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Morphological Characterization of Gac Fruit (*Momordica cochinchinensis* SPRENG) Based on Qualitative and Quantitative Traits

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ABSTRACT

Momordica cochinchinensis is a fruit which originated from South-East Asia and it is a newly introduced crop in Malaysia. It is a superfruit with high nutritional and medicinal properties. However, being an introduced crop, gac fruit is a less-known fruit in Malaysia. A study was conducted in International Islamic University Malaysia (IIUM), Kuantan Pahang involving a total of four gac fruit accessions. The objective of this study was to characterize gac fruit morphology involving qualitative and quantitative morphological traits. Completely randomized design with five replications was used. Based on qualitative traits, variations were observed in parameters such as leaf color, leaf venation, leaf apices, leaf bases, fruit shape and spike density. Generally, the gac fruits were reddish-orange in color, the leaf was dark green on the adaxial part and light green on the abaxial part, and the female and male flower was light yellow and white in color. Analysis of variance revealed significant differences ($P<0.05$) among accessions in all quantitative traits evaluated. The fruit weight ranged from 193.72 g (Gac Damansara, GD) to 334.70 g (Gac Hulu Langat, GH), fruit length ranged from 9.42 cm (Gac Damansara, GD) to 12.13 cm (Gac Hulu Langat, GH), leaf size ranged from 218.43 cm^2 (Gac Damansara, GD) to 337.96 cm^2 (GM) and seed weight ranged from 1.43g (Gac Melaka, GM) to 3.94g (Gac Kuantan, GX). Overall, the study revealed significant morphological differences among the accessions evaluated, indicating genotypic diversity that can be incorporated into breeding programs.

Keywords: Characterization, gac fruit, morphology, qualitative, quantitative

INTRODUCTION

Gac fruit or its scientific name is *Momordica cochinchinensis*, a family of Cucurbitaceae, where it has the following characteristics in general, a dioecious tendril-bearing climber, scarcely without tendrils and they are present with one per node. Gac fruit is native to South-East Asia region found commonly grown as food crop in Vietnam, Thailand, Laos, Myanmar and Cambodia (Le et al., 2018). Gac fruit is reported to have various uses from its seed to its fruit. The aril is cooked along with rice to extract its red pigments and its flavour oil is used to make "Xoi Gac", which is a rice used during festivals in Vietnam (Toan et al., 2017). Young gac fruits and shoots are used widely as food ingredients in Thai cuisine (Kubola & Siriamornpun, 2011). Aside from being used as food source, gac fruit also possess medicinal properties. Seeds are reported to have therapeutic effects on various

conditions such as fluxes, liver and spleen disorders, haemorrhoids, treating wounds, bruises and swelling (Behera et al., 2011). Studies also revealed that high-value compounds such as lycopene, β-carotene, vitamin E and high amount of antioxidant with good bioavailability are present in the gac fruit (Abdulqader et al., 2018). It is very valuable for anti- inflammatory and anti-cancer activities and reducing cardiovascular diseases (Abdulqader et al., 2019).

Despite the importance of gac fruit are tremendous, the crop remains neglected and underutilized in many countries including Malaysia. Morphological characterization is essential to describe the characteristics of cultivars and landraces which then serve as a genetic guide in selection of parents for hybridization while broadening the genetic base of the cultivated plant varieties (Tembe et al., 2020). However, there are limited studies that have characterized gac fruit accessions. Lack of information available on genetic diversity of gac fruit hinders its crop improvement programs. Information on genetic diversity is considered important and vital for plant breeding program to help selecting the right genetic material to be used (Toan et al., 2018). To date, there has been no detailed study on variations in the gac fruits traits in Malaysia. Therefore, the aim of this study was to evaluate qualitative and quantitative morphological traits in a collection of gac fruit accessions. These findings should also help with the selection of core collections and accessions that can be used for gac fruit breeding in the near future.

MATERIALS AND METHODS

Planting materials preparation

A total of four gac accessions (seeds) were used in this study (Table 1). The gac fruit seeds were gathered from around Malaysia. The seeds of the gac fruit were planted by hand in plastic pots and transplanted into polybags at Kuliyyah of Science International Islamic University Malaysia's open field experimental plot (IIUM), Kuantan Pahang. The experimental design made use of a Completely Randomized Design (CRD). The experimental units had five replications of each of the four different gac accessions, with a distance of one metre between rows and fifty centimetres between plants in each row. Structures made of polyvinyl chloride (PVC) were utilized as trellises to support plants as they twisted and climbed. The rows were lined with the trellis. Weekly applications of organic chicken dung were applied. Caviota 2000 liquid fertilizer were also applied through spraying. The plants were irrigated twice daily through an automated overhead sprinkler system. When necessary, weeding is also practised and application natural fungicide was also used.

