Bangladesh J. Nuclear Agric, 37(1): 23-30, 2023 *ISSN 0258-7130*
DOI: https://doi.org/10.3329/bjnag.v37i1.69920

BINALEBU-2: A HIGH YIELDING, YEAR-ROUND, SCENTED AND SEEDLESS VARIETY OF LEMON

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Abstract

Citrus fruits, especially Lemon (*Citrus limon*) belonging to the family Rutaceae are the most important nutritional fruits in Bangladesh. Twenty local and exotic lemon germplasm were collected from home and abroad. The germplasm CL-1 and CL-2 were collected from Darziling, India. The germplasm was evaluated during 2016-17, 2017-18 and 2018-19 at Mymensingh and Tangail and the experiments were carried out following randomized complete design with three replications. Binalebu-1 was used as a check variety in the experiments. Data were recorded on plant height, number of fruits per plant, fruit length, fruit breadth, individual fruit weight, fruit yield per plant, vitamin C and juice contents, and seeds per fruit were recorded. Moreover, reactions to major diseases and insect-pests infestation were also recorded. From the results it was observed that CL-1 was found to be superior to other exotic genotypes and to check variety Binalebu-1. During 2016-17, 2017-18 & 2018-19 at Mymensingh, the highest fruit yield plant^{-1} (25.45, 32.11 and 40.36 kg), vitamin C (30.11, 29.78 and 29.65 mg 100 g^{-1}), plant height (162.55, 22.41 and 265.23 cm), fruit length (7.72, 7.51 and 7.50 cm), number of fruits plant^{-1} (172.3, 221.1 and 281.77), juice content fruit^{-1} (55.25%, 54.11% and 54.31%) and the lowest number of seeds fruit^{-1} (4, 4 and 4.1) was recorded from CL-1 in all the three consecutive year trials. Similarly at Tangail the highest fruit yield plant^{-1} (24.94, 31.36, and 35.41 kg), vitamin C (28.44, 30.12 and 30.15 mg 100 g^{-1}), plant height (160.2, 220.9 and 260.54 cm), fruit length (7.66, 7.56 and 7.48 cm), number of fruits plant^{-1} (170, 223 and 261), juice content fruit^{-1} (52%, 52% and 53%) and lowest number of seeds fruit^{-1} (4.1, 4.6 and 5) was recorded from CL-1, which was the highest compared to CL-2 and Binalebu-1 at both locations. The lowest fruit yield plant^{-1} and vitamin C, highest number of seeds fruit^{-1} observed at CL-2 at both of Mymensingh and Tangail. Considering the better performance of fruit yield, vitamin C content, juice content and less number of seeds compare to CL-2 and Binalebu-1, CL-1 genotype was selected as a new variety naming Binalebu-2 to grow commercially all over Bangladesh.

Key words: Lemon, seedless variety, high yield, scented, selection, year-round.

Introduction

Bangladesh is a country with 168.95 million people. Approximately 70% of the total population suffer from malnutrition, most importantly different types of vitamins, viz. vitamin A, Vitamin C etc. (Abdullah and Rahman, 2015; Rahman *et al.*, 2016). Reports show that around 93% people of Bangladesh suffer from vitamin C deficiency and unlike other vitamins; it cannot be stored in the body (Mamun *et al.*, 2015). Vitamin C intake in Bangladesh is far below the recommended dietary allowance (Nielsen, 2000; Hels *et al.*, 2003; Khan and Ahmed, 2005).

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Thus, intake of vitamin C containing fruits on a regular basis is necessary to maintain the supply of vitamin C in our body.

Bangladesh is blessed with a huge diversity of fruits and circa, 70 types of fruits are grown all over the country (Hussain *et al*., 2011). To meet the mineral requirements and to strengthen body defense mechanisms against various biotic and abiotic stresses and for proper health, per capita fruit requirement is 115g. (Rahman and Rahman, 2014). Citrus fruits are very important in respect of their food values, especially being very rich in vitamin C. It is a source of macro and micronutrients (Ting, 1980) and of dietary fiber (Marin *et al*., 2007). They are also rich in antioxidant compounds (Liu *et al*., 2012), reveal anticancer, and anti-inflammatory properties (Ma *et al*., 2020), and are effective at reducing the risk of cardiovascular diseases, osteoporosis, and type-2 diabetes (Cirmi *et al*., 2016). It also contains some organic compounds, which work against asthma, antidepressant, stress relief, aids digestion, colds, flu, fever, nosebleeds, mouth ulcers, throat infection and boils (Sfgate, 2017).

