# CHAPTER 4
# RESULTS

## Part 1 Evaluation of male sterility in chili and improvement of parental lines

### Experiment 1 Evaluation of male sterility in chili by fertility scoring method

$F_1$ hybrid seeds between the germplasm and male sterile chilies were grown for fertility scoring. Thirty eight $F_1$ hybrids were evaluated. They were classified into three groups (Table 3) according to their pollen viability (Figure 2). Nine accessions showed fertile pollen. This group consisted of: PEPAC30-4 × CA597-2, PEPAC32-5 × CA598-1, PEPAC36-16 × CA1274-2, PEPAC36-3 × CA1321-3, PEPAC36-15 × CA1428-F-1, PEPAC36-16 × CA1428-G-1, PEPAC32-18 × CA1447-4-12, PEPAC 36-9 × CA1574-5 and PEPAC38-1 × CA006-1. Accordingly, the male parental accessions: CA006-1, CA597-2, CA598-1, CA1274-2, CA1321-3, CA1428-F-1, CA 1428-G-1, CA1447-4-12 and CA1574-5 and should have genotypes of N/S *RfRf*.

Seven accessions showed no pollen on some plants and fertile pollen on other plants in the same accession. This group consisted of: PEPAC32-9 × CA683-1, PEPAC36-3 × CA614-A-4, PEPAC36-11 × CA1038, PEPAC36-7 × CA1395-A-2, PEPAC36-10 × CA1403-7, PEPAC36-1 × CA042-5 and PEPAC32-7 × CA1448-5-13. Accordingly, the male parental accessions: CA683-1, CA614-A-4, CA1038, CA 1395-A-2, CA 1403-7, CA 042-5 and CA1448-5-13 should all have genotypes of N/S *Rfrf*.

Twenty two accessions showed no pollen or some non-viable pollen. This group consisted of: PEPAC30-6 × CA254-6, PEPAC30-18 × CA489-2, PEPAC34-2 × CA1159-3, PEPAC36-16 × CA443-1, PEPAC36-5 × CA617-D-6, PEPAC36-5 × CA633-2, PEPAC36-1 × CA646-5, PEPAC36-8 × CA720-3, PEPAC36-8 × CA780-6, PEPAC36-2 × CA1303-1, PEPAC36-5 × CA1374-4, PEPAC36-3 × CA1377-D-2, PEPAC36-8 × CA1401-1, PEPAC36-17 × CA1440-6, PEPAC36-8 × CA1441-1, PEPAC38-11 × CA1445-1, PEPAC32-37 × CA1449-3-9, PEPAC36-17 × CA1450-7,

PEPAC38-1 × CA005-1, PEPAC38-1 × CA319-1, PEPAC38-15 × CA1442-1 and PEPAC38-16 × CA1442-F-7. Accordingly, the male parental accessions: CA254-6, CA489-2, CA1159-3, CA443-1, CA617-D-6, CA633-2, CA646-5, CA720-3, CA780-6, CA1303-1, CA1374-4, CA1377-D-2, CA1401-1, CA1440-6, CA1441-1, CA1445-1, CA1449-3-9, CA1450-7, CA005-1, CA319-1, CA1442-1 and CA1442-F-7 should have genotypes of N *rfrf*.

Table 3 Fertility scoring of pollen of $F_1$ hybrids and prospective genotype of the $F_1$ hybrids and the male parents

| No. | $F_1$ hybrid | Viability of pollen (No. of plant) | | Prospective genotype | |
|---|---|---|---|---|---|
| | | Fertile | Sterile | $F_1$ hybrid | Male parent |
| 1 | PEPAC30-4 × CA597-2 | 30 | 0 | S *Rfrf* | N/S *RfRf* |
| 2 | PEPAC32-5 × CA598-1 | 30 | 0 | S *Rfrf* | N/S *RfRf* |
| 3 | PEPAC36-16 × CA1274-2 | 30 | 0 | S *Rfrf* | N/S *RfRf* |
| 4 | PEPAC36-3 × CA1321-3 | 17 | 12(I) | S *Rfrf* | N/S *RfRf* |
| 5 | PEPAC36-15 × CA1428-F-1 | 30 | 0 | S *Rfrf* | N/S *RfRf* |
| 6 | PEPAC36-16 × CA1428-G-1 | 30 | 0 | S *Rfrf* | N/S *RfRf* |
| 7 | PEPAC32-18 × CA1447-4-12 | 30 | 0 | S *Rfrf* | N/S *RfRf* |
| 8 | PEPAC36-9 × CA1574-5 | 30 | 0 | S *Rfrf* | N/S *RfRf* |
| 9 | PEPAC38-1 × CA006-1 | 30 | 0 | S *Rfrf* | N/S *RfRf* |
| 10 | PEPAC32-9 × CA683-1 | 11 | 6+5(I) | S *Rfrf* : S *rfrf* | N/S *Rfrf* |
| 11 | PEPAC36-3 × CA614-A-4 | 12 | 8(I) | S *Rfrf* : S *rfrf* | N/S *Rfrf* |
| 12 | PEPAC36-11 × CA1038 | 4 | 3+4(I) | S *Rfrf* : S *rfrf* | N/S *Rfrf* |
| 13 | PEPAC36-7 × CA1395-A-2 | 20 | 6(I) | S *Rfrf* : S *rfrf* | N/S *Rfrf* |
| 14 | PEPAC36-10 × CA1403-7 | 2 | 6+7(I) | S *Rfrf* : S *rfrf* | N/S *Rfrf* |
| 15 | PEPAC36-1 × CA042-5 | 3 | 16 | S *Rfrf* : S *rfrf* | N/S *Rfrf* |
| 16 | PEPAC32-7 × CA1448-5-13 | 6 | 12 | S *Rfrf* : S *rfrf* | N/S *Rfrf* |
| 17 | PEPAC30-6 × CA254-6 | 0 | 30 | S *rfrf* | N *rfrf* |
| 18 | PEPAC30-18 × CA489-2 | 0 | 30 | S *rfrf* | N *rfrf* |
| 19 | PEPAC34-2 × CA1159-3 | 0 | 10+13(I) | S *rfrf* | N *rfrf* |
| 20 | PEPAC36-16 × CA443-1 | 0 | 14 | S *rfrf* | N *rfrf* |
| 21 | PEPAC36-5 × CA617-D-6 | 0 | 30 | S *rfrf* | N *rfrf* |
| 22 | PEPAC36-5 × CA633-2 | 0 | 30 | S *rfrf* | N *rfrf* |
| 23 | PEPAC36-1 × CA646-5 | 0 | 15+2(I) | S *rfrf* | N *rfrf* |
| 24 | PEPAC36-8 × CA720-3 | 0 | 30 | S *rfrf* | N *rfrf* |
| 25 | PEPAC36-8 × CA780-6 | 0 | 30 | S *rfrf* | N *rfrf* |
| 26 | PEPAC36-2 × CA1303-1 | 0 | 30 | S *rfrf* | N *rfrf* |

I = fertile pollen on some plants and sterile pollen on some plants of the same hybrid

Table 3 Fertility scoring of pollen of $F_1$ hybrids and prospective genotype of the $F_1$ hybrids and the male parents (continued)

| No. | $F_1$ hybrid | Viability of pollen (No. of plant) | | Prospective genotype | |
|---|---|---|---|---|---|
| | | Fertile | Sterile | $F_1$ hybrid | Male parent |
| 27 | PEPAC36-5 × CA1374-4 | 0 | 30 | S *rfrf* | N *rfrf* |
| 28 | PEPAC36-3 × CA1377-D-2 | 1 | 22 | S *rfrf* | N *rfrf* |
| 29 | PEPAC36-8 × CA1401-1 | 0 | 21 | S *rfrf* | N *rfrf* |
| 30 | PEPAC36-17 × CA1440-6 | 0 | 30 | S *rfrf* | N *rfrf* |
| 31 | PEPAC36-8 × CA1441-1 | 0 | 21 | S *rfrf* | N *rfrf* |
| 32 | PEPAC38-11 × CA1445-1 | 0 | 30 | S *rfrf* | N *rfrf* |
| 33 | PEPAC32-37 × CA1449-3-9 | 0 | 30 | S *rfrf* | N *rfrf* |
| 34 | PEPAC36-17 × CA1450-7 | 0 | 30 | S *rfrf* | N *rfrf* |
| 35 | PEPAC38-1 × CA005-1 | 0 | 28 | S *rfrf* | N *rfrf* |
| 36 | PEPAC38-1 × CA319-1 | 0 | 22(I) | S *rfrf* | N *rfrf* |
| 37 | PEPAC38-15 × CA1442-1 | 0 | 30 | S *rfrf* | N *rfrf* |
| 38 | PEPAC38-16 × CA1442-F-7 | 0 | 30 | S *rfrf* | N *rfrf* |