Table 1. List of four gac accessions were used in the analysis

Accession Name Code	Accession Name	Region of seed collection
GD	Gac Damansara	Kota Damansara, Selangor
GM	Gac Melaka	Melaka Tengah, Melaka
GH	Gac Hulu Langat	Hulu Langat, Selangor
GX	Gac Kuantan	Kuantan, Pahang

Morphological evaluation

Qualitative morphological evaluation

The morphological characteristics of gac fruits were investigated and observed. Fruits were cut into slices, and seeds were removed from arils for storage at -20 °C. The traits of the plant, including its leaves, flowers, fruits, and seeds were evaluated (Table 2).

Table 2. Qualitative characters of gac fruit

Characters	Descriptions (Grouped into categories)
Growth habit	Climbing
Branching habit	Orthotropic
	Leaf
Leaf shape	Palmatipartite, Clasping base
Leaf color	Dark green, Deep green, Light green
Leaf lobes	None, Three, Five
Leaf venation	Palmate, Reticulate
Leaf apices	Acuminate, Acute
Leaf bases	Cordate, Sagittate
Leaf edges	Serrate, Doubly serrate
Leaf surface	Smooth, Glabrous, Shiny
Leaf arrangement	Alternate
	Flower
Petal color	Light yellow, Yellow, Deep yellow, Creamy, Light creamy, Deep creamy
	Fruit
Fruit color	Reddish, orange reddish, orange
Fruit shape	Globose, Globose oval, Oval, Tapered
Surface (Spike density)	Dense, Medium, Sparse
	Seed
Seed shape	Round, Oblong
Seed color	Light brown, Blackish brown, Brown, Light brown
Seed surface	Smooth, Rough

Quantitative morphological evaluation

Quantitative characters of gac were characterized which include: (i) fruit weight, (ii) fruit width, (iii) fruit length, (iv) seed weight, (v) seed length, (vi) number of mature and immature seed, (vii) number of flower petal, (viii) leaf width and (ix) number of leaf lobes. A ruler was used to measure the width, length, leaf width, and seed length of the fruits. All characterizations, such as the minimum and maximum record, mean, coefficient of variation (%), and Mean SE, were recorded and analysed.

Morphological data analysis

Thirty samples with complete fruit, seed and leaf morphology data were included in the analysis (Table 2). Analysis of variance (ANOVA) was performed to compare the means of all the recorded parameters and the Tukey test was employed to see whether there were any statistically significant differences between the means of any of the quantitative features. The post-hoc Tukey HSD (Honestly Significant Difference) test was also used to determine the significance of a comparison.

RESULTS AND DISCUSSION

Morphological analysis

Qualitative Characteristics of gac fruit

The leaf had a palmatipartite shape, an alternating arrangement and a glabrous surface. The adaxial and abaxial portions of the leaf were each a different shade of green. The apices had a dentate border and were extensively acuminate. Gac features short, sub-apical bracts, rotating, wheel-shaped corollas, and both male and female petals that range in hue from creamy yellow to light yellow. Male flowers, on the other hand, were inflorescences that could be both cymose and racemose. Male flower sepals were coriaceous and shaped like ovate-oblongs, whereas female flower sepals were linear oblongs. The fruit was round with spiky spikes that ranged from sparse to medium and dense. Gac fruit ranges in colour from orange to red. The seed ranged in colour from dark brown to black. The summary of qualitative morphological data on four gac accessions is shown in Table 3.

Gac fruit leaves

Results analysis revealed a wide range of variability in the leaf's characteristics. In terms of colour and leaf parts, GD, GM, and GH all had the same leaf morphology. Three accessions were identified as having dark green adaxial and light green abaxial parts. The adaxial part of accession GX, on the other hand, was deep green in colour, whereas the other three accessions had broadly acuminate apices. With its abruptly acuminate apices, GH stood out from the rest of the accessions. GX accession was also the only accession with a distinct leaf base that was cordate with a doubly serrate margin (Figure 1).