Despite enormous health benefits of citrus, Bangladesh ranks in a very lower position in respect of the production of citrus fruits compare to other citrus fruit growing countries. According to the available statistics, the total area under lemon fruits was 63,309 ha while total production was 58552.00 tons in the year 2019-20 (BBS, 2020). Major lemon producing regions of Bangladesh are Sylhet, Chattogram and the Hill Tracts of Rangamati region in the orchards as well as in the homestead areas of many households (Umar *et al*., 2015). It is, therefore, necessary to give proper attention to increase the production of lemon and to improve their qualities to meet the increasing demand of the people of Bangladesh. The main reasons for low yield are lack of high yielding varieties as well as traditional production technologies. The yield of lemon can be increased through selection of high yielding germplasm as variety(s) along with adoption of improved production technologies. Various strategies to increase genetic variability can be pursued by such as seed introduction, hybridization, and mutation (Soeranto, 2011). Introduction as well as selection is one of the main strategies for varietal improvement. In many citrus species, several varieties have developed through selection (Caruso *et al*., 2020). Hence the objective of this study was to select a high-quality citrus genotype (in terms of size, vitamin C content, juice yield, and seedlessness), year-round bearing, tolerant or resistant to different abiotic and biotic stresses, and with high productivity.

Materials and Methods

Twenty local and exotic lemon germplasm were collected from home and abroad. Among them CL-1 and CL-2 was collected from Darziling, India. Collected genotypes (CL-1 & CL-2) along with check variety Binalebu-1 were primarily evaluated in three consecutive years (2016-17, 2017-18 and 2018-19) at Kashiarchar, Mymensingh and Garobazar, Madhupur in Tangail district. All the trials were laid out in randomized complete block design with three replications. Pit size was 0.5×0.5 m^2 with plant-to-plant distance

2.5m maintained for all the trials. 20 kg cow dung, 300g mustard oilcake, 500g bone meal and 2 kg ash were applied in the pit before planting and after every 3 months 200g Urea, 250g TSP and 250g MoP fertilizer were applied in every pit. Intercultural operations like irrigation, weeding, application of insecticide and fungicide were followed when necessary to ensure normal plant growth and development. Lemon plant cannot tolerate water logging condition, so maintained well drainage. Data on various characters, such as plant height, fruit length, fruit breath, individual fruit weight, number of fruits plant^{-1}, juice content fruit^{-1}, peel thickness (with slide calipers), number of seed fruits^{-1}, vitamin C content following Ranganna (1991), and fruit yield were taken from each plant. The analysis of variance for various fruit yield and yield contributing characters was done following the F-test. Mean comparisons of the treatments were adjudged by the Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Results and Discussion

Results showed significant difference in lemon yield, yield contributing parameters and quality between the evaluated genotypes (Table 1). Among the genotypes, CL-1 showed better field performance considering fruit yield plant^{-1}, individual fruit weight, vitamin C content and other important agronomic characteristics. From the result, it was observed that CL-1 was also to be tolerant compared to another genotype and check variety Binalebu-1 to major diseases and insect pests' infestations.

Mymensingh

During 2016-17 two germplasm viz. CL-1 and CL-2 with check variety Binalebu-1 were evaluated at Kashiar char, Mymensingh. The longest plant (162 cm) was recorded in CL-1 followed by CL-2 (149 cm) and Binalebu-1 (157 cm). The fruit length ranged from 5.7 cm (CL-2) to 7.7 cm (CL-1) and fruit breadth was 4.2 cm (CL-2) to 6.3 cm (CL-1). The highest juice fruit^{-1} (55.3%) was recorded from CL-1 and lowest (18.3%) from CL-2. The highest peel thickness (5.5 mm) was obtained from CL-2 and the lowest peel thickness (3.9 mm) from CL-1. The highest number of seed fruit^{-1} (11) was found in CL-2 and the lowest no. of seed fruit^{-1} (4) was present in CL-1. The highest vitamin C content (30.1 mg 100 g^{-1}) was found in CL-1 and the lowest vitamin C content (20.9 mg 100g^{-1}) was found in CL-2 followed by Binalebu-1 (25.8 mg 100 g^{-1}). The maximum number of fruits plant^{-1} (172) was obtained from CL-1 and minimum was from CL-2 (113). In case of fruit yield, highest yield (25.5 kg tree^{-1}) was obtained from CL-1 and lowest from CL-2 (15.1 kg tree^{-1}).

