

## Study on the agro-biological characteristics of Bac Son yellow mandarin genetic resources in Lang Son Province, Vietnam

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### Abstract

This study was conducted to evaluate the agro-biological characteristics of the Bac Son yellow mandarin variety (*Citrus reticulata Blanco*), a specialty fruit of Bac Son district, Lang Son province. The analysis revealed that Bac Son mandarin displays strong growth potential with an average tree height of  $8.34 \pm 1.04$  m, trunk diameter of  $38.23 \pm 2.60$  cm, and canopy diameter of  $7.22 \pm 0.89$  m. Leaves averaged  $10.69 \pm 2.58$  cm in length and  $3.60 \pm 1.19$  cm in width and contain characteristic essential oils. Flowers are clustered, typically with 6 petals; the average petal length is  $2.04 \pm 0.28$  cm and the number of stamens is about  $20.74 \pm 3.53$ . Fruits weighed on average  $107.22 \pm 4.69$  g with a diameter of  $7.72 \pm 0.83$  cm; the pulp is juicy with a distinctive flavor. However, this variety is affected by pests and diseases such as stem borers, psyllids, and greening disease. The study recommends technical measures including improved cultivation practices, the use of disease-free planting material, and integrated pest management to enhance production efficiency and fruit quality of Bac Son yellow mandarin.

**Keywords:** Bac Son yellow mandarin, agro-biological characteristics, growth, yield, pests and diseases

### Introduction

species such as orange, mandarin, lemon, and pomelo provide important nutritional benefits and have considerable economic value. Many citrus varieties grown worldwide offer a range of flavor profiles - from sour to mildly sweet to very sweet - meeting diverse consumer preferences across age groups. Citrus products serve as nutritious food, diet items, medicinal ingredients, beverages, and marmalades. The nutritional composition of citrus fruits varies by species; total sugars typically range from about 6% to over 10% (excluding very sour fruits like lemons), protein from 0.6 to 0.9%, fat around 0.1–0.2%, vitamin C approximately 50–100 mg/100 g fresh fruit, and organic acids around 0.4–0.6%. In addition, citrus fruits contain vitamins such as B1 and E, minerals including Ca, Fe and Zn, and roughly 15 free amino acids.

Bac Son yellow mandarin (*Citrus reticulata Blanco*) is an endemic cultivar of Bac Son district, Lang Son province, contributing significantly to local economic and nutritional needs. This mandarin is valued for its aromatic flavor, thin and easily peelable rind, juicy segments, and relatively high sugar content. In addition to its commercial value, the cultivar adapts well to the karst mountain ecology of the region, supporting local agricultural livelihoods. However, in recent years the planted area and yield of Bac Son mandarin have tended to decline due to environmental changes, pest and disease pressure, and suboptimal cultivation techniques.

A major challenge for Bac Son mandarin is infestation by pests and diseases such as greening (huanglongbing), leafroller (or similar leaf-feeding larvae), mealybugs, and fruit fly species. These agents reduce both growth vigor and fruit quality, causing significant economic losses. Furthermore, non-scientific cultivation practices, lack of investment in disease-free planting material, and inadequate nutritional management contribute to suboptimal yields.

Therefore, investigating the agro-biological characteristics of Bac Son yellow mandarin is necessary to assess growth status, adaptability, and factors affecting production

efficiency and fruit quality. Based on these findings, the study proposes technical recommendations—such as improved crop management, integrated pest management, better propagation of healthy seedlings, and market development—to conserve and sustainably develop this specialty variety and to enhance farmers' incomes in the area.

### Materials and Methods

#### 1. Study object

The study was conducted on Bac Son yellow mandarin trees older than 10 years in Lang Son province during the period from October 2020 to December 2021.

#### 2. Study contents

- Investigation of morphological characteristics of trunk, leaves, flowers, fruits, and seeds.
- Study of growth traits of Bac Son yellow mandarin.
- Study of flowering and fruit set characteristics.
- Study of fruit traits, production efficiency and fruit quality.
- Survey of pest and disease status on the Bac Son yellow mandarin cultivar.

