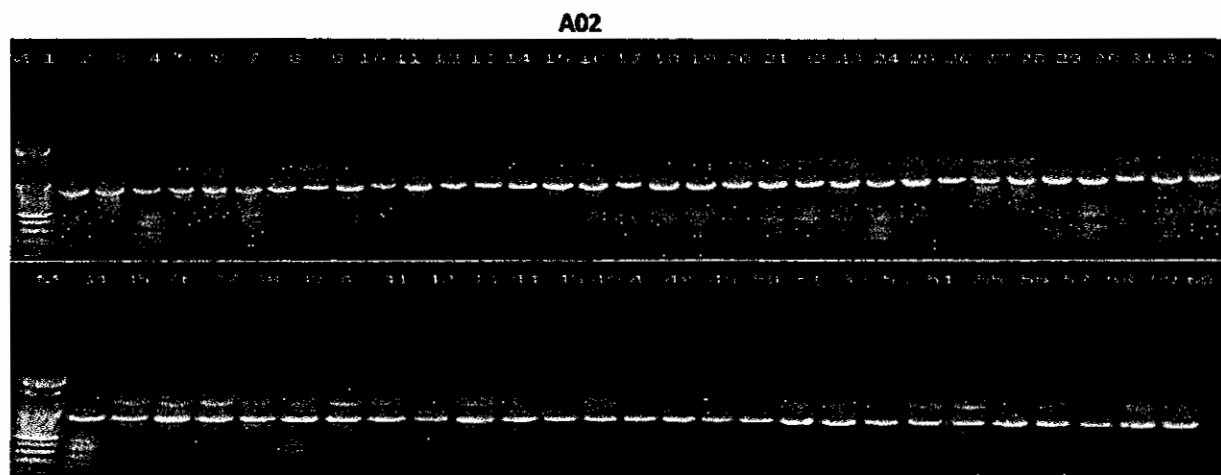
PCR is the technique of choice for nucleic acid quantification. The DNA quantity was determined by 260 nm and the UV spectrophotometer readings showed that the presence of DNA for the PCR stock. However, successful quantification depends crucially on the quality of the sample DNA analyzed. Whereas, Puchooa (2004) reported the yield of DNA per gram of leaf tissue extracted using a UV-VIS Spectronic Genesys spectrophotometer at 260 nm. Similarly, Katarina *et al.* (2006) confirmed the quality of DNA by 0.8 % Agarose Gel

Electrophoresis and DNA quantity was determined by 260 nm and quantified DNA was subjected to PCR amplification. Like others the purified DNA was quantified at 260 nm and the UV spectrophotometer readings (Table 6) showed that the presence of DNA at high concentration and subsequently, diluted the DNA to 100 ng/mL as per requirements for ideal PCR.

Table 6. UV spectrophotometer readings at 260nm showed the presence of DNA

GP No.	260 nm	GP No.	260 nm	GP No.	260 nm	GP No.	260 nm
01	0.086	16	0.045	31	0.043	46	0.026
02	0.068	17	0.026	32	0.037	47	0.025
03	0.029	18	0.051	33	0.040	48	0.027
04	0.021	19	0.023	34	0.027	49	0.041
05	0.076	20	0.064	35	0.048	50	0.027
06	0.027	21	0.022	36	0.038	51	0.026
07	0.046	22	0.031	37	0.034	52	0.022
08	0.041	23	0.061	38	0.031	53	0.024
09	0.048	24	0.031	39	0.035	54	0.032
10	0.060	25	0.029	40	0.039	55	0.025
11	0.026	26	0.038	41	0.038	56	0.024
12	0.025	27	0.051	42	0.022	57	0.025
13	0.046	28	0.036	43	0.027	58	0.031
14	0.033	29	0.039	44	0.005	59	0.024
15	0.038	30	0.031	45	0.037	60	0.025

The PCR was run with five primers and among them four primers showed reproducibility. The PCR product reproducibility and banding pattern was confirmed by 1.5 % and 2 % Agarose Gel Co-Electrophoresis with 1 kb and 100 bp ladders. In which it was found out that the perfect and clear banding pattern revealed from 2% Agarose Electrophoresis and most of band was similar to 100bp segregation ladder. This result is almost similar to others. All of the four representative polymorphic gel profiles using the primers (A02, A03, S7 and S18) are shown in figure 2.