In 2017-18, the highest plant (222cm) was recorded in CL-1genotype at Mymensingh while the smallest plant (189 cm) was recorded in CL-2. The fruit length ranged from 7.5 cm (CL-1) to 5.5 cm (CL-2) and fruit breadth was 6.1 cm (CL-1) to 4.2 cm (CL-2). The highest juice fruit^{-1} (54%) was recorded from CL-1 and lowest (18.6%) from CL-2. The highest peel thickness (5.4 mm) was obtained from CL-2 and the lowest peel thickness (3.9 mm) was from CL-1. The highest number of seeds fruit^{-1} (10) was present in CL-2 and the lowest number of seeds fruit^{-1} (4) was present in CL-1. The highest vitamin C content (29.8 mg 100g^{-1}) was found in CL-1 and the lowest vitamin C content (21.0 mg 100g^{-1}) was found

in CL-2 followed by Binalebu-1 (23.0 mg $100g^{-1}$). In case of fruit yield, highest fruit yield (32.1 kg $tree^{-1}$) was recorded from CL-1 and the second highest fruit yield (25.9 kg $tree^{-1}$) from Binalebu-1. The lowest fruit yield (20.5 kg $tree^{-1}$) was recorded from CL-2 germplasm.

In 2018-19, the significant longest plant (265 cm) was found in CL-1genotype at Mymensingh while the smallest plant (229 cm) was recorded in CL-2. The fruit length ranged 7.5 cm (CL-1) to 5.5 cm (CL-2) and fruit breadth was 6.1 cm (CL-1) to 4.3cm (CL-2). Maximum no. of fruits $plant^{-1}$ (282) was obtained from CL-1 and minimum no. of fruits $plant^{-1}$ CL-2 (224). The highest juice $fruit^{-1}$ (54.3%) was recorded from CL-1 and the lowest (19.4%) from CL-2. The highest peel thickness (5.4 mm) was obtained from CL-2 and the lowest peel thickness (3.9 mm) was CL-1. The highest number of seeds $fruit^{-1}$ (12.1) was present in CL-2 and the lowest number of seeds $fruit^{-1}$ (4.1) was present in CL-1. The highest vitamin C content (29.7 mg $100g^{-1}$) was found in CL-1and the lowest (20.6 mg $100g^{-1}$) was found in CL-2 followed by Binalebu-1 (22.9 mg$100g^{-1}$). In case of fruit yield, the highest yield (40.4 kg $tree^{-1}$) was obtained from CL-1, the second highest yield (32.1 kg $tree^{-1}$) was recorded in Binalebu-1 and the lowest (24.8 kg $tree^{-1}$) CL-2 (Table 1).

Tangail

During 2016-17, two germplasm viz. CL-1 and CL-2 with check variety Binalebu-1 were evaluated at Deldwar, Tangail. The longest plant (160 cm) was recorded in CL-1 followed by Binalebu-1 (155 cm) and the smallest plant CL-2 (146 cm). The fruit length ranged from 5.4 cm (CL-2) to 7.7 cm (CL-1) and fruit breadth was 4.0 cm (CL-2) to 6.0 cm (CL-1). The highest juice $fruit^{-1}$ (52.1%) was recorded from CL-1 and lowest (18.0%) from CL-2. The highest peel thickness was also obtained from CL-2 (5.5 mm) and the lowest peel thickness was CL-1 (4.1 mm). Maximum number of fruits $plant^{-1}$ (170) was obtained from CL-1 followed by Binalebu-1 (150) and minimum number of fruits $plant^{-1}$ CL-2 (131). In case of fruit yield, the highest yield (24.9 kg $tree^{-1}$) was obtained from CL-1 and the second highest yield (23.6 kg $tree^{-1}$) was recorded in Binalebu-1 and the lowest (13.9 kg $tree^{-1}$) from CL-2.