I = fertile pollen on some plants and sterile pollen on some plants of the same hybrid

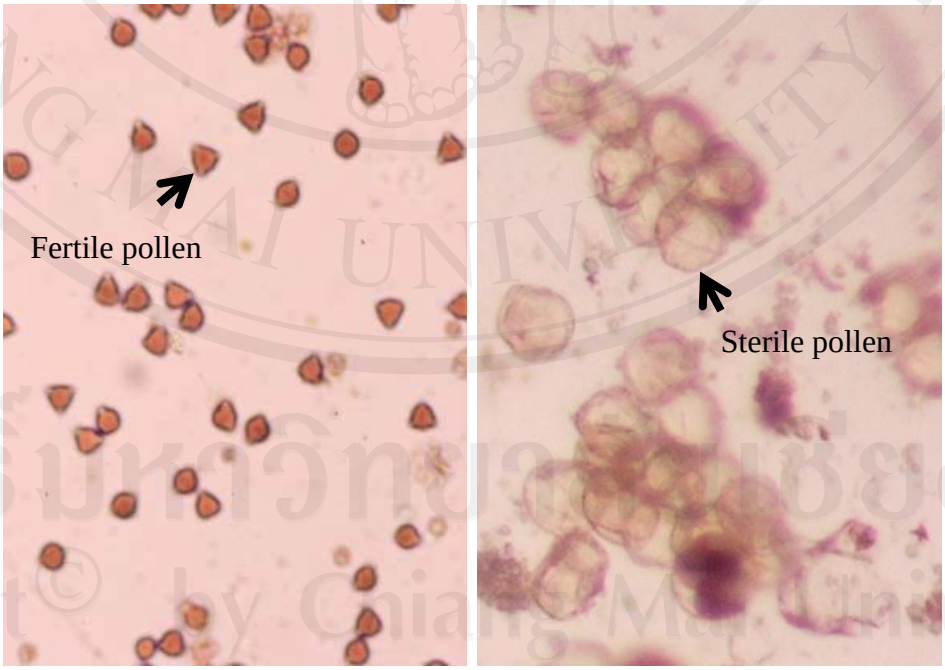



Figure 2 Fertile pollen with red stained and sterile pollen with white color

**Experiment 2** Molecular markers of male sterility genes of chili

Evaluation of male sterility of chili was based on PCR reaction using primer developed from CAPS DNA marker by Kim (2005). Different procedures were tested to get suitable conditions for each chili variety in the following aspects: PCR composition (quantity adjustment), PCR reaction stages (temperature, time, and cycle adjustment). The condition that allows DNA amplification, is 20 µl PCR composition encompassing DNA template 1 µl, *Taq* polymerase (5 unit/µl) 0.1µl, *Taq* buffer (10x) 2µl, dNTP mix (2 mM) 0.5 µl, $MgCl_2$ (25 mM) 1.2 µl, forward primer (10 µM) 0.4 µl, reverse primer (10 µM) 0.4 µl, and $ddH_2O$ 14.4 µl. PCR result showed amplified DNA band, not precisely clear, and cannot tell apart among the sampled chilies (Figure 3). Then amplified DNA was consequently truncated by *Rsa* I or *Mse* I enzymes, which are four-base pair restriction enzymes (RE). However, both enzymes could not cut the amplified DNA, thus it was not possible to discriminate male sterility of chili based on this DNA.

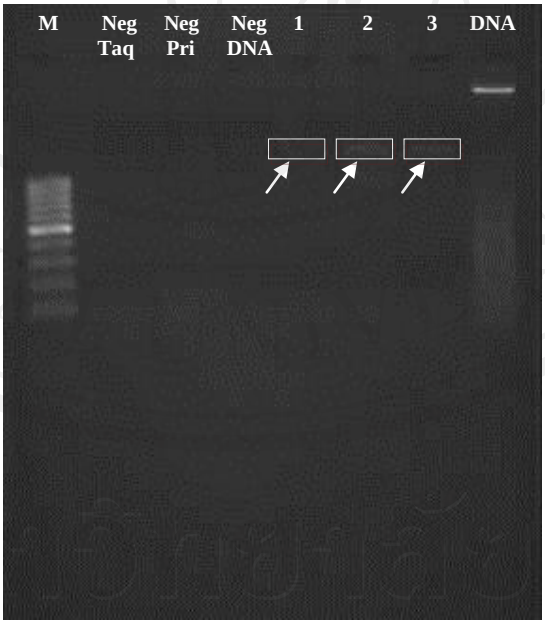



Figure 3 DNA amplification by PCR technique
(Arrows pointing to DNA bands from samples of three chili varieties)

For the study of DNA markers associated with phenotype characteristics, DNA amplification was endeavored by RAPD technique for sample chilies. From

OPF 01 - 12 primer screening, OPF01-05, OPF09 and OPF10 were found to be able to increase DNA magnitude but only OPF01 was observed to provide a band with intense clarity (Figure 4).

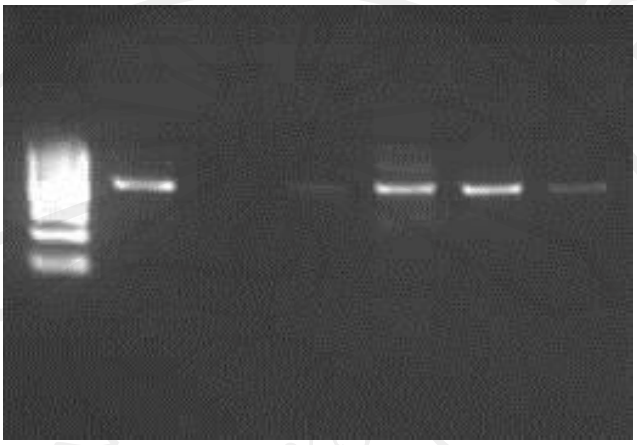


Figure 4 DNA amplification by OPF01 primer

**Experiment 3 Improvement of parental lines**

A male sterile chili variety, KY16, was crossed with 3 good chili maintainers. The $F_1$ hybrids were backcrossed with respective male parents for 2 generations. Three backcrossed male sterile chilies were obtained. The list $BC_2$KY16 varieties shown in Table 4. A male sterile chili variety, PEPAC32, was crossed with 3 good chili maintainers. The $F_1$ hybrids were backcrossed with respective male parents for 2 generations. The second backcrossed male sterile chilies were obtained. The list $BC_2$PEPAC 32 varieties shown in Table 4.

Table 4 List of $BC_2$KY16 and $BC_2$ PEPAC32 varieties of chilies

| No. | Male sterile variety | Maintainer variety | Backcross variety |
|---|---|---|---|
| 1 | KY16 | CA1445-7-8 | $BC_2$ KY16 × CA1445-7-8 |
| 2 | KY16 | CA1449-2-4 | $BC_2$ KY16 × CA1449-2-4 |
| 3 | KY16 | CA1450-7-10 | $BC_2$ KY16 × CA1450-7-10 |
| 4 | PEPAC32 | CA1445-7-8 | $BC_2$ PEPAC32 × CA1445-7-8 |
| 5 | PEPAC32 | CA1449-2-4 | $BC_2$ PEPAC32 × CA1449-2-4 |
| 6 | PEPAC32 | CA1450-7-10 | $BC_2$ PEPAC32 × CA1450-7-10 |

**Part 2 Combining ability study in chili maintainers (B line)**

**2.1 Comparative study of 9 $F_1$ hybrids, parental varieties and standard varieties in green chili, winter 2010**

**Plant height**

All 9 $F_1$ hybrids had plant height in 57.33 - 78.78 cm range with obvious variation among them at statistically significant level (Table 5). The $F_1$ hybrid CA1450 × CA1448 exhibited the minimum plant height while the $F_1$ hybrid CA1449 × CA1448 possessed the maximum. Many $F_1$ hybrids got plant height not statistically significantly different from the levels of their 3 maternal parents which were maintainer varieties, namely CA1445, CA1449 and CA1450.