A03

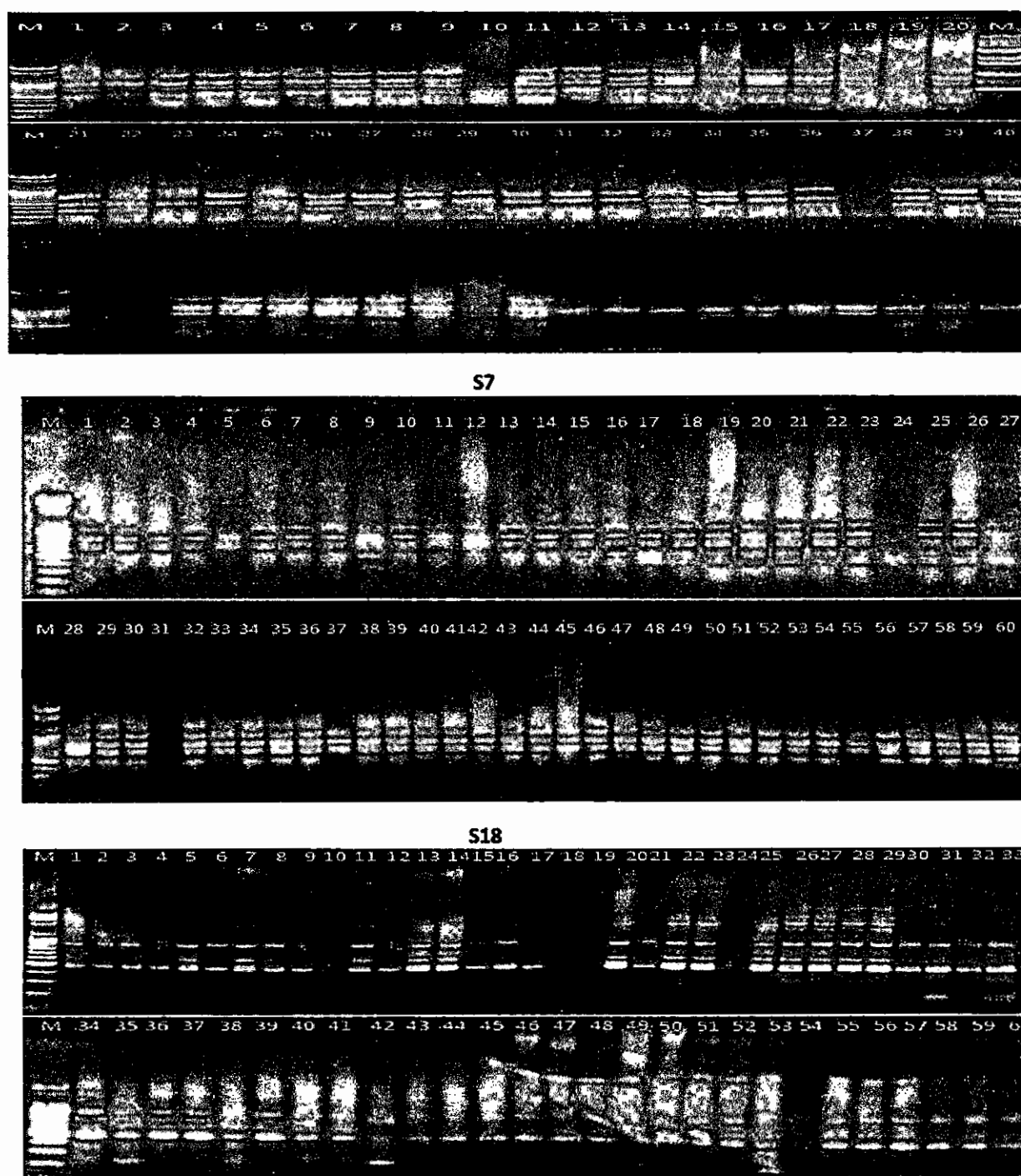


Figure 2. DNA bands generated by different RAPD primers

It is well established that RAPD technique had been successfully used in variety of taxonomic and genetic diversity studies (Rodriguez *et al.* 1999; Alam *et al.* 2009) and it was found suitable for use with *A. heterophyllus* genotype because of its ability to generate reproducible polymorphic bands. Monomorphic bands are those which are present in all individuals, polymorphic are present in one or more but not all individuals and unique ones are present in at least one individual not in any other (Mehetre *et al.* 2004). Indeed, we found (Table 7) 33 unambiguous, readable and reproducible RAPD markers were produced using

the four selected primers. The number of bands obtained the average of 8.25 bands using the primers, with the sizes ranging from 100 bp to 7.5 kb. Of the 33 bands, 21 bands (63.63%) were polymorphic and shared between in sixty germplasm while 12 bands (36.36%) were monomorphic whereas primer A02 and S18 is more reproducible.