The other three accessions (GD, GM, and GH) had auriculate bases and dentate margins. This suggested that the character was shared by all, implying that the gene responsible for the auriculate base and dentate margin is expressed more phenotypically than the cordate and doubly serrate margin. The four accessions also shared similar characteristics in terms of leaf shape (palmatipartite), alternate leaf arrangement, palmate leaf venation, and the presence of tendrils and petioles (Nakano, 2020). This indicates that heterozygous alleles control both characters. Except for GX, which had a smoother and shinier surface, all four accessions had glabrous surfaces. The morphology of gac leaves is depicted in Figure 1. It is unclear whether genetic or environmental factors are to blame for the variances in leaf diversity. Similarly, it is unknown whether the diversity of gac vegetative components correlates with traits that are important economically, like enhanced fruit productivity (number and size of fruits produced per plant) or nutritional and phytochemical content.

Gac fruit flowers

Gac's male and female flowers were both light yellow in colour. The female flower of GH, on the other hand, was a creamy yellow in colour, similar to GX accessions. In another study, the flower petals ranged from white to ivory yellow, with vexillary aestivation, a rotated corolla and a wheel-shaped corolla in both male and female flowers (Bharathi and John, 2013; Wimalasiri et al., 2016). According to Gerrath et al. (2008), male flowers are carried by racemose or cymose inflorescences. Female flowers are usually solitary and have a smaller ovary. Figure 2 depicts the morphology of gac fruit flowers.

Table 3. Summary of qualitative morphological data on 4 gac fruit accessions

Accessions/Morphology				Damansara (GD)	Melaka (GM)	Hulu Langat (GH)	Kuantan (GX)
Leaf	Color	Adaxial (upper part)		Dark green	Dark green	Dark green	Deep green
		Abaxial (bottom part)		Light green	Light green	Light green	Light green
	Shape			Palmatipartite	Palmatipartite	Palmatipartite	Palmatipartite
	Arrangement			Alternate	Alternate	Alternate	Alternate
	Venation			Palmate	Palmate	Palmate	Palmate
	Apices			Broadly acuminate	Broadly acuminate	Abruptly acuminate	Broadly acuminate
	Bases			Auriculate	Auriculate	Auriculate	Cordate
	Surface			Glabrous	Glabrous	Glabrous	Glabrous, smooth, shiny
	Margin			Dentate	Dentate	Dentate	Doubly serrate
	Tendril			Presence	Presence	Presence	Presence
	Petiole			Presence	Presence	Presence	Presence
Accessions/Morphology				Damansara (GD)	Melaka (GM)	Hulu Langat (GH)	Kuantan (GX)
Flower	Petal	Color	Male	Light yellow and white	Light yellow and white	Light yellow and white	Light yellow and white
			Female	Light yellow and white	Light yellow and white	Creamy	White
		Aestivation	Male	Vexillary	Vexillary	Vexillary	Vexillary
			Female	Vexillary	Vexillary	Vexillary	Vexillary
		Corolla	Male	Rotate, wheel-shaped	Rotate, wheel-shaped	Rotate, wheel-shaped	Rotate, wheel-shaped
			Female	Rotate, wheel-shaped	Rotate, wheel-shaped	Rotate, wheel-shaped	Rotate, wheel-shaped
	Sepal	Surface	Male	Coriaceous	Coriaceous	Coriaceous	Coriaceous
			Female	Coriaceous	Coriaceous	Coriaceous	Coriaceous
		Shape	Male	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong
			Female	Linear oblong	Linear oblong	Linear oblong	Linear oblong

Accessions/Morphology				Damansara (GD)	Melaka (GM)	Hulu Langat (GH)	Kuantan (GX)
Flower	Bract	Shape	Male	Subapical	Subapical	Subapical	Subapical
			Female	Small and subapical	Small and subapical	Small and subapical	Small and subapical
Fruit	Stage			Ripe	Unripe	Fully ripe	Fully ripe
	Color			Reddish-orange	Yellowish-orange	Orange	Orange
	Shape			Globose-oval	Globose-oval	Tapered	Globose-oval
	Spike density			Medium	Dense	Sparse	No spikes
Seed	Shape			Round	Round	Round	Round
	Color		Mature	Dark brown	No mature seeds	Black	Brown
			Immature	Creamy-yellow	Creamy-yellow	No immature seeds	No immature seeds
	Surface			Wrinkled	Wrinkled	Wrinkled	Wrinkled