#### 3. Observations and measurement methods

Morphological descriptions follow the guidelines of the International Plant Genetic Resources Institute (IPGRI), now Bioversity International. A concentrated orchard with trees older than 10 years was selected. Fifteen trees uniform in growth, propagation method and care were chosen, arranged in three replicates (each replicate included five trees). The following indicators were recorded:

#### Tree characteristics

- Trunk height (m): measured with a measuring tape from ground level to the highest point of the canopy; number of observed trees = 15.
- Branching level: number of branching orders on the tree, counted on 15 observed trees.

- Canopy diameter: measured from the top view in two directions East–West and North–South; canopy diameter = (East–West diameter + North–South diameter)/2 (unit: m); number of observed trees = 15.
- Trunk diameter: measured with a tape at 1 m above ground; measured on 15 trees.

#### Leaf characteristics

- Leaf attributes (color, length, width, leaf blade thickness, shape, etc.).
- Leaf length, leaf width, petiole length (cm): leaves were sampled from fruiting branches; for each tree 10 leaves were taken, from 5 trees × 10 leaves; leaves sampled were the 4th and 5th leaf from the branch tip.

#### Flower characteristics

- Number of petals per flower: count based on 30 flowers per tree, observed on 15 trees.
- Number of stamens per flower: count based on 30 flowers per tree, observed on 15 trees; total stamen counts averaged.
- Petal length and petal width: measured on 30 flowers per tree, observed on 15 trees; results averaged (unit: cm).

#### Fruit characteristics

- Fruit diameter and fruit height were measured using a vernier caliper (Palme style). Five trees were selected along a diagonal; for each tree 10 fruits were measured; marked fruits were evenly distributed around the canopy and at different canopy levels.
- Fruit height: measured from the apex to the base parallel to the fruit axis (cm).
- Fruit diameter: measured at the widest part of the fruit (cm).

#### Shoot growth characteristics

- Number of flushes were monitored.
- Start of flushing: recorded when 5% of branches per tree had flushes.
- End of flushing: recorded when 80% of flushes on a tree matured.
- Number of shoots per branch: four branches (one per cardinal direction) per tree were sampled on 5 trees; all shoots on sampled branches were counted and recorded with marking and dates.
- Measurements of shoot length, diameter and leaf number per shoot: taken randomly on four active shoots per tree from 5 sampled trees located diagonally in the orchard.
- Shoot length: measured from the base to the tip of the shoot.
- Shoot diameter: measured at the largest point.
- Leaves per shoot: counted.
- Total number of shoots per flush: monitored by marking and counting all shoots per flush per tree.

#### Flowering and fruit set parameters

- Flowering start: recorded when 10% of flowers appeared on the tree.
- End of full bloom: recorded when 80% of flowers were open.
- Total flowers: counted on four sampled branches (one per direction).

- Total fruits set: counted for retained fruits after two abscission events on sampled branches.
- Fruit set ratio: calculated as the number of fruits set divided by the number of flowers on sampled branches. Each tree was sampled on 4 branches evenly distributed across canopy levels. The fruit set ratio was calculated using the following formula:

$$\text{Fruit set ratio (\%)} = \frac{\text{number of fruits set}}{\text{number of flowers/fruits on sampled branches}} \times 100$$

#### Yield components and yield

- **Number of fruits set per tree:** total fruits on five monitored trees averaged (fruits/tree).
- **Average fruit weight:** fruits were weighed per tree (one sampling), 10 fruits per tree for 5 repeats (n = 50).

$$\text{Yield (kg/tree)} = \text{Average number of fruits set per tree} \times \text{Average weight per fruit (kg)}$$

- **Edible portion (pulp weight):** fruits were selected from five monitored trees at evenly distributed points; 10 fruits per tree were peeled and pulp weighed and averaged.
- **Number of segments per fruit:** counted for sampled fruits.
- **Number of seeds per fruit:** counted for sampled fruits.

#### 4. Data analysis methods

Collected data were processed using basic statistical methods in Microsoft Excel.

#### Results and Discussion

##### 1. Tree morphology of Bac Son yellow mandarin

Bac Son yellow mandarin trees are woody and semi-shrubby with widely spreading branches. Trunks and branches often bear thorns and may shed when reaching older ages. Branch growth follows a sympodial pattern: a shoot elongates to a certain length then stops, and lateral buds beneath the growing tip break to form secondary shoots which then grow to a certain length and repeat the pattern. Branch types include fruiting branches, scaffold branches, vegetative branches, and water sprouts. The average lifespan is 20–30 years, with the commercial production period commonly around 15–25 years. The observed morphological indicators of trees older than 10 years are presented in Table 3.1.