The $F_1$ hybrid CA1449 × CA1448 which yielded the maximum plant height among the 9 $F_1$ hybrids. The height was not statistically significantly different in comparison with the maintainer varieties, CA1445 and CA1449 (Table 5). However it differed statistically significantly when compared with the CA1450 variety. Many $F_1$ hybrids showed plant height at levels not statistically significantly different from those of their male parents, CA1447 and CA1448 (Table 5).

The $F_1$ hybrid CA1449 × CA1448 which had the highest plant height compared with other $F_1$ hybrids in the experiment. It was higher statistically significant in comparison with its CA1447 and CA1448 male parents but not different from CA683 male parent at statistically significant level (Table 5).

The $F_1$ hybrids CA1450 × CA1448, CA1450 × CA1447 and CA1445 × CA1448 which got the minimum plant heights among all the 9 $F_1$ hybrids were not different at statistically significant level from their CA1447 and CA1448 male parents (Table 5) but different at statistically significant level from their CA683 male parent in this aspect.

**Canopy width**

The 9 $F_1$ hybrids obtained the canopy width in 64.22 - 80.78 cm range which were not different from one another's at statistically significant level (Table 5; Figure 5). The $F_1$ hybrid CA1450 × CA683 exhibited the smallest canopy width while the $F_1$ hybrid CA1449 × CA683 gave the largest canopy width. However, canopy widths of all $F_1$ hybrids were not different at statistically significant levels when compared with those of their female parents, male parents, as well as the 3 commercial varieties.

**Yield**

Yields of the $F_1$ hybrids under experiment varied in the range of 2.346 - 6.794 t/rai and differed from one another at statistically significant level (Table 5). The $F_1$ hybrid CA1449 × CA1448 performed the poorest while the $F_1$ hybrid CA1450 × CA1448 was most productive in yield. These minimum and maximum levels differed statistically significant in comparison with those of the female parents, male parents and commercial varieties. The $F_1$ hybrids CA1450 × CA1447 and CA1450 × CA1448 while they were not different statistically significant from each other in terms of yield level but they differed at statistically significant level in the productivity performance when compared with their female parents, male parents and YokSiam variety but they were not different statistically significantly when compared with JomThong 2 and Jakkrapat varieties. Most $F_1$ hybrids performed not statistically significantly different from the commercial varieties in terms of output per rai.

The female parents, CA1445, CA1449 and CA1450 varieties, produced 2.735 - 4.551 t/rai (Table 5) with differences at statistically significant level. Variety CA1450 produced the highest yield while variety CA1445 produced the lowest. Most maintainer varieties, or the female parents, obtained yield at levels not different at statistically significant level from those of the commercial varieties. Some $F_1$ hybrids

appeared superior to the female parent varieties at statistically significant level in terms of yield. However, the majority of the $F_1$ hybrids under this study did not differ at statistically significant level from the female parent varieties in output performance.

The male parent varieties, CA683, CA1447 and CA1448, yielded output in the range of 2.583 - 4.542 t/rai (Table 5) and the levels differed statistically significant among them. Variety CA1448 was most productive while variety CA683 appeared the poorest in output performance, compared with the commercial varieties, the male parent varieties in this study generally were not different at statistically significant levels in terms of yield levels. A few $F_1$ hybrids produced yield at statistically significant levels and higher than those of the male parent varieties but in most cases the differences in yield levels were not statistically significant.

**Fruit weight per plant**

The 9 $F_1$ hybrids under experiment produced fruit weight per plant at levels different statistically significantly ranging from 0.37 to 1.06 kg/plant (Table 5). The $F_1$ hybrid CA1449 × CA1448 was the poorest while the $F_1$ hybrid CA1450 × CA1448 was the best in this nature, in consonance with their output per rai levels, the poorest and the highest respectively, from the present experiment. The $F_1$ hybrids CA1450 × CA1448 and CA1450 × CA1447 were not different at statistically significant level between them in their fruit weight per plant but they performed better than their female and male parents and the differences were statistically significant. The $F_1$ hybrid CA1450 × CA1448 was significantly different from all commercial varieties while the $F_1$ hybrid CA1450 × CA1447 was not different from two commercial varieties in terms of fruit weight per plant. Most of the $F_1$ hybrids appeared not significantly different from the female and male parental varieties as well as the commercial varieties regarding this yield component.

**Number of fruits per plant**

The 9 $F_1$ hybrids exhibited statistically significant differences in their number of fruits per plant ranging from 15 to 42 fruits/plant. The $F_1$ hybrid CA1450 × CA683 yielded the least while the $F_1$ hybrid CA1445 × CA683 got the most number of fruits per plant and their feature in this aspect differed from that of all female parents and all

male parents at statistically significant level but did not differ statistically significantly when compared with two commercial varieties. The majority of $F_1$ hybrids were not significantly different from the female, male parental varieties and Jakkrapat variety in the number of fruits per plant. Most of the $F_1$ hybrids gave lower number of fruits per plant than JomThong 2 and YokSiam varieties. The differences were statistically significant.

**Fruit weight**

Fruit weight of the 9 $F_1$ hybrids, varied from 20.53 to 51.17 g/fruit, the differences were statistically significant (Table 5). Fruit weight of the $F_1$ hybrid CA1449 × CA1448 was the lowest and those of $F_1$ hybrids CA1450 × CA1448 and CA1450 × CA1447 were the highest from the present experiment. The latter two varieties outperformed all other $F_1$ hybrids, all female parental varieties, all commercial varieties, and one male parental variety under study. Many $F_1$ hybrids produced relatively better fruit weight than all commercial varieties, at statistically significant level.

**Fruit width**

The 9 $F_1$ hybrids differed significantly in fruit width in the 2.16 - 3.27 cm range (Table 5; Figure 5-9). The $F_1$ hybrid CA1445 × CA683 produced minimum while the $F_1$ hybrids CA1450 × CA1448, CA1450 × CA1447 and CA1449 × CA1447 yielded maximum fruit width which were significantly higher than the rest of $F_1$ hybrid varieties and all the commercial varieties. However, they were not significantly different from most female and most male parental varieties. Most $F_1$ hybrid varieties, produced larger fruit width than all commercial varieties. The differences were significantly different. However, they were smaller than most female and male parental varieties and the differences were significantly different.

Apart from the color and the peppery hotness, the size of green chili fruits for making northern Thai styled chili dip does matter. The individual green chili fruit should be large, with great fruit width and length as well as pericarp thickness such that it can be peeled easily after being grilled.

**Fruit length**

The 9 $F_1$ hybrids obtained fruit length differently at statistically significant level in 14.45 - 19.91 cm range (Table 5; Figure 5-9). The $F_1$ hybrid CA1450 × CA683 variety produced the shortest while the $F_1$ hybrids CA1445 × CA1448, CA1449 × CA683, CA1450 × CA1448, CA1450 × CA1447 and CA1445 × CA1447 obtained the longest fruit length. The differences were statistically significant in comparison with almost all the other $F_1$ hybrids, all female parental varieties, one male parental variety and two commercial varieties. Most $F_1$ hybrid varieties performed better in terms of greater fruit length, statistically significant, in comparison with their female parents and some commercial varieties, but not statistically significantly different from most male parental varieties.

