



Morpho-physiological characteristics and yield of baichi (*Flacourtia indica*)

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Abstract

An investigation was undertaken to evaluate the various morpho-physiological traits and yield contributing characters of baichi germplasms (GP) at Patuakhali Science and Technology University (PSTU). A number of baichi seedlings collected from different homesteads of Patuakhali coast were conserved at PSTU Germplasm Centre. Among the five survived germplasms (GP₁-GP₅), two were male (GP₂ and GP₄) and the remaining three were female (GP₁, GP₃ and GP₅). The longest leaf length (4.45cm) was exhibited in GP₄. Maximum leaf blade width (2.83cm) was observed in GP₅. Although all the studied germplasms flowered at age 7, however, flower bud initiation started in male plants during the first week of February and continued to the last week of March and in female plants, it was started during the second week of February and continued to the mid of March. Length of flower bud was noticed among female genotypes of GP₅ (4.67mm), GP₁ (4.65mm) and GP₃ (4.62mm). Importantly, the flowers were apetalous in both male and female cases of all five germplasms. The highest fruit set (74.83%) and the fruit retention (80.88%) were recorded in GP₃ while the lowest fruit set (69.51%) and fruit retention (77.16%) were noticed in GP₁. GP₅ had the biggest individual fruit size (11.24mm × 12.10mm), maximum edible portion (78.57%) and the highest fruit yield (10.5kg/plant) while the lowest individual fruit weight (1.19 gm) and fruit yield (8.6 10.5kg/plant) were observed in GP₃. Based on the morpho-physiological traits among the three fruiting plants it may conclude that GP₅ was superior over other fruiting plants in relation to fruit size, edible part, individual fruit weight and yield. Therefore, a performance grading of the three female plants on the basis of yield can be as follows: GP₅ > GP₁ > GP₃.

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Introduction

Flacourtia indica belonging to the family Selicaceae is one of the underutilized indigenous fruits of Bangladesh. Its common name is governor's plum. It is locally known as baichi or "kantabohori" that is believed to be native to much of Africa and tropical and temperate parts of Asia. Baichi is an erect, branched, more or less spiny shrub or small tree. This species is dioecious in nature. Baichi produces fruit that is eaten fresh and has a pleasant rather sour taste. The fruits make a good jelly with the seeds and skin being discarded (Tredgold, 1986). The fruit can be fermented to produce wine. Fruits are used as appetizing, diuretic, and digestive, in jaundice and enlarged spleen. Barks are used for the treatment of intermittent fever and are also believed to be effective for arthritis. Roots are used in nephritic colic and gum is used in cholera (Kirtikar and Basu, 1998, Nazneen *et al.*, 2002). The leaves and roots are used in herbal medicine for treatment of snakebite. Most parts of the plant are used for cough, pneumonia, and bacterial throat infection. After child birth among the poor the seeds is grind to powder with turmeric and rubbed all over the body to prevent rheumatic pains from exposure to damp winds. Pharmacological investigation includes the assessment of antihistaminic activity of ethanolic leaf extract of baichi in experimental guinea pig model (Tyagi *et al.*, 2011). Gum is administered along with other ingredients in cholera. The glistening leaves of baichi can be very attractive when the tree is planted as an ornamental. When closely planted, it forms a close impenetrable barrier that serves as a hedge; it tolerates frequent trimming.

People of Bangladesh are generally poorly nourished despite substantial increase of food production in the country over past few decades. Most people suffer from mal-nutrition and resultant diseases. Ceaseless effort is therefore needed to improve the nutritional status and to increase food security, particularly for the rural poor (FAO, 1992). If minor food crops are properly utilized; they may help to contribute in food security, nutrition, health, income generation and environmental services (Kunkel, 1984). Wild fruits add variations in diets improve the palatability of staple foods and provide

essential vitamins, minerals, proteins, carbohydrates and fats. Wild fruits of *Flacourtia jangomas* add variations in diets improve the palatability of staple foods and provide protein (3.9%), carbohydrates (21%), vitamin C (218mg), calcium (175mg), potassium (158mg), phosphorous (147mg), iron (118), and magnesium (57mg) per 100 gm dry weight basis (Hossain *et al.*, 2011; Baruah and Neog, 2016).