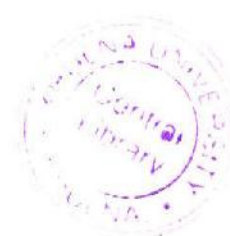


Table 7. RAPD primers data and the percentage of polymorphic bands

Primer code	Total no. of fragments	No. of monomorphic fragments (%)	Size of monomorphic fragments	No. of polymorphic fragment (%)	Size of polymorphic fragments
A02	09	04 (44.44%)	8 kb-5 kb	05 (55.56%)	4 kb -2.961 kb
			2.961 kb-1.6 kb		1.6 kb - 0.5 kb
A03	08	03 (37.50%)	1 kb-0.7 kb	05 (62.50%)	1.6 kb-1.2 kb
			0.4 kb-0.2 kb		0.5 kb-0.3 kb
S7	07	03 (42.86%)	1.2 kb-0.6 kb	04 (57.14%)	0.7 kb-0.3 kb
S18	09	02 (22.22%)	1 kb-0.8 kb	07 (77.78%)	2.5 kb- 1 kb
			0.6 kb-0.4 kb		0.5 kb-0.1 kb
Total	33	12 (36.36%)		21 (63.63%)	

However, evaluation of fragments patterns was carried out by diversity index. By scoring the data as for presence 1 and 0 for absence of bands and then RAPD analyzed using the Nei's genetic distance index (Nei and Li, 1979). On the basis of equation, $DI = 1 - 2N_{ij} / (N_i + N_j)$. Where N_{ij} is the common bands shared between samples i and j , N_i and N_j are the total no. of DNA bands for genotypes i and j , respectively. These results were used to calculate genetic distances and to prepare a dendrogram on basis of the distance matrix data by UPGMA analysis. The similarity between the analyzed variants ranged from 60.4 to 98.3% indicating their close relation. The lower genetic distance coefficient less than 2 % was between Gp4, Gp5, Gp7, Gp20, Gp18, Gp19 and Gp46, Gp47. The lower genetic similarity was between Gp24 and sub-clusters together, indicating a diverse genetic relationship at a linkage distance of 1.0% in the dendrogram (Figure 3). The dendrogram was constructed using neighbor joining method of cluster analysis separated all the sixty germplasm into two clusters at 0.13 distance coefficient. Cluster 1 (C-I) has only Gp24 accession. Cluster 2 (C-IA and C-IB) contained the remaining fifty nine accessions separated into 2 sub clusters. From the sub cluster C-IB and C-IA, it is found that Gp53, Gp54 and Gp56 are in a clad while all other are in a separate clad. The lowest diversity value of 0.017 indicates high similarity between Gp7 and Gp20. The genetic distance index between Gp27 and Gp53 was highest with a value of 0.396 (Table 8).

Table 8. Genetic diversity index from RAPD data of different jackfruit germplasm

Sample	Op1	Op2	Op3	Op4	Op5	Op6	Op7	Op8	Op9	Op10	Op11	Op12	Op13	Op14	Op15	Op16	Op17	Op18	Op19	Op20	Op21	Op22	Op23	Op24	Op25	Op26	Op27	Op28	Op29	Op30	Op31
Op1																															
Op2	0.001																														
Op3	0.12	0.14																													
Op4	0.14	0.18	0.18																												
Op5	0.001	0.001	0.001	0.001																											
Op6	0.001	0.001	0.001	0.001	0.001																										
Op7	0.001	0.001	0.001	0.001	0.001	0.001																									
Op8	0.001	0.001	0.001	0.001	0.001	0.001	0.001																								
Op9	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001																							
Op10	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001																						
Op11	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001																					
Op12	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001																				
Op13	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001																			
Op14	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001																		
Op15	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001																	
Op16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001																
Op17	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001															
Op18	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001														
Op19	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001													
Op20	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001												
Op21	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001											
Op22	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001										
Op23	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001									
Op24	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001								
Op25	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001							
Op26	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001						
Op27	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001					
Op28	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001				
Op29	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001			
Op30	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Op31	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	