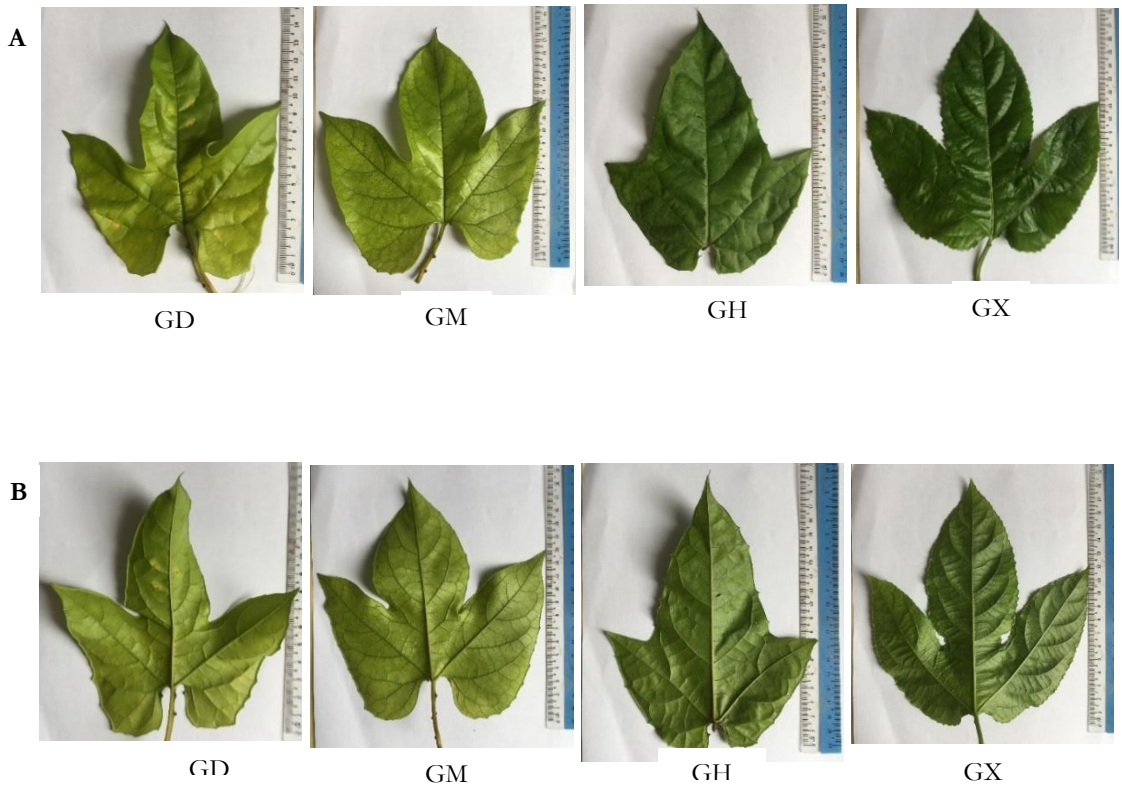


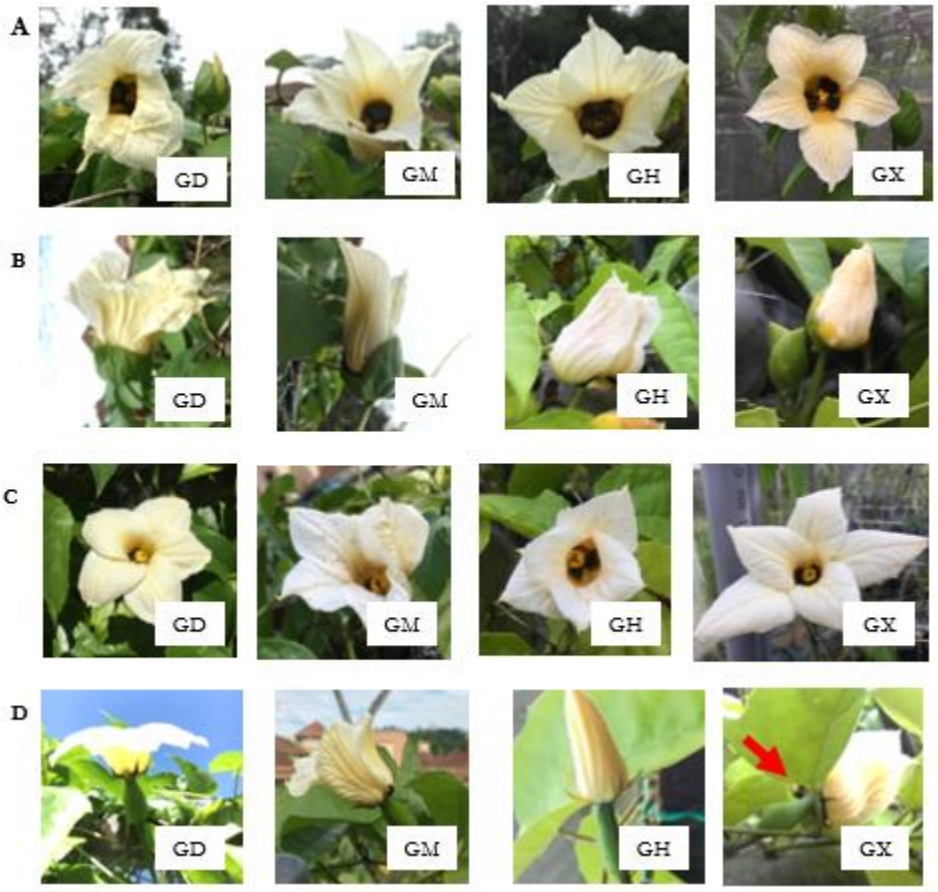
Fig. 1. (A) Adaxial part of leaves (B) Abaxial part of leaves. Scale bars: 2 cm
Note: Gac Damansara (GD), Gac Melaka (GM), Gac Hulu Langat (GH), Gac Kuantan (GX)