**Pericarp thickness**

Pericarp thickness of the 9 $F_1$ hybrids differed statistically significantly in 0.20 - 0.29 mm range (Table 5). The $F_1$ hybrid CA1449 × CA1448 had the minimum while the $F_1$ hybrids CA1450 × CA1448 and CA1450 × CA1447 got the maximum pericarp thickness from the present experiment. They were significantly different from those of the other $F_1$ hybrids, two female parents, one male parent and all commercial varieties. In other words, most $F_1$ hybrids produced fruits with lesser pericarp thickness in comparison with most male parental varieties at statistically significant difference level but no statistically significant differences were found in their comparison with most female parents and all commercial varieties.

Table 5 Yield components and horticultural characteristics of $F_1$ hybrids, male parents, female parents and commercial varieties, winter 2010

| Variety/Cultivar | Plant height (cm) | Canopy width (cm) | Yield (t/rai) | Fruit weight/ plant (kg/plant) |
|---|---|---|---|---|
| **$F_1$ Hybrid** | | | | |
| CA1445 × CA683 | 74.89 a-d[1/] | 79.22 | 4.734 cde | 0.740 cde |
| CA1445 × CA1447 | 63.56 d-h | 80.22 | 4.677 cde | 0.731 cde |
| CA1445 × CA1448 | 59.89 gh | 77.33 | 5.033 bcd | 0.786 bcd |
| CA1449 × CA683 | 74.45 a-e | 80.78 | 4.066 def | 0.635 def |
| CA1449 × CA1447 | 62.78 e-h | 77.67 | 5.059 bcd | 0.791 bcd |
| CA1449 × CA1448 | 78.78 ab | 70.33 | 2.346 h | 0.367 h |
| CA1450 × CA683 | 64.78 c-h | 64.22 | 3.412 fg | 0.533 fg |
| CA1450 × CA1447 | 59.11 gh | 77.11 | 5.912 ab | 0.924 ab |
| CA1450 × CA1448 | 57.33 h | 79.78 | 6.794 a | 1.061 a |
| **Male Parent** | | | | |
| CA683 | 80.89 ab | 72.22 | 2.583 gh | 0.404 gh |
| CA1447 | 62.11 fgh | 76.11 | 4.127 def | 0.645 def |
| CA1448 | 58.56 gh | 66.89 | 4.542 cde | 0.710 cde |
| **Female Parent** | | | | |
| CA1445 | 69.33 b-g | 79.78 | 2.735 gh | 0.428 gh |
| CA1449 | 72.45 a-f | 74.33 | 3.899 ef | 0.609 ef |
| CA1450 | 52.89 h | 76.22 | 4.551 cde | 0.711 cde |
| **Commercial** | | | | |
| Jakkrapat | 76.00 abc | 73.67 | 5.026 bcd | 0.785 bcd |
| JomThong 2 | 81.78 a | 78.78 | 5.412 bc | 0.846 bc |
| YokSiam | 74.22 a-e | 76.22 | 4.169 def | 0.652 def |
| **C.V. (%)** | 9.11 | 9.29 | 12.44 | 12.34 |

[1/] Means within column with different letters differ significantly at P<0.05 according to DMRT.

Table 5 Yield components and horticultural characteristics of $F_1$ hybrids, male parents, female parents and commercial varieties, winter 2010 (continued)

| Variety/Cultivar | Number of fruit per plant | Fruit | | | Pericarp thickness (mm) |
|---|---|---|---|---|---|
| | | Weight (g) | Width (cm) | Length (cm) | |
| **$F_1$ Hybrid** | | | | | |
| CA1445 × CA683 | 41.67 a[1/] | 20.93 gh | 2.16 c | 15.84 e | 0.22 def |
| CA1445 × CA1447 | 28.17 b | 32.93 cd | 2.52 b | 19.13 ab | 0.22 de |
| CA1445 × CA1448 | 27.13 bc | 32.87 cd | 2.52 b | 19.91 a | 0.23 de |
| CA1449 × CA683 | 24.70 bc | 36.90 c | 2.73 b | 19.70 a | 0.24 d |
| CA1449 × CA1447 | 22.13 cd | 43.70 b | 3.18 a | 18.22 bcd | 0.24 cd |
| CA1449 × CA1448 | 15.03 e | 20.53 gh | 2.20 c | 14.50 fg | 0.20 fg |
| CA1450 × CA683 | 14.83 e | 28.63 def | 2.60 b | 14.45 fg | 0.22 def |
| CA1450 × CA1447 | 25.53 bc | 51.17 a | 3.19 a | 19.21 ab | 0.28 ab |
| CA1450 × CA1448 | 25.93 bc | 50.20 a | 3.27 a | 19.23 ab | 0.29 a |
| **Male Parent** | | | | | |
| CA683 | 26.82 bc | 16.53 h | 2.00 c | 14.20 fg | 0.19 g |
| CA1447 | 24.97 bc | 47.50 ab | 3.16 a | 18.92 abc | 0.26 bc |
| CA1448 | 17.83 de | 46.77 ab | 3.20 a | 19.26 ab | 0.28 ab |
| **Female Parent** | | | | | |
| CA1445 | 28.33 b | 17.93 h | 2.12 c | 13.65 g | 0.21 efg |
| CA1449 | 27.87 bc | 32.23 d | 3.05 a | 13.86 g | 0.25 cd |
| CA1450 | 24.32 bc | 44.33 b | 3.26 a | 15.38 ef | 0.29 ab |
| **Control** | | | | | |
| Jakkrapat | 25.90 bc | 30.23 de | 2.15 c | 18.74 abc | 0.23 de |
| JomThong 2 | 37.48 a | 27.67 ef | 2.20 c | 17.79 cd | 0.24 cd |
| YokSiam | 37.23 a | 24.83 fg | 2.07 c | 17.09 d | 0.19 g |
| **C.V. (%)** | 11.15 | 7.45 | 4.82 | 4.09 | 5.88 |

[1/] Means within column with different letters differ significantly at P<0.05 according to DMRT.


Figure 5 $F_1$ hybrids of chilies



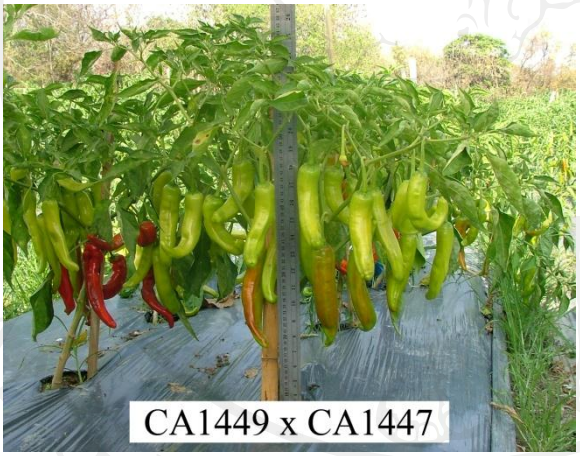






Figure 5 $F_1$ hybrids of chilies (continued)







Figure 5 $F_1$ hybrids of chilies (continued)