*Nei's diversity coefficient generated by UPGMA analysis

The genetic structure of plant populations reflects the interactions of many different processes such as the long-term evolutionary history of the species (e.g., shifts in distribution, habitat fragmentation, and/or population isolation), mutation, genetic drift, mating system, gene flow, and selection (Slatkin, 1987; Schaal *et al.* 1998). All of these factors can lead to complex genetic structuring within populations. Genetic diversity is of great importance to the sustainability of plant populations. The results obtained confirm the usefulness and applicability of the RAPD method in determining genetic similarity. Although these all genotypes represented different geographical locations in south-western region of Bangladesh, the majority of them had a little physico-chemical diverse attributes.

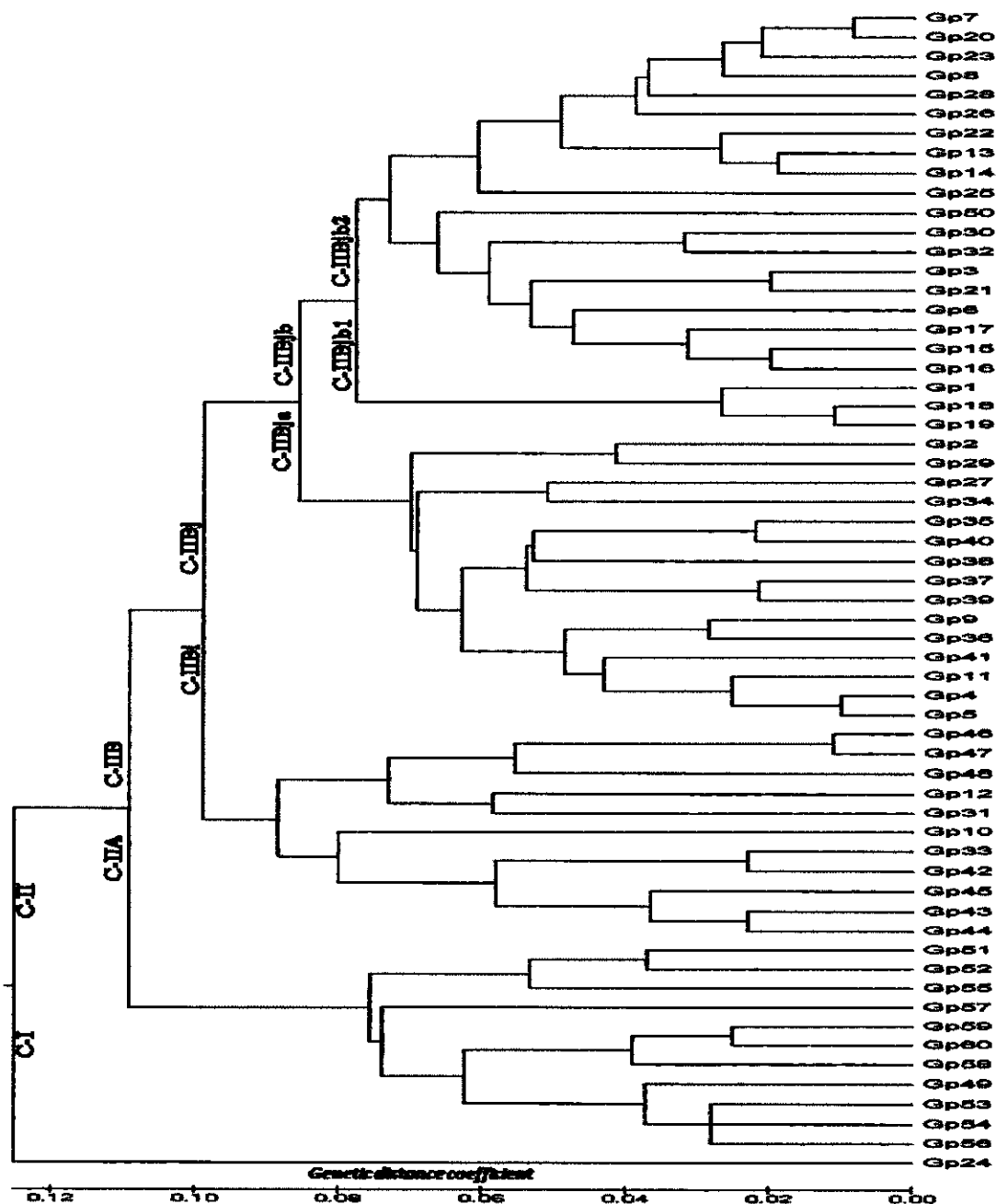


Figure 3. Dendrogram obtained from RAPD analysis using UPGMA

Based on the above results there are collections with high similarity index, even though they may be belonging to geographically different locations. High similarity indices suggest that the individuals in the population have close genetic relation among them. This situation can rise in natural populations when there is a possibility of free/random pollen flow and fertilization. The genetic similarity of the samples slightly correlated with their close geographic locations (Sayed *et al.* 2009). Sources of polymorphism in RAPD assay may be due to deletion, addition or substitution of base within the priming site sequence (Williams *et al.* 1990). High diversity is the reflection of adaptation to environment, which is beneficial to its propagation, resources conservation, the domestication of wild species and the screen of specified locus. Geographically isolated individuals tend to accumulate genetic variations during the course of environmental adaptations (Sarwat, 2008). Effective conservation of a species depends largely on the knowledge of patterns of genetic variation. For example, the spatial structure of genetic variation can provide information for sampling strategies for ex situ or in situ conservation (Torre *et al.* 2008). This study was an attempt to establish the genetic diversity background in *A. heterophyllus* with RAPD markers. High levels of polymorphism found in the present work showed that RAPD markers as a suitable tool for genetic diversity studies. This study could pave the way for detailed research to understand all the aspects of this divergence of Jackfruits.

5. SUMMARY AND CONCLUSION