Sarker *et al.* (2015) reported a wide range of fruit diversity in Patuakhali coast of Bangladesh, of which most species were minor ones. Despite the many beneficial characteristics baichi is overlooked as a fruit plant and there is no organized orcharding and no recognized cultivars for this fruit crops. As a result baichi is in the verge of extinction. The main reasons for the under-utilization of germplasm, according to curators, scientists and other users of plant genetic resources, is the lack of adequate passport, characterization, and evaluation data; people cannot use genetic resources that lack essential information. Therefore, the accurate documentation of information about the origin, characterization, and performance of this germplasm is essential for effective conservation and use (Biodiversity, 2007). Considering the problem statements, the present study was undertaken with the objective to find out the morpho-physiologically improved baichi germplasm (s) with higher yield contributing traits.

Materials and methods

The study was carried out during February, 2018 to January, 2019 at the Germplasm Centre and the Postharvest Laboratory, Department of Horticulture, Patuakhali Science and Technology University. With a view to selecting the potential germplasm of baichi, a number of seedlings were collected from different homestead of Patuakhali district and conserved at PSTU Germplasm Centre. Among those only five germplasms survived well. Those five germplasms were selected for the present study. The experiment was conducted in Randomized Block Design. Each selected plant was considered as a treatment. Each treatment was replicated for 4 times by selecting 4 branches randomly (in East, West, North and South direction). So, the experiment was comprised of 5

treatments with 4 replications. The passport data of these plants are presented in Table 1.

Table 1. Passport data of selected baichi germplasm conserved at PSTU Germplasm Centre.

Germplasm	Place/location of collection	GPS coordination	
		Latitude (North)	Longitude (East)
GP ₁	Basbunia, Dumki	22°27'20"	90°18'41"
GP ₂	Kartikpasa, Dumki	22°26'56"	90°20'27"
GP ₃	Eatimkhana, Kalapara Sadar	22°1'16"	90°16'22"
GP ₄	Mirzaganj, Patuakhali	22°22'23"	90°14'11"
GP ₅	Mirzaganj, Patuakhali	22°22'30"	90°14'25"

Collection of morpho-physiological data

Characters like plant type, canopy shape, leaf arrangement, leaf apex, leaf base, number of lateral nerves, color of flower bud and number of sepal, petal, filament, and stigma were recorded through eye estimation. Width of leaf (cm), length of flower bud (mm), fruit length (mm) and fruit width (mm) were measured by using slide calipers.

Length of leaf (cm) was measured from base to tip by using meter scale and a total of 200 leaves (10 leaves × 4 branches × 5 plants) were used to determine the length of leaf.

Time of flower bud initiation and duration of flowering season (duration of first flower to last flower) were recorded by regular visual observation.

The fruit shape was described as oval or round through eye estimation.

Individual fruit weight (g) was measured from fully matured fruits gradually collected to find out the mean weight and other measurement of fruits. The weight was taken in gram with the help of an electrical balance.

Yield per plant was calculated as: Weight of individual fruit × Number of fruit in each replicated branch × Number of branches. Yield per plant was calculated in gram and converted to kilogram.

The weight of pulp (g/fruit) was worked out by deducting the weight of seed from the total weight of the fruit. Number of seeds per fruit was manually counted after the fruit ripe. Total numbers of 120 fully

ripen and soft fruits were used to calculate the number of seeds per fruit.