Figure 6 Male parental varieties of chilies

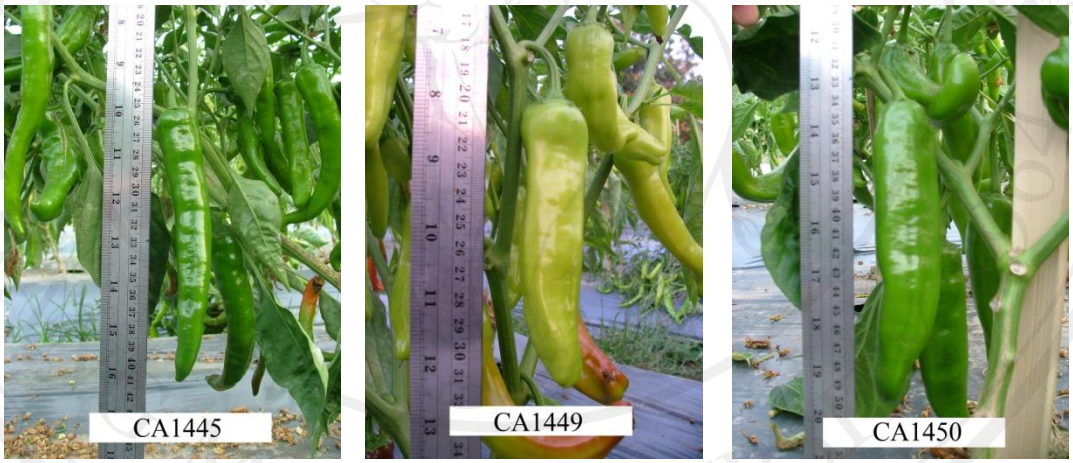



Figure 7 Female parental varieties of chilies


Figure 8 Commercial varieties of chilies

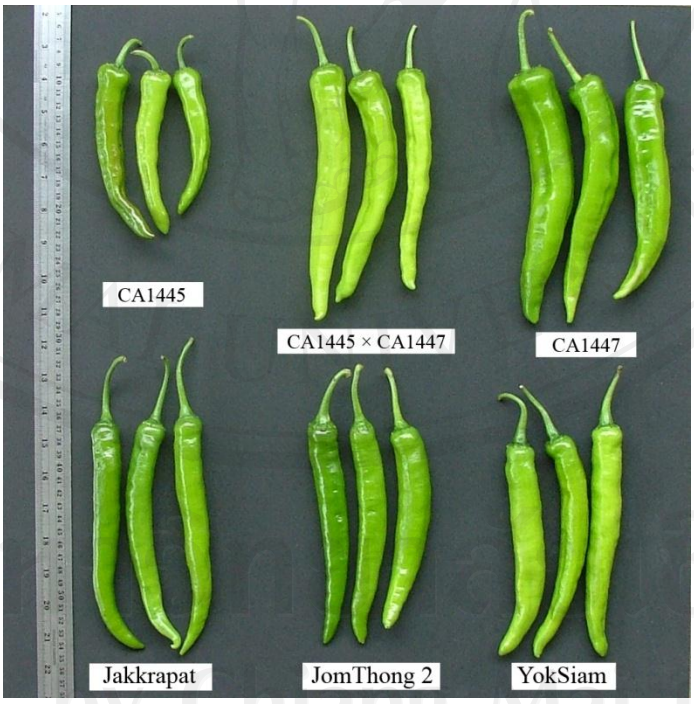




Figure 9 Fruits of $F_1$ hybrids, male parents, female parents and commercial varieties of chilies



Figure 9 Fruits of $F_1$ hybrids, male parents, female parents and commercial varieties of chilies (continued)

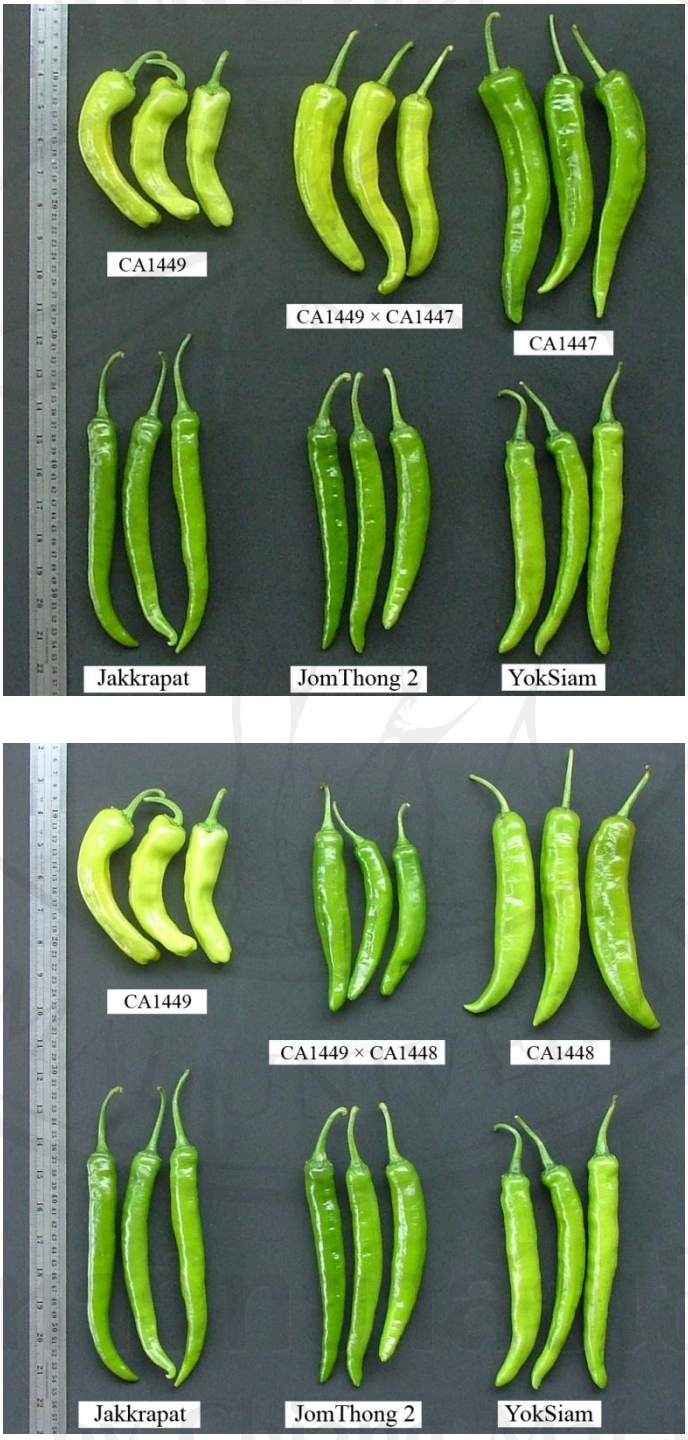
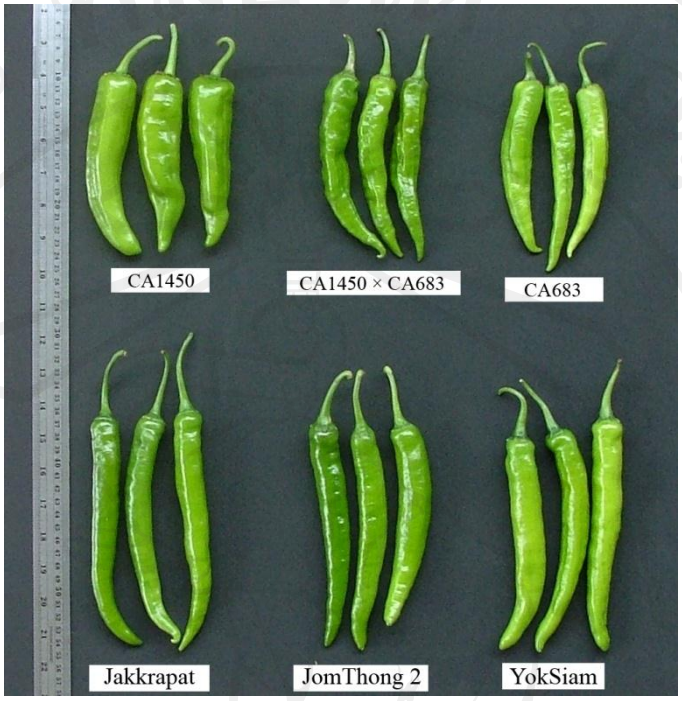



Figure 9 Fruits of $F_1$ hybrids, male parents, female parents and commercial varieties of chilies (continued)



