‘Taichung No. 6’: A Bush Common Bean Cultivar for Frozen Processing

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The common bean (Phaseolus vulgaris L.; 2n = 2x = 22), one of the most important legume crops that originated in southern Mexico to Central America, is cultivated in tropical, subtropical, and temperate regions. It is produced mainly for dry beans (seeds harvested at full maturity), shell beans (seeds harvested at physiologic maturity), and green or snap beans (pod harvested before seed development), all of which are eaten fresh, canned, or frozen (Gepts, 1998).

Depending on growth and twining habit, the common bean is classified into two groups: bush and pole. Three genes, L/l (long stem/short stem), A/a (indeterminate growth/determinate growth), and T/t (twining/nontwining), govern stem growth (Miklas and Singh, 2007). A bush bean plant generally grows to a height of less than 60 cm and reaches harvest maturity in a relatively short period. Thus, its harvest can be mechanized easily with low labor input, and it can fit into a niche of a short growing period of 2 to 3 months for concentrated production. Nevertheless, this can afford relatively little competition to their companion crops (Hyman et al., 2008).

The objectives for common bean breeding focus primarily on improving yield, quality, environmental adaptability, and profitability (Singh and Singh, 2015). In response to the demands of the frozen vegetable market, bush cultivars for food processing must have greater yield and include pod traits fit for frozen quality. These specific characteristics of pods for frozen processing especially for Japan’s export market are dark-green color, straight, stringless, a diameter of 7 to 9 mm, and a high sugar content. In addition, it needs a more upright plant architecture to offering cultivation advantages, such as ease of crop management (particularly in mechanical operations), reduction of pod loss at harvest with better quality, and lower incidence of disease by facilitating air circulation (Pires et al., 2014).

The greatest difficulty in obtaining new cultivars with these target traits is the large number of controlled genes involved and the effect of the environment on their expression. The general principle for cultivar preparation is using recurrent selection; however, this process is time-consuming when evaluating and recombining progeny selection (Hallauer et al., 2010). Alternative selection systems, pure-line and mass selection, which have shown efficiency in autogamous crops, were suggested for high heritable traits (Allard, 1960).

The Taichung District Agricultural Research and Extension Station (TDARES) announced the release of the ‘Taichung No. 6’ common bean—an open-pollinated bush-type cultivar for frozen pod production. This cultivar was developed using a series of pure-line and mass selections, and then was evaluated for field performance. The ‘Taichung No. 6’ common bean has an upright shoot, vigorous branching, and a high pod setting with excellent pod quality. It can be sown from September to February in tropical Taiwan.

Origin

All breeding, selection, and performance studies were conducted in field conditions in TDARES (lat. 24°08’N, long. 120°32’E) starting in 2013. The experiment was arranged within different germplasms in a completely randomized design with three replicates in each accession. Plants were planted in double rows, spaced 45 cm apart, with 10-cm spacing within rows. Fifty plants were planted and 10 plants were sampled randomly for analysis in each replicate. SAS software version 8.2 (SAS Institute Inc.,

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pan) and CFC was analyzed according to
refractometer (ATAGO PR-101, Tokyo, Ja-
recorded. TSSC was measured by a digital
after boiling-water blanching for 2 min] was
total soluble solid content (TSSC), crude
characteristics included plant height, upright-
ness measured by the angle between the
plasms, including commercial cultivars and
breeding lines collected from the Nether-
lands, Italy, France, the United States, Japan,
Taiwan, were evaluated for their poten-
tial as frozen processing cultivars and were
cultivated from October to November in
2013 and 2014 (average temperature, 23.6
and 25.8 °C; maximum temperature, 28.6 and
32.9 °C; daylength, 11 h). Horticultural
characteristics included plant height, upright-
ess measured by the angle between the
ground and the main stem, days to flowering
(DTF), days to harvest (DTH), and yield per
square meter. Pod quality [length, diameter,
total soluble solid content (TSSC), crude
fiber content (CFC), and color before and
after boiling-water blanching for 2 min] was
recorded. TSSC was measured by a digital
refractometer (ATAGO PR-101, Tokyo, Ja-
pan) and CFC was analyzed according to
Kitcherside et al. (2000). Color ratings were
made based on a 1 to 5 scale, in which 1 =
light green and 5 = dark green.
Eight cultivars of those 36 germplasms
had traits that fit the breeding goal. Among
them, commercial cultivars Sonnet (Sakata
Seed Co., Ltd., Japan), with strong branching
and superior yield, and Vivid (Taiwan Asso-
ciation of Frozen Vegetable and Fruit Man-
ufacturers, Taiwan), with upright shoots and
dark green pods, were selected as female and
male parents, respectively. Three elite plants
of cultivars Sonnet and Vivid were then
crossed using bud pollination in Nov. 2014.
From 2015 to 2016, pure-line selection was
applied at the F 2–F4 generations, followed by
progeny population size was ≈100 to 150
plants, and three to five superior plants were
selected. Their seeds were subsequently col-
lected individually during pure-line selec-
tion, or together during mass selection.
A comparative test for elite lines was then
performed from Feb. to Mar. and Oct. to
Nov. 2017. Line 2017DCB-13 was selected based
on its overall field performance and pod traits.
Seed production and distinctness, uniformity,
and stability testing were conducted from Jan.
to Mar. 2018. Based on the results of trait
performance from the cropping, 2017DCB-17
was named the new common bean cultivar
‘Taichung No. 6’ after evaluation.