According to Toan et al. (2018), the female flower bud appears relatively later than the male flower. In this study, the opposite was observed. Female flower buds developed later on the vine than male flower buds in some gac accessions. Female flower buds appeared as early as 2 to 2.5 months after planting in other accessions, while male flower buds appeared later. Flowers from 16 gac accessions ranged in colour from predominantly white with yellow to white light yellow. Specifically, most GD and GM flowers began to flower in about a year or longer. Flowers took about 1 to 2 weeks to bloom from buds to full bloom. If there is no pollination, the flowers are not fertilised and begin to wilt. On the contrary, once pollination occurred, the flowers would turn into fruits in a matter of weeks.

Only twelve of the remaining planted plants developed fruits, which indicates that there was very little pollination of the gac fruit flowers. The male and female blooms were on separate plants because gac fruit is a dioecious plant. Before the plants began to bloom, it took almost a year to determine the gender of the plants. The male flower lacks any reproductive tissue, but the female flower has a carpel above the pedicel. Up to this moment, all four gac accessions from the four different gac collections had produced blooms. However, not all plants produced blooms, making it impossible to determine the gender of some plants.

Some limitations in gac reproductive behaviour were also discovered. Female flowers developed slowly and the production ratio to male flowers was lower, resulting in a lower pollen supplementation proportion of flowering maturing into fruit (Parks et al., 2013a; Tran et al., 2021). Even though there were female and male flowers, pollinators, specifically stingless bees (Meliponinae), the manual method of hand pollination was proven to be failed. The presence of stingless bees in the experiment field could aid in flower pollination. However, according to the findings of this study, the process was halted due to the presence of its adversary, weaver ants (*Oecophylla smaragdina*) (Duangphakdee et al., 2009). Weaves ants frequently attack stingless bees while scavenging for food.

Fig. 2. Flower morphology (A) Front view of male flowers (B) Side view of male flowers (C) Front view of the female flower (D) Side view of female flowers. The red arrows indicate the presence of the ovary (Female reproductive part)