The percentage of edible (pulp) portion was measured by using the following formula:

$$\text{Per cent of edible portion (\%)} = \frac{\text{Weight of edible parts}}{\text{Weight of whole fruit}} \times 100$$

The percentage of non-edible (seed) was measured by using the following formula:

$$\text{Per cent of non-edible portion (\%)} = \frac{\text{Weight of non-edible parts}}{\text{Weight of whole fruit}} \times 100$$

The collected data on various parameters under this study were statistically analyzed, compiled and tabulated. Analysis of variance was done with the help of MSTAT-C computer package program. The mean differences among the treatments were calculated with the help of Duncan's Multiple Range Test (DMRT) at 1% and 5% levels of probability.

Results and discussion

The present investigation "Exploration of morpho-physiological characteristics of baichi (*Flacourtia indica*)" was conducted on five germplasms to evaluate them for different morphological and physiological parameters.

Morphological characteristics

The plants were small shrub having pale grey bark. They were spiny and canopy shape varied from glabrous (GP₁, GP₃ and GP₅) to densely pubescent (GP₂ and GP₄).

Arrangement of leaves

From detailed study it was observed that the arrangement of leaves of baichi was alternate in all of the germplasms [With an alternate pattern, each leaf arises at a different point (node) on the stem].

Leaf apex and leaf base

Leaf apex shape exhibited variations (acute, obtuse or rounded) among the germplasms in this study (Plate 1

and Table 2). GP₂ and GP₄ exhibited acute leaf apex while GP₁, GP₃ and GP₅ exhibited obtuse or rounded leaf apex. Orwa *et al.* (2009) recorded the leaves to be variable in size and as oval to round in baichi. Leaf base shape was also found to vary among the

germplasms (Plate 1 and Table 2). GP₁, GP₃ and GP₅ were found to have obtuse to rounded leaf base. Conversely, GP₂ and GP₄ were found to have cuneate or acute leaf base. Fig. 1 shows the differences between leaf apex of baichi.

Table 2. Leaf apex, leaf base, leaf length, leaf width and number of lateral nerves of baichi.

Germplasm	Leaf apex	Leaf base	Leaf length (cm)	Leaf width (cm)	Number of lateral nerves
GP ₁	Obtuse/ Rounded	Obtuse/ Rounded	3.75 b	2.70 a	11.73
GP ₂	Acute	Cuneate/ acute	4.25 a	2.44 b	11.29
GP ₃	Obtuse/ Rounded	Obtuse/ Rounded	3.77 b	2.68 a	11.58
GP ₄	Acute	Cuneate/ acute	4.45 a	2.43 b	11.18
GP ₅	Obtuse/ Rounded	Obtuse/ Rounded	3.76 b	2.83 a	11.37
Level of sign.			**	**	NS
CV (%)			3.83	4.31	3.60

Numbers in column followed by different letters differ significantly, but with common letter (s) does not differ significantly by DMRT. ** = Significant at 1% level and NS= Non-significant.

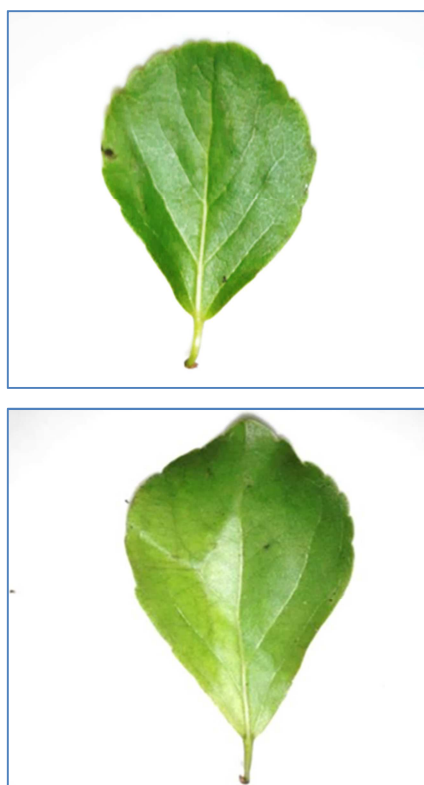


Fig. 1. Variations in leaf apex shape of baichi.