**Table 1:** Morphological Characteristics of Bac Son Yellow Mandarin

Indicator	Value
Tree height (m)	8.34 ± 1.04
Trunk diameter (cm)	38.23 ± 2.60
Canopy diameter (m)	7.22 ± 0.89
Canopy shape	Conical

Bac Son yellow mandarin is an evergreen woody tree typically with a conical crown. Average tree height is approximately 8.34 ± 1.04 m, trunk diameter 38.23 ± 2.60 cm and canopy diameter 7.22 ± 0.89 m.

##### Leaf morphology of Bac Son yellow mandarin

Leaves are simple, alternate, often constricted at the petiole forming a winged petiole and leaf blade; they possess a petiole and pinnate venation. Leaves are glossy, relatively

thick and contain essential oil glands; older leaves may curl. The morphological characteristics of the leaves are summarized in Table 3.2.

**Table 2:** Morphological Characteristics of the Leaves of Bac Son Yellow Mandarin – Lang Son province

Indicator	Value
Leaf length (cm)	10.69 ± 2.58
Leaf width (cm)	3.60 ± 1.19
Petiole length (cm)	1.58 ± 0.53
Leaf blade thickness (mm)	0.26 ± 0.02
Leaf color	Dark green with visible oil glands
Number of vein pairs	5.98 ± 0.43

According to Table 3.2, the mean leaf length is 10.69 ± 2.58 cm and mean leaf width is 3.60 ± 1.19 cm. Mean leaf blade thickness is 0.26 ± 0.02 mm. Bac Son leaves have on

average 5.98 ± 0.43 vein pairs and petiole length of 1.58 ± 0.53 cm. Young leaves are light green, maturing to dark green with visible essential oil pockets on the surface. Although individual leaves are not large, leaf number per tree is substantial.

#### Flower morphology of Bac Son yellow mandarin

Mandarin flowers are arranged in clusters, typically with six petals arranged in two whorls and with fused stamens. The ovary is 6–10 locular. Flowers are fragrant and attractive to pollinators. Buds are ovate and white; petals are slightly revolute. Average petal length is 2.04 ± 0.28 cm and petal width 0.80 ± 0.12 cm. Calyx is green with hairs; pedicel length is 1.12 ± 0.21 cm. The average number of stamens is 20.74 ± 3.53. Male stamens are longer than the pistil; nectar glands are small and scented. These floral features are characteristic of mandarin varieties [7, 8].

**Table 3:** Morphological Characteristics of Bac Son Yellow Mandarin Flowers

Indicator	Value
Petals per flower	6
Stamens per flower (count)	20.74 ± 3.53
Petal length (cm)	2.04 ± 0.28
Petal width (cm)	0.80 ± 0.12
Pedicel length (cm)	1.12 ± 0.21
Flower type	Clusters; petals in two whorls; bisexual; at shoot tips or axils

#### Fruit morphology of Bac Son yellow mandarin

Fruit maturity occurs from September to December. Bac Son mandarins are widely cultivated across the mountainous Bac Son district and present two main fruit shapes: round and slightly flattened. Round fruits have a golden-yellow

peel when ripe, thin rind, easy to peel, relatively fiberless pulp, and a strong sweet aroma; some fruits have a hollow cavity in the center. Flattened fruits have a depressed apex and are somewhat flattened, often with a thicker peel, more difficult to peel, and slightly sour in taste.

**Table 4:** Morphological Characteristics of Bac Son Yellow Mandarin Fruit

Indicator	Value
Fruit shape	Round and slightly flattened
Peel color	Golden yellow when ripe
Pulp color	Light yellow
Segment characteristics	Yellow, smooth, juicy
Flavor	Sweet with a distinctive aroma

When green, chlorophyll in the peel allows some photosynthesis. Ripe peel color is due to xanthophylls or anthocyanin pigments. The peel contains oil glands interspersed with parenchymatic tissue [10].

#### 2. Shoot growth characteristics of Bac Son yellow mandarin

Studying the growth potential and quality of flushes is important for determining proper management practices and for regulating growth and development. The characteristics of shoot growth are shown in Table 3.5.