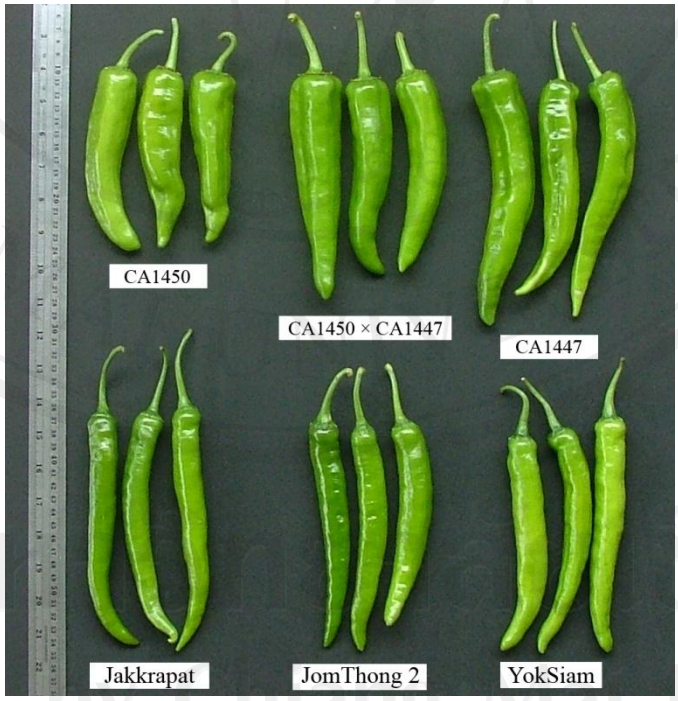




Figure 9 Fruits of $F_1$ hybrids, male parents, female parents and commercial varieties of chilies (continued)

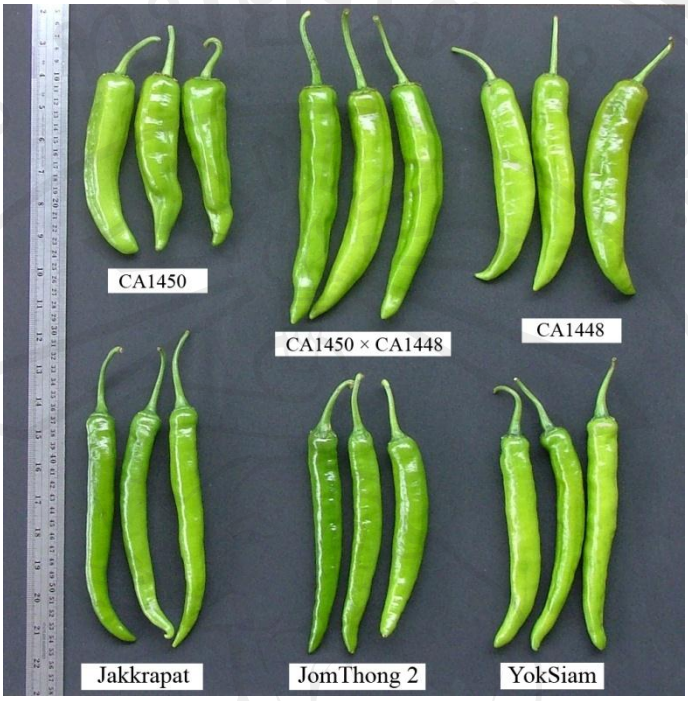



Figure 9 Fruits of $F_1$ hybrids, male parents, female parents and commercial varieties of chilies (continued)

## 2.2 Assessment of $F_1$ heterosis

### Heterosis in horticultural characteristics

#### Plant height

Among the nine $F_1$ hybrids tested, only the $F_1$ hybrid CA1449 × CA1448 had heterosis overmidparent and none showed the extent of heterobeltiosis in plant height characteristics when assessed at statistically significant level (Table 6).

#### Canopy width

No $F_1$ hybrids had heterosis overmidparent nor heterobeltiosis over high parent in canopy width characteristics when tested for differences at statistically significant level (Table 6).

**Fruit weight per plant**

The heterosis overmidparent and the heterobeltiosis values of most $F_1$ hybrid regarding fruit weight per plant in most cases came out at statistically significant level (Table 6).

**Number of fruits per plant**

Among the 9 $F_1$ hybrids, four $F_1$ hybrids appeared to have heterosis overmidparent at statistically significant difference level while three $F_1$ hybrids showed heterobeltiosis over high parent at statistically significant level (Table 6).

**Fruit weight**

In term of fruit weight, the heterosis overmidparent exhibited in six $F_1$ hybrids and heterobeltiosis showed in three $F_1$ hybrids with the differences at statistically significant level (Table 6).

**Fruit width**

Four $F_1$ hybrids had heterosis overmidparent while two other varieties had heterobeltiosis over high parent in fruit width with the differences at statistically significant level (Table 6).

**Fruit length**

Among the nine $F_1$ hybrids, seven $F_1$ hybrids had heterosis overmidparent and $F_1$ hybrids four had heterobeltiosis over high parent in this characteristics, with differences at statistically significant level (Table 6).

**Pericarp thickness**

In terms of pericarp thickness, five $F_1$ hybrids showed heterosis overmidparent and only one $F_1$ hybrids appeared to have heterobeltiosis over high parent and the differences were at statistically significant level (Table 6).

It can be concluded that a number of $F_1$ hybrids from crossing CA1445, CA1449 and CA1450 (B-line) with male parents ( C-line) exhibited positive heterosis in some horticultural characteristic such as number of fruits per plant, fruit weight per plant, fruit weight, fruit length and pericarp thickness.

Table 6 Heterosis and heterobeltiosis in horticultural characteristics of $F_1$ hybrids, winter 2010

| **$F_1$ Hybrid** | **Plant height (cm)** | | **Plant width (cm)** | |
|---|---|---|---|---|
| | **%H** | **%Hb** | **%H** | **%Hb** |
| CA1445 × CA683 | -0.30 | -7.42 | 4.24 | -0.69 |
| CA1445 × CA1447 | -3.29 | -8.33 | 2.93 | 0.56 |
| CA1445 × CA1448 | -6.35 * | -13.62 ** | 5.45 | -3.06 |
| CA1449 × CA683 | -2.90 | -7.97 | 10.24 | 8.67 |
| CA1449 × CA1447 | -6.69 | -13.35* | 3.25 | 2.05 |
| CA1449 × CA1448 | 20.27 * | 8.74 | -0.39 | -5.38 |
| CA1450 × CA683 | -3.16 | -19.92 ** | -13.47 | -15.74 |
| CA1450 × CA1447 | 2.81 | -4.82 | 1.24 | 1.17 |
| CA1450 × CA1448 | 2.89 | -2.09 | 11.49 * | 4.67 |

H=Heterosis; Hb=Heterobeltiosis

*, ** significant difference at P<0.05 and P<0.01 levels, respectively.

Table 6 Heterosis and heterobeltiosis in horticultural characteristics of $F_1$ hybrids, winter 2010 (continued)

| $F_1$ Hybrid | Fruit weight per plant (kg/plant) | | Yield (t/rai) | |
|---|---|---|---|---|
| | %H | %Hb | %H | %Hb |
| CA1445 × CA683 | 78.03 ** | 73.03 ** | 77.94 ** | 72.96 ** |
| CA1445 × CA1447 | 36.28 ** | 13.34 ** | 36.28 ** | 13.33 ** |
| CA1445 × CA1448 | 38.28 ** | 10.80 ** | 38.19 ** | 10.71 ** |
| CA1449 × CA683 | 25.37 ** | 4.21 ** | 25.45 ** | 4.27 ** |
| CA1449 × CA1447 | 26.10 ** | 22.65 ** | 26.00 ** | 22.54 ** |
| CA1449 × CA1448 | -44.40 ** | -48.33 ** | -44.41 ** | -48.35 ** |
| CA1450 × CA683 | -4.33 ** | -25.02 ** | -4.39 ** | -25.05 ** |
| CA1450 × CA1447 | 36.23 ** | 29.85 ** | 36.23 ** | 29.89 ** |
| CA1450 × CA1448 | 49.43 ** | 49.25 ** | 49.41 ** | 49.30 ** |

H=Heterosis; Hb=Heterobeltiosis
*, ** significant difference at P<0.05 and P<0.01 levels, respectively.