In 2017-18, the highest plant (221cm) was recorded in CL-1genotype at Deldowar, Tangail while the second highest plant was from Binalebu-1 (212 cm). The highest juice $fruit^{-1}$ (52.14%) was recorded from CL-1 and lowest (18.0%) from CL-2. In case of fruit yield highest yield (31.4 kg $tree^{-1}$) was found in (CL-1) and the second highest fruit yield (28.6 kg $tree^{-1}$) was recorded in Binalebu-1. The lowest fruit yield (21.9 kg $tree^{-1}$) was recorded in CL-2 genotype.

In 2018-19, the significant longest plant height (261 cm) was found in CL-1 genotype at Tangail, while the smallest plant (203 cm) was recorded in CL-2. Maximum number of fruits $plant^{-1}$ (261) was obtained from CL-1 and the minimum number of fruits $plant^{-1}$ CL-2 (217) followed by Binalebu-1 (215). The highest juice $fruit^{-1}$ (53.3%) was recorded from CL-1 and lowest (24.2%) from CL-2. In case of fruit yield, the highest yield (35.4 kg $tree^{-1}$) was obtained from CL-1 and the second highest yield (28.1 kg $tree^{-1}$) was recorded in Binalebu-1 followed by CL-2 (24.0 kg $tree^{-1}$) (Table 2).

DOI: https://doi.org/10.3329/bjnag.v37i1.69920

Table 1. Fruit yield, Physico-chemical characteristics of three lemon genotypes at Mymensingh during 2016-17 to 2018-19

Genotypes		Plant height (cm)	Fruit length (cm)	Fruit breadth (cm)	Individual fruit wt. (gm)	No. of fruits/ Plant	Juice/ fruit (ml)	Peel thickness (mm)	No. of seed/ fruits	Wt. of peel (gm)	Wt. of carpel (gm)	Vit. C (mg/100gm)	Yield (kg/tree)
2016-17	CL-1	163a	7.7b	6.3a	148b	172a	55.3a	3.9b	4.0b	41.1a	49.5b	30.1a	25.5a
	CL-2	149b	5.7c	4.2b	113c	134c	18.2a	5.5a	11.0a	38.1b	53.9b	21.0b	15.1c
	Binalebu-1	157c	6.1a	5.3a	135a	151b	24.0b	4.1a	5.0b	45.9a	61.0a	26.0b	20.4b
2017-18	CL-1	222a	7.5b	6.1a	145b	221a	54.1a	3.9b	4.0b	40.2b	50.2b	29.8a	32.1a
	CL-2	189b	5.5c	4.2b	111c	184b	18.6a	5.4a	10.0a	36.9b	52.9a	21.0b	20.5b
	Binalebu-1	201c	6.0a	5.2a	133a	195c	24.1b	4.2a	6.0b	46.1a	51.0a	23.0b	25.9b
2018-19	CL-1	265a	7.5b	6.1a	143b	282a	54.3a	3.9b	4.1b	40.7b	48.3c	29.7a	40.4a
	CL-2	229b	5.5c	4.3b	111c	224c	19.4a	5.4a	12.1a	37.1c	53.2b	20.6b	24.8b
	Binalebu-1	242c	5.9a	5.2a	131a	245b	24.0b	4.0a	6.0b	47.9a	58.3a	22.9b	32.1b

Table 2. Fruit yield, Physico-chemical characteristics of three lemon genotypes at Madhupur, Tangail during 2016-19