Leaf length and leaf blade width

Significant variations were observed among the studied germplasms in respect of leaf length and leaf blade width (Table 2). The longest leaf length (4.45cm) was found in GP₄ while the shortest leaf length (3.75 b) was found in GP₁. The maximum leaf blade width (2.83cm) was observed in GP₅. However, the minimum leaf blade width (2.43cm) was observed

in GP₄. The Ayurvedic Pharmacopoeia of India (1999) recorded the leaves of baichi to be 3 to 5cm long and 1 to 3cm wide.

Number of lateral nerves

There was no significant differences among the germplasms in term of number of lateral nerves. The maximum number of lateral nerves (11.73) was found in GP₁ while minimum number of lateral nerves (11.18) was found in GP₄ (Table 2). Orwa *et al.* (2009) reported that leaves of baichi have 4–7 pairs of veins i.e. 8–14 in numbers clear on both surfaces.

Time of flower bud initiation, colour of flower bud and duration of flowering season

Flower bud initiation started during first week of February in GP₂ and GP₄ and during second week of February in GP₁, GP₃, and GP₅. Orwa *et al.* (2009) mentioned that the flowers appear from December to April together with the new leaves, which are a very beautiful fresh green color. Duration of flowering season was the first week of February to the last week of March in GP₂ and GP₄, while this time was the second week of February to the mid of March in GP₁, GP₃, and GP₅.

Color and length of flower bud

There were no distinct color differences in flower buds among the germplasms however, the color of

flower bud was recorded as light green. There were significant variations in relation to length of flower bud in all germplasms. GP₅ gave the maximum flower bud length (4.67mm) which was at par with GP₁ (4.65mm) and GP₃ (4.62mm). Conversely GP₄ gave the minimum flower bud length (4.47mm) which was statistically similar with GP₂ (4.48mm). The variation in flower bud length might be due genetic constitution of plants and their interaction with the environmental conditions.

Number of sepal and petal

There was significant difference among the germplasms for number of sepal. Flowers of GP₂ and GP₄ had 4 sepals while GP₃, GP₁ and GP₅ had 6 sepals. Orwa *et al.* (2009) recorded the number of sepal as 5–6 (min. 4; max. 7) in baichi. However, all five germplasms of baichi in this study were apetalous.

Number of filament and stigma

The number of filament and stigma varied significantly among the germplasms in this study. The flowers of GP₄ had a maximum filaments (86.46) which was statistically similar with GP₂ (86.19). Notably, flowers of GP₁, GP₃, and GP₅ were without any filament. The flowers of GP₁ and GP₅ had 6 stigmas while the flowers of GP₃ had 4 stigmas which was statistically different from GP₁ and GP₅. However, GP₂ and GP₄ were without any stigma. Based on the observations regarding number of filament and number of stigma it was evident that GP₁, GP₃, and GP₅ were female while GP₂ and GP₄ were male plant. Variation in flower bud between male and female plants (a= male flower bud, b= female flower bud) is showed in Fig. 2 and Variation in Sepal between male and female plant of “baichi” (a= sepal of male flower and b= sepal of female flower) is showed in Fig. 3. A stigma is shown in Fig. 4.

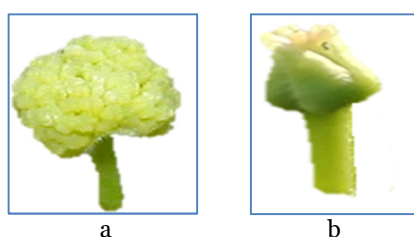


Fig. 2. Variation in flower bud between male and female plants (a= male flower bud, b= female flower bud).