Gac fruit fruits

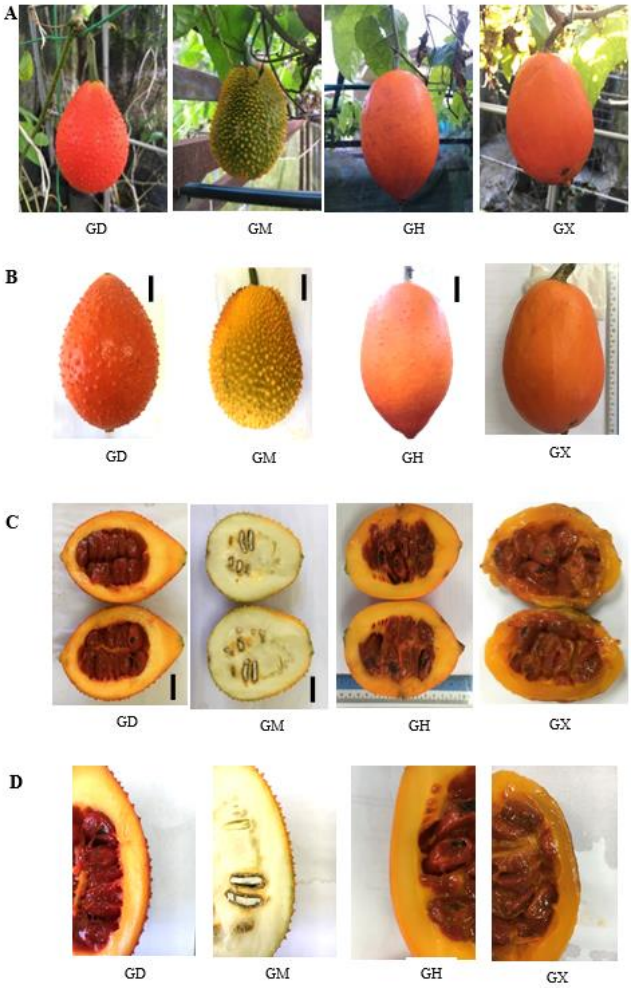
Fruit is a reproductive component with many variations. The fruit of the GD accession was reddish-orange in colour, globose-oval in shape and had a medium spike density. For GM accessions, the unripe fruit was yellowish-orange in colour, globose-oval in shape and densely spiked. At the same time, the GH accession's fruit was orange in colour, with a tapered shape and sparse spike density. GX, on the other hand, has ripe orange fruit with no spike density and a globose oval shape. According to previous research, the spine density of the fruits varies, ranging from dense spines that are hard and widely spaced (Vuong, 2000) to no spines (Wimalasiri, 2015). It is unclear whether these distinctions are genetic or environmental in nature, but they may be influenced by abiotic factors such as collecting locations or soil nutrients. This study will be critical in determining the origin of the cultivated gac. The fruit morphology of gac is depicted in Figure 3.

In a further study by Wimalasiri (2015), the fruit shapes in Southern Vietnam, Northern Vietnam (globose, globose oval, oval and tapering), Central Vietnam (globose oval and oval) and Thailand ranged from globose to globose oval (globose, globose oval and oval). Both Vietnam and Thailand accessions had globose and oval-shaped fruits, however only accessions from the country's northern region had tapering fruits. The fruits' prickly surfaces range in density from heavily to sparsely covered with spines. One accession from Northern Vietnam was the only one where scattered prickly surface was found. The most diverse fruit shape, surface texture, and seed types were found in Vietnam accessions, with globose to tapering morphologies highly correlated with

sparsely spiky surfaces. The fruits were picked when they were fully ripe and had turned an orangey-red to dark crimson colour, according to Toan et al. (2018). The fruit takes 4 to 10 weeks to reach maturity.

The ripe gac fruit can range in size. However, based on the observations, different accessions required different times for the fruit to ripen because the sizes varied. Larger fruits, particularly those collected from GH, took longer to mature. GD fruits appeared smaller than GH despite reaching the mature ripeness stage. At this rate, it took GD less than 5 weeks to harvest the fruit. The essential stage is important in this case because the gac fruit must be harvested before it is fully ripe to avoid wilting (Tran et al., 2020). Ripe gac fruit is dark orange to red in colour because gac fruit is a soft tree that is ready when the stalk end of the fruit or the exocarp and mesocarp parts feel fairly soft when gently squeezed (Tran et al., 2016). Until then, the harvesting time can be determined by cutting the pedicle or end of the stem of the gac fruit with a knife or scissor. Mechanically twisting the fruit would result in mechanical damage to the ripe gac fruit (Jalgaonkar et al., 2020). Because gac fruit is fragile and easily injured, it is easy to bruise it while handpicking. Proper harvesting and timing were required to prevent fruit from becoming over-ripe, causing it to fall and break (Anthon et al., 2011). It will be critical to identify the origin and genotype of plants in order to breed the best nutritional varieties, such as fruits that produce more aril and seed for gac oil. This can be accomplished by identifying the plants' origins and genotypes.

Fig. 3. Fruit morphology (A) Gac fruit at the field (B) Front view of gac fruit (C) Cross-section of gac fruit (D) Close-up of the cross-section abaxial part of leaves Scale bars: 2 cm