**Table 5:** Growth of Flush Shoots Throughout the Year of Bac Son Yellow Mandarin

Flush	Start date	End date	Shoot length (cm)	Shoot diameter (mm)	No Shoots per branch	No Leaves per shoot
Spring flush	03/02	11/03	10.84 ± 1.22	3.38 ± 0.31	19.65 ± 1.18	9.85 ± 0.65
Summer flush	27/04	30/05	19.56 ± 0.68	4.03 ± 0.28	22.30 ± 0.32	13.10 ± 0.57
Autumn flush	11/08	13/09	18.33 ± 1.06	3.10 ± 0.03	18.55 ± 1.20	12.05 ± 0.89

The spring flush appears in early February and ends in mid-March. Spring flush produced more shoots than the autumn flush with approximately 19.65 ± 1.18 shoots. Mean shoot length was 10.84 ± 1.22 cm and mean diameter 3.38 ± 0.31 mm, with 9.85 ± 0.65 leaves per shoot.

The summer flush starts in late April and ends in late May. Summer flush had about 22.30 ± 0.32 shoots per branch, mean shoot length 19.56 ± 0.68 cm, mean diameter 4.03 ± 0.28 mm and 13.10 ± 0.57 leaves per shoot.

The autumn flush begins around mid-August and ends mid-September. Autumn flush primarily arose from summer shoots and some spring shoots of the same year. The autumn flush had the lowest number of shoots compared with spring and summer (18.55 ± 1.20 shoots), mean shoot length 18.33 ± 1.06 cm, diameter 3.10 ± 0.05 mm and 12.05 ± 0.89 leaves per shoot.

### 3. Flowering and fruit set characteristics of Bac Son yellow mandarin

Like other citrus species, Bac Son mandarin produces abundant flowers but exhibits a low fruit set ratio. The period from flowering to fruit set is sensitive to external factors including temperature, light, humidity, nutrition and pests. Flowering typically starts from 14/02 to 16/02 and ends around 01/03 to 03/03, with a 7-day peak bloom during

which approximately 70% of the flowers open. The total number of flowers per tree is large—on average about 28,775.5—but fruit set is very low at about 1.14%, resulting in roughly  $328.30 \pm 7.91$  fruits per tree on average. Fruit set depends on genetics, physiological status and environmental conditions. Proper care, timely pest control and increased organic fertilization are recommended to improve fruit set. Table 3.6 summarizes flowering and fruit set characteristics.

**Table 6:** Flowering and Fruit-Setting Characteristics of Bac Son Yellow Mandarin

Indicator	Value
Flowering period	14/02 – 16/02
Peak bloom period	20/02 – 27/02
End of bloom period	01/03 – 03/03
Number of flowers	$28,775.5 \pm 2844.84$
First physiological fruit drop	April (about one month after bloom)
Second physiological fruit drop	June when fruits reach 3–4 cm, pedicel retained
Fruits set per tree	$328.30 \pm 7.91$
Fruit set (%)	$1.14 \pm 0.14$

Citrus species commonly experience flower and fruit drop as a physiological process due to formation of an abscission layer at the pedicel. Fruit drop can be an adaptive response to limited nutrients, water, and hormones—resulting in shedding of some young fruits to allocate resources to remaining fruits. Fruit drop is especially intense during rapid embryonic growth and fruit enlargement. Two physiological fruit drop events commonly occur during the season: (1) early drop (pedicel drop) one month after flowering (March–early April), and (2) later drop when fruits reach 3–4 cm (June), pedicel remains. After these two

drops, fruit growth accelerates—average diameter increases by 0.5–0.7 mm/day; growth slows briefly during seed formation then accelerates until the fruit attains maximum size.

### 4. Fruit characteristics, production efficiency and fruit quality of Bac Son yellow mandarin

Tree yield depends on the number of fruits per tree and average fruit weight. To assess fruit traits, yield and quality, the research team measured and counted fruits per tree; results are presented in Table 3.7.