Genotypes		Plant height (cm)	Fruit length (cm)	Fruit breadth (cm)	Individual fruit wt. (gm)	No. of fruits/ Plant	Juice/ fruit (ml)	Peel thickness (mm)	No. of seed/ fruits	Wt. of peel (gm)	Wt. of carpel (gm)	Vit. C (mg/100gm)	Yield (kg/tree)
2016-17	CL-1	160a	7.7a	6.0a	147b	170a	52.1a	4.1b	4.1b	41.6a	51.3b	28.4a	24.9a
	CL-2	146b	5.4b	4.01b	106c	131b	18.0a	5.5a	12.0a	37.1a	53.2a	20.6b	13.9b
	Binalebu-1	155a	6.1a	5.31a	132a	150a	26.1b	5.0a	5.7b	49.9b	54.0a	26.9a	23.6a
2017-18	CL-1	221a	7.6a	6.0a	141b	223a	52.1a	4.1b	4.6b	38.2a	49.7b	30.1a	31.4a
	CL-2	185b	5.0b	4.5b	115b	191c	18.0a	5.4a	12.2a	39.6a	56.9a	21.9b	21.9b
	Binalebu-1	212b	6.8a	5.2a	136a	210b	22.3b	4.6b	7.0b	41.9b	59.8a	25.2b	28.6a
2018-19	CL-1	261a	7.5b	6.1a	136c	261a	53.3a	4.2a	5.0b	38.6a	45.5b	30.2a	35.4a
	CL-2	203b	5.1c	4.3b	112b	217c	24.2b	5.3b	15.0a	35.9a	52.2a	21.0b	24.3b
	Binalebu-1	231b	6.1a	5.2a	125a	225b	26.7b	5.3b	6.0b	44.9b	54.1a	24.1b	28.1b

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The present study revealed that CL-1 genotype showed better fruit yield, vitamin C, juice content and less seed than CL-2 and check variety Binalebu-1, which are the most important characters to select a suitable variety. CL-1 performed 19.7, 20.0 and 55.9% higher fruit yield, vitamin C, juice content and 40.0% lower seed at Mymensingh and 11.6, 13.9 and 52.3% higher fruit yield, vitamin C, juice content and 36.7% lower seed at Tangail, respectively, compared to check variety. So, the CL-1 genotype can be selected as a new variety for high yielding, year-round, and seedless variety. Similar results in fruit characters in lemon cultivars were reported by Fallahi *et al*. (1990) and Prasad *et al*. (1997). Rashid, 2013 found significant variations in peel thickness and fruit weight in different types of lemon. Kayesh E. *et al.*, (2017) reported year-round, broad and seedless fruits of lemon with early flowering. Al-Mouei and Choumane, 2014 stated that variability of the juice contents may be due to the variation of the genetic potentiality of individual genotype. Shrestha *et al*., (2012) stated that a seedless variety of citrus contained the highest juice. So, the CL-1 genotype can be selected as a new variety for high yielding, year-round, scented and almost seedless variety.

The incidence of citrus greening, gummosis and scab, and insect (aphid, citrus leaf miner and citrus butterfly) infestation were also studied in different locations under field conditions. The advance line CL-1was found to be tolerant to citrus greening, gummosis and scab diseases and also showed lower infestation by insects. Overall infestation caused by leaf feeder insects like aphid, citrus leaf miner and citrus butterfly were lower in CL-1genotype compared to the check varieties (Table 3).

Table 3. **Disease reaction of fungal diseases and insect-pest infestations of lemon genotypes**

Genotypes	Disease reaction			Insect infestation		
	Citrus greening	Gummosis	Scab	Aphid	Citrus leaf miner	Citrus butterfly
CL-1	T	T	MT	T	MT	T
CL-2	MT	S	S	MT	S	MT
Binalebu-1	MT	MT	MT	MT	S	MT

N.B.: S means susceptible, MT means moderately tolerant, and T means tolerant.

Main distinguishing characteristics of new lemon variety Binalebu-2 (CL-1) which makes the variety different from other varieties:

- High yielding, year-round, scented and seedless variety
- Mostly oval to cylindrical in shape, fruit tip acute and fruit surface smooth
- 3-4 seeds contain in a mature fruit but most of the fruits are seedless
- Average single fruit weight: 135-147 g
- Thickness of fruit peel: 3.8-4.2 mm
- 31-35% juice is contained in a mature fruit
- First fruiting duration after planting: 11 months
- Vitamin C content is 30mg $100g^{-1}$ fruit weight
- This variety is tolerant to citrus greening disease and
- Average fruit yield 35-40 t ha^{-1}

Conclusion

The overall performance of CL-1genotype was better for different parameters mentioned above in three consecutive years' trails at two different districts of Bangladesh. So, it was decided to apply for the registration of this genotype as a high yielding variety named Binalebu-2 to the National Seed Board (NSB) of Bangladesh. Consequently, the NSB registered CL-1 as Binalebu-2 in 2021 for commercial cultivation in Bangladesh.

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