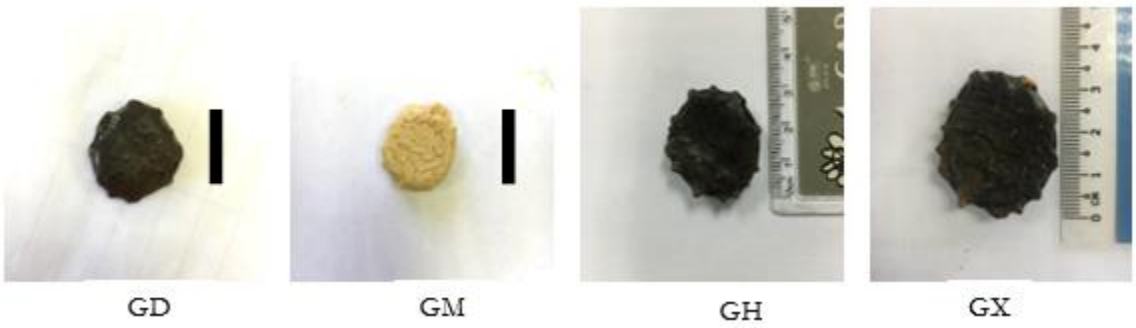


Gac fruit seeds

The gac seeds, which are the reproductive parts, can be divided into mature and immature seeds; the mature seeds for GD, GX, and GH were dark brown in colour and the juvenile seeds were black (Figure 4). The gac seeds' immature seeds were a creamy-yellow tint in colour. The seed was described in earlier literature as having wrinkled surfaces and changing in shape and colour from brown to light-black, brown to a blackish, black, and black (Wimalasiri, 2015; Toan et al., 2018). Germination time for gac seeds was three to four weeks. Under some conditions, only half of the gac seeds germinated within the four weeks. The other half took longer to germinate and some did not germinate at all. These could be due to a variety of factors such as seed storage, seed age, germination protocol, temperature, climate and medium type. These abiotic factors may cause variations in seed colour (Moncaleano-Escandon et al., 2013).

Gac seeds need adequate medium coverage and a sufficient amount of water, according to the observation. Given that Malaysia's climate is quite hot but humid, seeds can germinate more quickly in moist, well-aerated, loose soil with high moisture. Despite this, it is important to prevent wetting the seeds before germination. Therefore, having a better understanding of the morphology within gac in its natural habitats will be vital for plant selection for agricultural uses, strategic germplasm collection, and for the conservation of the species.

Fig. 4. Seed morphology



Quantitative data analysis

Morphological evaluations of gac quantitative data revealed significant differences among the ten morphological characters investigated. Quantitative differences in morphological characteristics such as fruit weight, fruit width, fruit length, seed weight, seed length, leaf length, and leaf width can be quantified. At p 0.05, the means of quantitative morphological characteristics of four gac accessions were compared in Table 4. The findings of this study were consistent with those of Wimalasiri et al. (2016), who found high genetic diversity in the gac accessions studied. However, fruit-morphological characters revealed highly significant differences among 16 gac accessions, with a high confidence interval at P 0.001.

Gac fruit leaves

The gac leaves were chosen at random using the Completely Randomized Design (CRD) plant plot. In terms of leaf width, GD had the smallest at 14.63 cm and the largest at 18.17 cm, demonstrating highly significant differences between these two accessions. GH and GX measured 15.93 cm and 17.20 cm, respectively. The shortest length recorded was 14.93 cm for GD, while the longest was 18.6 cm for GX. The leaf lengths of GH and GX were 18.50 cm and 18.43 cm, respectively (Table 4). The leaf length parameter revealed a significant difference, particularly in accessions GD when compared to the other three accessions (GM, GH and GX). Results for leaf width were comparable.

According to Bharathi and John (2013), leaves typically range in size from 10 to 16 cm. The gac accessions used in this study all had leaves with three lobes. However, according to Wimalasiri (2015), gac leaves can be found with three or five lobes. This could be as a result of the seeds being collected at several sites in Thailand and Vietnam.

Gac fruit flowers

According to the observations, both male and female flowers have five flower petals. Female and male flowers ranged in diameter from 6.23 to 9.13 cm. GX male and female flowers had the largest diameters, measuring 9.13 cm and 8.97 cm, respectively. GH male and female flowers, on the other hand, had the smallest diameters, measuring 6.55 cm and 6.23 cm, respectively. There was a significant difference between the GX and GH flowers in these. Male and female GD and GM flowers had diameters ranging from 7.03 cm to 7.15 cm. The findings were consistent with a previous study published in Wimalasiri et al. (2016), in which the diameter ranged from 1 to 10 cm.