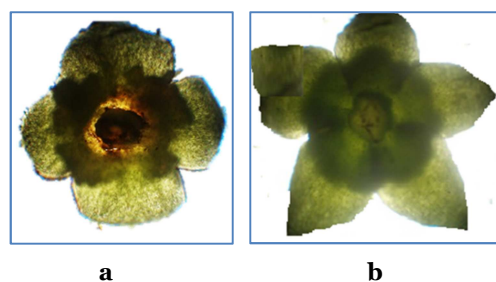


Fig. 3. Variation in Sepal between male and female plant of “baichi” (a= sepal of male flower and b= sepal of female flower).



Fig. 4. Stigma of “baichi”.

Fruit characteristics

According to flower characteristics, it was found that GP₂ and GP₄ were male; hence no fruiting occurred in these two plants. Fruiting occurred in GP₁, GP₃ and GP₅. Importantly, variability was observed among these three plants in respect of fruiting behavior and different physiological characteristics of fruits.

Table 3. Length of flower bud, number of sepal, number of petal, number of filament and number of stigma of baichi.

Germplasm	Length of flower bud (mm)	Number of sepal	Number of filament	Number of stigma
GP ₁	4.65 a	5.65 a	0.00 b	6.00 a
GP ₂	4.48 b	4.00 b	86.19 a	0.00 c
GP ₃	4.62 a	6.00 a	0.00 b	4.00 b
GP ₄	4.47 b	4.00 b	86.46 a	0.00 c
GP ₅	4.67 a	5.34 a	0.00 b	6.00 a
Level of sign.	**	**	**	**
CV (%)	0.96	1.43	1.00	0.00

Numbers in column followed by different letters differ significantly, but with common letter (s) do not differ significantly by DMRT. ** = Significant at 1% level.

Physiological characteristics of fruit

Per cent fruit set, fruit drop and fruit retention

There were significant differences among the germplasms for per cent fruit set, fruit drop and fruit

retention (Table 4). The highest per cent fruit set (74.83%) was recorded in GP₃ followed by GP₅ (72.25%) while the lowest per cent fruit set (69.51%) was observed in GP₁. GP₁ showed the maximum per cent fruit drop (22.84%) followed by GP₅ (20.78%). However, GP₃ showed minimum per cent fruit drop (19.11%). The highest fruit retention percentage (80.88%) was found in GP₃ which was statistically similar with GP₅, while the lowest fruit retention per cent (77.16%) was found in GP₁.

Table 4. Percent fruit set, fruit drop, and fruit retention of baichi.

Germplasm	Fruit set (%)	Fruit drop (%)	Fruit retention (%)	Fruit length (mm)	Fruit width (mm)
GP ₁	69.51 c	22.84 a	77.16 b	10.57 b	11.91 b
GP ₃	74.83 a	19.11 b	80.88 a	10.40 c	11.84 c
GP ₅	72.25 b	20.78 ab	79.22 a	11.24 a	12.10 a
Level of sign. CV (%)	**	**	**	**	**
	1.06	6.15	1.63	0.36	0.29

Numbers in column followed by different letters differ significantly, but with common letter (s) do not differ significantly by DMRT. ** = Significant at 1% level of probability.

Physical characteristics of fruit

Fruit shape, length and width

Observations for fruit shape revealed that the fruits of baichi were globular and the germplasms did not vary in this aspect. Significant variations were observed among the germplasms in case of fruit length and width of baichi. Maximum fruit length (11.24mm) and width (11.91mm) were found in GP₅, while minimum fruit length (10.40mm) and width (11.84mm) were found in GP₃ (Table 4).

Individual fruit weight and yield

Individual fruit weight and yield revealed that the baichi germplasms varied significantly in this aspect (Table 5). The highest individual fruit weight (1.44g) was recorded in GP₅, followed by GP₁ (1.28g) while GP₃ recorded the lowest individual fruit weight (1.19g). Bhattacharjee TN *et al.* (2019) recorded variability among selected jujube germplasm in respect of fruit weight. On the other hand, the highest fruit yield per plant (10.5kg) was observed in GP₅,

while the lowest yield (8.6kg) was observed in GP₃. The possible causes of lowest yield in GP₃ might be having less branches and small sized fruit.