Description and Performance

Bush common bean ‘Taichung No. 6’
demonstrated determinate growth, dwarf
shoots, strong branching, and upstanding
stems with a 58-cm plant height (Fig. 1A). It
blossomed 35 d after sowing. The first in-
florescence was located in the third node, ≈16
cm aboveground. On average, each inflo-
rescence had six flowers with a 1.5-cm pedicel.
DTH was 55 d in summer and 65 d in winter.
Its fresh pod is straight and stringless. The pod
length, diameter, and weight were 13.1 cm, 0.8
cm, and 4.6 g, respectively. The pod epidermis
was dark green and smooth (Fig. 1B). It had a
slightly sweet taste with a high sugar content at
6.0 °Brix. The plants showed vigorous, stable,
and uniform performance in the field during the
cropping season (Fig. 1C). In addition, the
seed was white and kidney shaped, with 100
seeds weighing 24.2 g.

Compared with the control cultivars—
female parent Vivid and male parent Sonnet—‘Taichung No. 6’ had more erect
shoots and superior branching (Fig. 2A) as
well as uniform maturity and dark-green pods
(Fig. 2B). It had significantly greater shoot
height, shorter DTF and DTH, and greater
pod yield. The yield of ‘Taichung No. 6’ was
7.4 kg·m⁻², whereas that of ‘Vivid’ and
‘Sonnet’ were 6.8 and 6.1 kg·m⁻², respec-
tively (Table 1). Pod traits, such as length,
diameter, and weight, did not differ between
the control cultivars. However, ‘Taichung
No. 6’ had a darker green color not only in
fresh, but also in blanched pods. It also had
to better taste quality, greater TSSC (6.0
Brix), and less CFC (10.6%) (Table 2).

There appears to be significant transgressive
segregation for several traits, including plant
height, DTF, DTH, yield, and fresh pod color.
It is suggested that hybridization followed by
pure-line and mass selection based on the traits
required by frozen processing is an optimal
method for bush common bean breeding.

Optimal Sowing Season

The optimal mean temperature for the
common bean is 20 to 25 °C. A high
temperature during the flowering stage leads
to abscission of flowers and a low pod set,
thus resulting in yield loss. Daytime temper-
atures of less than 20 °C delay maturity and
cause the development of empty mature pods
(Alghamdi and Ali, 2004). To determine the
optimal sowing season for new common bean
cultivars, the seeds of ‘Taichung No. 6’ and
control cultivars were sown on 28 Sept. 2017,
28 Dec. 2017, and 28 Mar. 2018. For each 2-
month cropping, the average temperature was
24.4, 16.2, and 27.7 °C, respectively; the
maximum temperature was 33.9, 29.3, and
33.2 °C, respectively.

Different sowing seasons demonstrated
significant effects in common bean plant

Fig. 2. Comparison of plant and pod performance of bush common bean ‘Taichung No. 6’ with control cultivars Vivid and Sonnet. ‘Taichung No. 6’ is more erect and has superior branching (A) as well as uniform maturity and dark green pods (B).
Table 1. Plant performance of bush common bean ‘Taichung No. 6’ compared with commercial control cultivars Vivid and Sonnet cultured in the 2018 field trial.a