**Table 7:** Fruit Characteristics, Production Efficiency, and Fruit Quality of Bac Son Yellow Mandarin

Indicator	Unit	Value
Peel color		Bright yellow, smooth
Fruit mass	Gr	$107.22 \pm 4.69$
Pulp mass	Gr	$87.79 \pm 3.82$
Fruit diameter	cm	$7.72 \pm 0.83$
Fruit height	cm	$5.20 \pm 0.45$
Segments per fruit	segments	$11.12 \pm 1.0$
Seeds per fruit	seeds	$15.08 \pm 3.10$
Edible fraction (%)	%	$81.95 \pm 3.37$
Theoretical yield (kg/tree)	kg/tree	$35.96 \pm 0.55$
Actual yield (kg/tree)	kg/tree	$32.90 \pm 1.87$

Round fruits, when ripe, have a golden-yellow peel, thin rind, are easy to peel and contain little fiber. Average fruit diameter is  $7.72 \pm 0.83$  cm and height  $5.20 \pm 0.45$  cm. Mean fruit mass is  $107.22 \pm 4.69$  g, containing about  $11.12 \pm 1.0$  segments and approximately  $15.08 \pm 1.10$  seeds per fruit. The edible portion is about  $81.95 \pm 3.37\%$  corresponding to mean pulp mass of  $87.79 \pm 3.82$  g. Average tree yield is approximately  $32.90 \pm 0.55$  kg/tree.

### 5. Survey of pests and diseases on Bac Son yellow mandarin

Survey and identification of principal pests and diseases followed the methods outlined in QCVN 01 - 119: 2012/ Ministry of Agriculture and Rural Development. Like other citrus species, Bac Son mandarin is susceptible to many pests and diseases that impact yield and fruit quality. Timely monitoring and detection are essential to implement effective control measures and to evaluate tree resilience. The observed pests and diseases are listed in Table 3.8.

**Table 8:** Status of Pests and Diseases on Bac Son Yellow Mandarin

No.	Pest/Disease	Scientific name	Damage level	Affected part
1	Powdery mildew	Erysiphe sp.	**	Leaves
2	Sooty mold / Mealybug infestation	Planococcus citri Risso	***	Young leaves, shoots
3	Stem borer	Nadezhdiella cantori Hope	***	Trunk, branches
4	Fruit fly (fruit borer)	Bactrocera sp.	**	Fruit
5	Mealybug	Citrus mealybug	**	Leaves, fruit

**Note:** \* Low; \*\* Medium; \*\*\* High

Powdery mildew and sooty mold (often associated with insect vectors) are the two main diseases observed. Sooty mold incidence persisted longer and caused more severe damage. Three common insect pests were stem borers, fruit flies (fruit borers), and mealybugs. Overall damage was usually moderate; however, stem borers can cause severe damage and even tree death, though their occurrence frequency was relatively low.

## 6. Fruit quality of Bac Son yellow mandarin – Lang Son

The fruit quality assessment is presented in Table 3.9.

**Table 9:** Evaluation of the Fruit Quality of the Bac Son Yellow Mandarin Variety

Parameter	Value
Total sugars (%)	8.57
Brix (%)	13.68
Total acid (%)	0.91
Vitamin C (mg/100 g)	32.14
Water (%)	89.87
Minerals (%)	0.45

When ripe, Bac Son mandarin shows bright yellow peel, thin rind, and juicy segments containing about 89.87% water. The sweet taste is reflected in a Brix of approximately 13.68 and total sugars of 8.57%. The fruit contains very little fiber and has a characteristic aroma not commonly found in other mandarins. Per 100 g of fruit, vitamin C content was about 32.14 mg and minerals about 0.45%, in addition to other trace elements.

## Conclusions and Recommendations

### Conclusions

The study evaluated agro-biological characteristics of Bac Son yellow mandarin in Bac Son district, Lang Son province. The results show:

- The Bac Son yellow mandarin displays strong growth potential with tall trees, wide canopies, thick leaves and abundant essential oils.
- Flowering and fruit set follow natural patterns, but fruit set is low at approximately 1.14%.
- Fruit quality is high, with a high edible fraction and Brix ~13.68%, total sugar 8.57% and vitamin C of 32.14 mg/100 g fruit.
- The variety is affected by several pests and diseases, notably greening (huanglongbing), stem borers and mealybugs.

### Recommendations

- Apply appropriate cultivation techniques including improved fertilizer practices, irrigation, and pruning to raise production efficiency.
- Strengthen research and propagation of disease-free planting material to conserve and maintain quality genetic resources of Bac Son yellow mandarin.

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