A significant variation in physico-chemical characters of the jackfruit germplasm was observed among the 75 germplasm. In case of the quantitative traits, higher variability was observed for the properties like rachis weight (25.73 %), rachis length (11.65 %), skin weight (9.09 %), skin thickness (11.99 %) and spine length (8.13 %) while other parameter showed moderate coefficient of variation. Of the qualitative characters studied, a high coefficient of variation was measured for ascorbic acid content (13.86 %) and carotenoid content (8.54 %). Moderate coefficient of variation was observed for flavonoid (3.92 %) and carbohydrate (5.27 %) content while other parameter showed lower variation. Thirty three unambiguous, readable and reproducible DNA bands were produced from the four primers with the average of 8.25 bands and the sizes ranging from 100 bp to 7.5 kbp. Of the 33 bands, 21 (63.63 %) were polymorphic while 12 (36.63 %) were monomorphic in sixty individuals. The distance matrix data by UPGMA analysis and dendrogram showed the similarity between variants ranged from 60.4 to 98.3 % indicating their close relation. The lower genetic distance coefficient less than 2 % was between Gp4, Gp5, Gp7, Gp20, Gp18, Gp19 and Gp46, Gp47, respectively. The lower genetic similarity was detected in between Gp24 and other germplasm. The dendrogram cluster analysis separated all the sixty germplasm into two clusters at 0.13 distance coefficient. Cluster 1 has only Gp24. Cluster 2 contained the remaining fifty nine germplasm separated into 2 sub clusters in which Gp53, Gp54 and Gp56 are in a clad while all other are in a separate clad. The lowest diversity value of 0.017 indicates high similarity between Gp7 and Gp20. The genetic distance index between Gp27 and Gp53 was highest with a value of 0.396. All these physico-chemical parameters of the jackfruits may be given due consideration to operate selection procedure for identifying elite selections. Most of the biochemical characters of bulbs showed comparatively lower coefficient of variation, pointing that these parameters are conserved during the process of evolution. In addition, RAPD markers have proved to be effective for characterizing the genetic basis of *A. heterophyllus* for assessing genetic diversity and relatedness between accessions. In this study, the PCR reactions were performed in optimal conditions and informative RAPD fragments were obtained with high reproducibility. Even though this study showed close relationships among a few genotypes studied, there were still no duplicates. Although we found a good correlation between genetic and geographical data, future studies involving a large number of morphological and biochemical traits with molecular markers should have important implications for germplasm management. The result of this study is of critical importance for jackfruit breeding programs and efficient management of germplasm collections.

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