| Genotype     | Plant ht (cm) | Days to flowering | Days to harvest | No. of pods/plant | Yield (kg·m⁻²) |
|--------------|---------------|-------------------|-----------------|-------------------|----------------|
| Taichung No. 6 | 58.4 ± 2.9 a  | 36.4 ± 2.2 a    | 56.4 ± 1.5 a    | 34.8 ± 2.1 a      | 7.4 ± 0.2 a    |
|              | 13.7 ± 1.2 a  | 30.5 ± 3.2 c     | 56.1 ± 2.5b     | 27.6 ± 3.1 a      | 5.7 ± 0.3 a    |
|              | 12.2 ± 1.0 a  | 46.2 ± 3.1 a     | 63.2 ± 3.1a     | 42.8 ± 2.8 a      | 6.4 ± 0.4 a    |
|              | 12.9 ± 2.5 a  | 37.8 ± 2.7 b     | 62.2 ± 3.1a     | 8.3 ± 2.8 a       | 2.1 ± 0.3 b    |
| Vivid        | 45.9 ± 2.3 c  | 7.4 ± 0.3 a      | 4.8 ± 0.4 a     | 6.2 ± 0.4 a       | 11.8 ± 0.5 a   |
| Sonnet       | 51.8 ± 2.1 b  | 40.4 ± 1.7 b     | 60.6 ± 1.9 b    | 23.8 ± 3.1 b      | 6.1 ± 0.3 c    |

aTrail were conducted from Jan. to Mar. 2018 with average temperature at 17.3 °C.

Table 2. Pod quality of bush common bean ‘Taichung No. 6’ compared with commercial control cultivars Vivid and Sonnet cultured in the 2018 field trial.a

| Genotype     | Pod length (cm) | Pod diam (mm) | Pod wt (g) | Fresh pod color* | Blanched pod color | Brix | CFC (%) |
|--------------|-----------------|---------------|------------|------------------|-------------------|------|--------|
| Taichung No. 6 | 13.1 ± 1.3 a  | 8.5 ± 0.4 a  | 4.6 ± 0.4 a | 4.2 ± 0.2 a     | 6.0 ± 0.7 a      | 10.6 ± 0.3 b |
|              | 13.7 ± 1.2 a  | 30.5 ± 3.2 c | 56.1 ± 2.5b | 27.6 ± 3.1 a    | 5.7 ± 0.3 a      | 11.8 ± 0.5 a |
|              | 12.2 ± 1.0 a  | 46.2 ± 3.1 a | 63.2 ± 3.1a | 42.8 ± 2.8 a    | 6.4 ± 0.4 a      | 2.1 ± 0.3 b  |
| Vivid        | 12.9 ± 2.5 a  | 37.8 ± 2.7 b | 62.2 ± 3.1a | 8.3 ± 2.8 a     | 2.1 ± 0.3 b      | 11.5 ± 0.3 b |
| Sonnet       | 12.2 ± 0.9 a  | 7.4 ± 0.3 a  | 4.8 ± 0.4 a | 6.2 ± 0.4 a     | 11.8 ± 0.5 a     | 2.1 ± 0.3 b  |

aDifferent letters indicate significant differences between genotypes by Fisher’s least significant difference at P ≤ 0.05.

Table 3. Effect of sowing day on plant growth of bush common bean ‘Taichung No. 6’.

| Sowing date | Plant ht (cm) | Days to flowering | Days to harvest | No. of pods/plant | Yield (kg·m⁻²) |
|-------------|---------------|-------------------|-----------------|-------------------|----------------|
| 28 Sept. 2017 | 57.6 ± 3.9 b | 30.5 ± 3.2 c     | 56.1 ± 2.5b     | 27.6 ± 3.1 a      | 5.7 ± 0.3 a    |
| 28 Dec. 2017 | 48.6 ± 2.5 c | 46.2 ± 3.1 a     | 63.2 ± 3.1a     | 42.8 ± 2.8 a      | 6.4 ± 0.4 a    |
| 28 Mar. 2018 | 66.5 ± 4.1 a | 37.8 ± 2.7 b     | 62.2 ± 3.1a     | 8.3 ± 2.8 a       | 2.1 ± 0.3 b    |

Different letters indicate significant differences between genotypes by Fisher’s least significant difference at P ≤ 0.05.

Table 4. Effect of sowing day on pod traits of bush common bean ‘Taichung No. 6’.

| Sowing date | Pod length (cm) | Pod diam (mm) | Pod wt (g) | TSSC* (Brix) | CFC (%) |
|-------------|-----------------|---------------|------------|-------------|--------|
| 28 Sept. 2017 | 13.7 ± 1.2 a | 7.4 ± 0.5 b  | 4.8 ± 0.4 a | 6.1 ± 0.6 a | 11.5 ± 0.3 b |
| 28 Dec. 2017 | 12.2 ± 1.3 a | 7.2 ± 0.3 b  | 4.7 ± 0.3 a | 6.2 ± 0.4 a | 11.9 ± 0.2 b |
| 28 Mar. 2018 | 9.2 ± 0.9 b | 9.3 ± 0.7 a  | 5.3 ± 0.3 a | 5.0 ± 0.4 b | 12.9 ± 0.4 a |

Different letters indicate significant differences between genotypes by Fisher’s least significant difference at P ≤ 0.05.

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