Table 6 Heterosis and heterobeltiosis in horticultural characteristics of $F_1$ hybrids, winter 2010 (continued)

| $F_1$ Hybrid | Number of fruits per plant | | Fruit Weight (g) | |
|---|---|---|---|---|
| | %H | %Hb | %H | %Hb |
| CA1445 × CA683 | 51.09 ** | 47.06 ** | 21.47 ** | 16.73 ** |
| CA1445 × CA1447 | 5.69 | -0.59 | 0.66 | -30.67 ** |
| CA1445 × CA1448 | 17.56 ** | -4.24 | 1.60 | -29.72 ** |
| CA1449 × CA683 | -9.67 ** | -11.37 ** | 51.33 ** | 14.48 ** |
| CA1449 × CA1447 | -16.22 ** | -20.58 ** | 9.62 ** | -8.00 * |
| CA1449 × CA1448 | -34.20 ** | -46.06 ** | -48.02 ** | -56.09 ** |
| CA1450 × CA683 | -41.99 ** | -44.69 ** | -5.91 * | -35.41 ** |
| CA1450 × CA1447 | 3.60 ** | 2.27 ** | 11.43 ** | 7.72 ** |
| CA1450 × CA1448 | 23.02 ** | 6.59 * | 10.21 * | 7.34 |

H=Heterosis; Hb=Heterobeltiosis
*, ** significant difference at P<0.05 and P<0.01 levels, respectively.

Table 6 Heterosis and heterobeltiosis in horticultural characteristics of $F_1$ hybrids, winter 2010 (continued)

| $F_1$ Hybrid | Fruit width (cm) | | Fruit length (cm) | | Pericarp thickness (mm) | |
|---|---|---|---|---|---|---|
| | %H | %Hb | %H | %Hb | %H | %Hb |
| CA1445 × CA683 | 4.85 ** | 1.88 ** | 13.78 ** | 11.55 ** | 15.73 ** | 10.75 ** |
| CA1445 × CA1447 | -4.61 ** | -20.25 ** | 17.49 ** | 1.11 * | -5.94 ** | -18.25 ** |
| CA1445 × CA1448 | -5.51 ** | -21.44 ** | 20.99 ** | 3.36 ** | -3.96 ** | -18.66 ** |
| CA1449 × CA683 | 7.92 ** | -10.60 ** | 40.36 ** | 38.68 ** | 10.34 ** | -5.08 ** |
| CA1449 × CA1447 | 2.52 ** | 0.74 ** | 11.12 ** | -3.73 ** | -6.56 ** | -9.52 ** |
| CA1449 × CA1448 | -29.64 ** | -31.32 ** | -12.43 ** | -24.70 ** | -29.37 ** | -33.58 ** |
| CA1450 × CA683 | -1.14 ** | -20.22 ** | -2.34 ** | -6.09 ** | -7.62 ** | -25.36 ** |
| CA1450 × CA1447 | -0.67 ** | -2.25 ** | 11.97 ** | 1.50 | 2.27 ** | -2.17 ** |
| CA1450 × CA1448 | 1.13 ** | 0.20 | 11.00 ** | -0.17 | 0.74 ** | -0.72 ** |

H=Heterosis; Hb=Heterobeltiosis
*, ** significant difference at P<0.05 and P<0.01 levels, respectively.

**Heterosis in physico-chemical properties of $F_1$ hybrids**

**Skin color**

From L* value criteria, three $F_1$ hybrids had heterosis overmidparent while two $F_1$ hybrids had heterobeltiosis over high parent with differences at statistically significant level (Table 7). From Chroma value criteria, three $F_1$ hybrids showed heterosis overmidparent at statistically significant level while all nine $F_1$ hybrids under experiment appeared to have heterobeltiosis over high parent but the differences were not statistically significant (Table 7). However, judging from the Hue angle values, the heterosis overmidparent and heterobeltiosis over high parent of all $F_1$ hybrids were not statistically significant (Table 7).

**Moisture content**

In terms of moisture content, the CA1450 × CA1447 $F_1$ hybrid had heterosis overmidparent with difference at statistically significant level while the remaining

eight $F_1$ hybrids demonstrated the heterobeltiosis over high parent but the differences were not significant statistically (Table 7).

**Total soluble solids content**

For this characteristics, only three $F_1$ hybrids showed heterosis overmidparent and one $F_1$ hybrid exhibited heterobeltiosis over high parent, however, all the differences were statistically significant (Table 7).

**Vitamin C content**

Four $F_1$ hybrids demonstrated heterosis overmidparent and one $F_1$ hybrid had heterobeltiosis over high parent regarding vitamin C content, at statistically significant level (Table 7).

**Capsaicin content**

No statistically significant differences were revealed to indicate the heterosis overmidparent nor the heterobeltiosis over high parent of the nine $F_1$ hybrids under trial concerning capsaicin content (Table 7).

**Chlorophyll content**

In terms of chlorophyll a content, seven $F_1$ hybrids had heterosis overmidparent and three $F_1$ hybrids showed heterobeltiosis over high parent at statistically significant difference level (Table 7). For chlorophyll b content, eight $F_1$ hybrids had heterosis overmidparent and six $F_1$ hybrids showed heterobeltiosis with differences at statistically significant level (Table 7).

The assessment of total chlorophyll contents indicated heterosis overmidparent and heterobeltiosis over high parent occurred in seven and four $F_1$ hybrids respectively, at statistically significant difference level (Table 7).

The assessment results provided the conclusion that a number of $F_1$ hybrids from crossing CA1445, CA1449 and CA1450 (B-line) with various male parents (C-line) showed positive heterosis in some physico-chemical properties such as the L* value, Chroma value, total soluble solids content, vitamin C content, chlorophyll a and b contents, as well as total chlorophyll content.

Table 7 Heterosis and heterobeltiosis in physico-chemical properties of $F_1$ hybrids, winter 2010

| $F_1$ Hybrid | L | | Chroma | | Hue | |
|---|---|---|---|---|---|---|
| | %H | %Hb | %H | %Hb | %H | %Hb |
| CA1445 × CA683 | -8.94 ** | -13.83 ** | -10.87 ** | -16.93 ** | 1.84 | 0.12 |
| CA1445 × CA1447 | 4.15 * | 3.87 * | 3.18 | 1.91 | -0.91 | -1.11 |
| CA1445 × CA1448 | -1.70 | -3.66 | -3.33 | -6.44 * | -0.39 | -0.55 |
| CA1449 × CA683 | 3.44 * | -6.04 ** | 7.86 ** | 3.57 | -1.72 ** | -4.65 ** |
| CA1449 × CA1447 | 6.79 ** | 1.99 * | 3.53 * | 1.57 | -1.12 | -2.24 * |
| CA1449 × CA1448 | -13.82 ** | -19.05 ** | -7.17 * | -7.31 * | 4.16 | 2.62 |
| CA1450 × CA683 | -4.30 | -6.16 * | -4.01 | -4.21 | 0.42 | -0.84 |
| CA1450 × CA1447 | -3.29 ** | -6.49 * | -6.01 ** | -11.20 ** | 0.92 | 0.27 |
| CA1450 × CA1448 | -2.97 | -4.57 | -3.01 | -6.54 * | 0.82 | 0.53 |

H=Heterosis; Hb=Heterobeltiosis
*, ** significant difference at P<0.05 and P<0.01 levels, respectively.

Table 7 Heterosis and heterobeltiosis in physico-chemical properties of $F_1$ hybrids, winter 2010 (continued)

| $F_1$ Hybrid | Moisture (%) | | Total Soluble Solids (%) | |
|---|---|---|---|---|
| | %H | %Hb | %H | %Hb |
| CA1445 × CA683 | -1.07 | -1.83 | 10.00 ** | -4.35 ** |
| CA1445 × CA1447 | 0.72 | -2.59 ** | -20.92 ** | -25.48 ** |
| CA1445 × CA1448 | 0.57 | -2.55 ** | -18.60 ** | -19.25 ** |
| CA1449 × CA683 | 0.68 | -0.35 | 24.40 ** | 16.77 ** |
| CA1449 × CA1447 | 0.57 | -1.00 * | 2.48 ** | -10.58 ** |
| CA1449 × CA1448 | -4.33 ** | -5.64 ** | -4.68 ** | -12.83 ** |
| CA1450 × CA683 | -3.85 ** | -6.10 ** | -8.42 ** | -8.76 ** |
| CA1450 × CA1447 | 0.63 * | 0.40 | -29.28 ** | -41.35 ** |
| CA1450 × CA1448 | 0.40 | 0.37 | 0.62 | -12.83 ** |

H=Heterosis; Hb=Heterobeltiosis
*, ** significant difference at P<0.05 and P<0.01 levels, respectively.