Table 5. Individual fruit weight, yield per plant pulp weight, seed weight, number of seeds per fruit, percent edible and non-edible portion.

Germplasm	Individual fruit wt (g)	Yield/ plant (kg)	Pulp wt (g) /fruit	No. of seeds/ fruit	Edible portion (%)	Non-edible portion (%)
GP ₁	1.28 b	9.3 b	0.95 b	10.25 a	74.56 c	25.06 a
GP ₃	1.19 c	8.6 c	0.91 b	8.25 b	76.47 b	22.89 b
GP ₅	1.44 a	10.2 a	1.13 a	9.25 ab	78.57 a	20.91 c
Level of sign. CV (%)	**	**	**	**	**	**
	1.99	2.95	2.22	7.21	0.84	3.88

Numbers in column followed by different letters differ significantly, but with common letter (s) do not differ significantly by DMRT. ** = Significant at 1% level of probability.

Number of seeds per fruit

There were significant variations among the baichi germplasms in relation to number of seeds per fruit. The number of seeds per fruit was maximum (10.25) in GP₁ followed by GP₅ (9.25). Conversely, the minimum number of seeds per fruit (8.25) was found in GP₃.

Pulp weight

The pulp weight was significantly different among the studied germplasms. The maximum pulp weight (1.13g) was observed in GP₅, while GP₃ gave minimum pulp weight (0.91g) which was statistically similar with GP₁ (0.95g).

Per cent non-edible and edible portion

Per cent of non-edible and edible fruit portion varied significantly among the studied germplasms (Table 5). The maximum per cent of non-edible portion (25.06) was observed in GP₁ followed by GP₃ (22.89), while GP₅ recorded the minimum per cent of non-edible portion (20.91). GP₅ showed for the highest per cent of edible portion (78.57) followed by GP₃ (76.47). In contrast, the lowest per cent of edible portion (74.56) was observed in GP₁.

Conclusions

The experiment was conducted to observe the morpho–physiological characteristics and yield of selected germplasms of baichi. An important observation of this study was that among the five germplasms, two were male (GP₂ and GP₄) and three were female (GP₁, GP₃ and GP₅). The leaves of baichi were alternately arranged. GP₂ and GP₄ exhibited acute leaf apex and cuneate or acute leaf base while GP₁, GP₃ and GP₅ exhibited obtuse or rounded leaf apex and leaf base. The longest leaf length was exhibited in GP₄. Maximum leaf blade width was observed in GP₅. The leaves of all the five germplasms had about 6 pairs of lateral nerves. Flower bud initiation started during the first week of February in GP₂ and GP₄ and continued to the last week of March. Flower bud initiation started during the second week of February in GP₁, GP₃, and GP₅ and continued to the mid of March. The maximum flower bud length was recorded in GP₅. The flowers of baichi do not have any petal. It was observed that the flowers of GP₁, GP₃, and GP₅ were without any filament and the flowers of GP₂ and GP₄ were without any stigma. The highest per cent fruit set and the lowest per cent fruit drop were recorded in GP₃. GP₁ gave the maximum value for per cent fruit drop. The highest fruit retention per cent was recorded in GP₃. The fruit of baichi was globular shaped. Fruit size was found maximum in GP₅, while minimum fruit size was observed in GP₃. The highest individual fruit weight was recorded in GP₅ with the highest fruit yield and the lowest yield was obtained from GP₃. The morpho–physiological characteristics of baichi assessed in this study might be helpful to characterize them molecularly as well as releasing of promising variety. In addition, findings obtained from this study could be used to formulate methods and strategies for conservation.

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