Gac fruit fruits

According to Table 4, GX accession had the highest fruit weight of 384.73 g, followed by GH (334.70 g), GM (285.57 g), and GD (285.57 g) (193.72 g). This demonstrated that GD and GH differed significantly from one another. With 8.67 cm, GH had the largest fruit width. GX had the second-largest fruit width with 8.57 cm, followed by GM with 8.13 cm and GD had the smallest fruit width with 7.93 cm. GH had the longest fruit at 12.13 cm, followed by GX (11.68 cm), GM (11.17 cm) and GD (11.17 cm) (9.42 cm). Toan et al. (2018) found that the fruit weight ranged from 0.6 to 2.7 kg per fruit and the fruit length ranged from 13.7 to 21.3 cm. Fruit diameter ranged from 9.7 to 17 cm, with a mean of 13.8 cm. This demonstrated that the gac exhibited significant variability in the fruit morphological parameters studied.

Gac fruit seeds

The average weight per 10 seeds was 22.9 g for GD, 34.9 g for GH, 14.3 g for GM and 39.4 g for GX, indicating that accessions GX and GM differed significantly (Table 4). The seed length of the gac revealed that GD had 2.98 cm, GM had the shortest length of 1.43 cm, GH had 3.49 cm, and GX had the longest length of 3.94 cm. This demonstrated that the accessions GM and GX differed significantly from one another (Table 4). Toan et al. (2018) found that the 10-seed weight of 16 gac accessions ranged from 21.9 to 44.4 g.

Furthermore, the total number of seeds per fruit for GD, GH and GX was 21 and 20 for GM. In a study conducted in Thailand, the highest number of seeds per fruit recorded was 40 seeds, compared to 10 seeds in South Vietnam. Wimalasiri (2015) discovered that the seed weight ranged from 0.88 to 4.64 mg and the length ranged from 18.03 to 34.84 mm. The seed length ranged from 18.03 to 34.84 mm. The number of seeds per fruit can range between 7 and 54. The country and location of seed collection have an effect on the morphological variability of the seeds.

Table 4. Means comparison of quantitative morphological characteristics of 4 gac fruit accessions

Traits	Accessions				p-value
	GD	GM	GH	GX	
Leaf width (cm)	14.63 ± 0.85^{b}	18.17 ± 1.04^{a}	15.93 ± 0.51^{ab}	17.20 ± 0.98^{a}	0.00549
Leaf length (cm)	$14.93 + 0.15^{b}$	18.6 ± 0.66^{a}	18.5 ± 1.25^{a}	18.43 ± 1.01^{a}	0.002067
Male flower diameter (cm)	7.03 ± 0.15^{b}	7.15 ± 0.26^{b}	6.55 ± 0.24^{a}	9.13 ± 0.45^{a}	0.0015

Female flower diameter (cm)	7.13± 0.15[b]	7.06± 0.15[b]	6.23± 0.21[a]	8.97± 0.06[a]	0.00101
Fruit length (cm)	9.42 ± 0.07[c]	11.17 ± 0.2[b]	12.13 ± 0.15[a]	11.68 ± 0.08[b]	5.34e-08
Fruit weight (g)	193.72 ± 0.33[c]	285.57 ± 0.51[b]	334.70 ± 0.44[a]	384.73 ± 0.21[a]	2e-16
Fruit width (cm)	7.93 ± 0.15[b]	8.13 ± 0.15[b]	8.67 ± 0.21[a]	8.57 ± 0.06[a]	0.00104
Mature seed weight (g)	2.29 ± 0.02[a]	1.43 ± 0.03[c]	3.49 ± 0.10[a]	3.94 ± 0.01[b]	2.67e-15
Seed length (cm)	2.98 ± 0.19[a]	2.20 ± 0.26[b]	3.10 ± 0.10[a]	3.93 ± 0.03[c]	1.40e-05

Note. Mean±SD in a column followed by the same letter is not significantly different at P-value ≤ 0.05 according to Tukey's honestly significant difference test.

CONCLUSION

The morphological characterization is considered as a first approach towards the assessment of genetic diversity in a plant species. Characterization plays a vital role to maintain the genetic purity of a genotype. The genotypes with good horticultural characteristics can be utilized in crop breeding programme for development of superior genotypes. In the current investigation, morphological variability of gac fruit accessions was characterized. Considerable variability was noted in all four gac fruit accessions studied. The variability suggest potential for future substantial improvement in gac fruit in Malaysia. The genetic differences among the accessions are relevant to breeding programmes in that the variability created through hybridization of the contrasting forms could be exploited. Furthermore, gac fruit could become a new source for the production of a functional food or value-added ingredients in our dietary system and further enrich the range of fruit commodities nationally. Further study which includes Pearson's Correlation Coefficient could be done in the future for improved analysis in differentiating similarities and dissimilarities among gac fruit accessions in pursuit towards better parental combination for future gac fruit breeding improvement.

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