Table 7 Heterosis and heterobeltiosis in physico-chemical properties of $F_1$ hybrids, winter 2010 (continued)

| $F_1$ Hybrid | Vitamin C | | Chlorophyll a (mg/100 g fresh weight) | | Chlorophyll b (mg/100 g fresh weight) | |
|---|---|---|---|---|---|---|
| | %H | %Hb | %H | %Hb | %H | %Hb |
| CA1445 × CA683 | 14.25** | 0.00 | 54.63** | 19.55** | 76.41** | 24.39** |
| CA1445 × CA1447 | -11.09** | -19.97** | 63.22** | 16.93** | 94.66** | 30.81** |
| CA1445 × CA1448 | -11.09** | -19.97** | -17.92** | -22.10** | -21.19** | -24.66** |
| CA1449 × CA683 | 14.25** | 0.00 | 17.72** | -6.25** | 17.66** | -12.86** |
| CA1449 × CA1447 | -11.09** | -19.97** | 28.61** | -5.49** | 45.02** | 1.77** |
| CA1449 × CA1448 | -11.09** | -19.97** | 10.81** | 1.25** | 13.68** | 1.03** |
| CA1450 × CA683 | 24.95** | 0.00 | 31.94** | -2.02** | 72.68** | 19.86** |
| CA1450 × CA1447 | 20.02** | 20.02** | 20.27** | -16.74** | 68.42** | 11.63** |
| CA1450 × CA1448 | 0.00 | 0.00 | -15.51** | -15.97** | 1.49** | -0.34** |

H=Heterosis; Hb=Heterobeltiosis
*, ** significant difference at P<0.05 and P<0.01 levels, respectively.

Table 7 Heterosis and heterobeltiosis in physico-chemical properties of $F_1$ hybrids, winter 2010 (continued)

| $F_1$ Hybrid | Total Chlorophyll (mg/100 g fresh weight) | | Capsaicin (Scoville unit) | |
|---|---|---|---|---|
| | %H | %Hb | %H | %Hb |
| CA1445 × CA683 | 51.49** | 18.88** | 1.32 | -45.61 |
| CA1445 × CA1447 | 62.53** | 20.44** | -4.08 | -44.71 |
| CA1445 × CA1448 | -16.84** | -20.40** | 122.22 | 92.31 |
| CA1449 × CA683 | 15.25** | -6.48** | -83.12 | -84.99 |
| CA1449 × CA1447 | 27.82** | -2.39** | -45.62 | -56.00 |
| CA1449 × CA1448 | 10.33** | 1.28** | 1.36 | -45.82 |
| CA1450 × CA683 | 39.40** | 5.99** | -98.31** | -98.58* |
| CA1450 × CA1447 | 34.46** | -3.14** | 181.08 | 141.35 |
| CA1450 × CA1448 | -6.85** | -6.85** | 172.66 | 47.26 |

H=Heterosis; Hb=Heterobeltiosis
*, ** significant difference at P<0.05 and P<0.01 levels, respectively.

**2.3 Assessment of general combining ability and specific combining ability**

**General combining ability and specific combining ability of green chili grown in winter 2010**

General combining abilities for different horticultural characteristics showed that among the B-line parents: CA1445, CA1449 and CA1450. CA1445 was superior in terms of number of fruits per plant, CA1449 was good for plant height and CA1450 had good effects regarding yield, fruit weight per plant, average fruit weight, fruit width and fruit length, all at statistically significant differences from 0 level (Table 8).

It was found that general combining abilities in physico-chemical properties of the B line parents were at statistically significant difference from 0 level. The CA1445 parent showed statistically significant differences from 0 level in chlorophyll a, b and total chlorophyll. The CA1449 showed statistically significant differences from 0 level in L*, Chroma and total soluble solids while CA1450 showed statistically significant differences from 0 level in moisture content, vitamin C content, capsaicin content, chlorophyll b and total chlorophyll content.

Specific combining abilities of the three $F_1$ hybrids which CA1445 were female parents, showed statistically significant differences from 0 level in number of fruits per plant, fruit weight and fruit length. Specific combining abilities of the three $F_1$ hybrids which CA1449 was the female parent showed statistically significant differences from 0 level in plant height, yield, fruit weight, fruit width, fruit length and pericarp thickness and specific combining abilities of the three $F_1$ hybrids which CA1450 was the female parent showed statistically significant differences from 0 level in fruit weight per plant, yield, number of fruits per plant, fruit weight, fruit width, fruit length and pericarp thickness.

Specific combining abilities of the three $F_1$ hybrids which CA1445 was the female parent showed statistically significant differences from 0 level in L*, Hue angle, total soluble solids, chlorophyll a, chlorophyll b, total chlorophyll and capsaicin content. Specific combining abilities of the three $F_1$ hybrids which CA1449 was the female parent showed statistically significant difference from 0 level in L*,

Chroma, Hue angle, total soluble solids, moisture, chlorophyll a, chlorophyll b, total chlorophyll and capsaicin content. Specific combining abilities of the three $F_1$ hybrids which CA1450 was the female parent showed statistically significant differences from 0 level in L value, total soluble solids, moisture, chlorophyll a, chlorophyll b, total chlorophyll and capsaicin content.

Table 8 General combining abilities and specific combining abilities in horticultural characteristics and physico-chemical properties of male parents, female parents and $F_1$ hybrids chilies, winter 2010

| Variety/Lines | Plant height (cm) | Plant width (cm) | Fruit weight per plant (kg/plant) |
|---|---|---|---|
| ***General combining ability*** | | | |
| ***Lines*** | | | |
| CA1445 | -0.06 | 2.63 | 0.023 |
| CA1449 | 5.83 ** | -0.04 | -0.132 ** |
| CA1450 | -5.77 * | -2.59 | 0.110 ** |
| ***Testers*** | | | |
| CA683 | 5.20 * | -1.56 | -0.094 ** |
| CA1447 | -4.36 * | 2.04 | 0.085 ** |
| CA1448 | -0.84 | -0.48 | 0.008 |
| ***Specific combining ability*** | | | |
| CA1445 × CA683 | 3.58 | 1.85 | 0.081 |
| CA1445 × CA1447 | 1.80 | -0.74 | -0.107 * |
| CA1445 × CA1448 | -5.38 | -1.11 | 0.026 |
| CA1449 × CA683 | -2.75 | 6.07 | 0.131 * |
| CA1449 × CA1447 | -4.87 | -0.63 | 0.108 * |
| CA1449 × CA1448 | 7.62 * | -5.44 | -0.239 ** |
| CA1450 × CA683 | -0.83 | -7.93 | -0.213 ** |
| CA1450 × CA1447 | 3.06 | 1.37 | -0.001 |
| CA1450 × CA1448 | -2.23 | 6.56 | 0.214 ** |

*, ** significant difference at P<0.05 and P<0.01 levels, respectively.

Table 8 General combining abilities and specific combining abilities in horticultural characteristics and physico-chemical properties of male parents, female parents and $F_1$ hybrids chilies, winter 2010 (continued)

| Variety/Lines | Yield (t/rai) | Number of fruits per plant | Fruit weight (g) |
|---|---|---|---|
| ***General combining ability*** | | | |
| ***Lines*** | | | |
| CA1445 | 0.144 | 7.31 ** | -6.41 ** |
| CA1449 | -0.846 ** | -4.39 ** | -1.61 |
| CA1450 | 0.702 ** | -2.92 ** | 8.02 ** |
| ***Testers*** | | | |
| CA683 | -0.599 ** | 2.05 * | -6.50 ** |
| CA1447 | 0.545 ** | 0.26 | 7.28 ** |
| CA1448 | 0.054 | -2.32 * | -0.79 |
| ***Specific combining ability*** | | | |
| CA1445 × CA683 | 0.519 | 7.29 ** | -1.48 |
| CA1445 × CA1447 | -0.682 * | -4.42 * | -3.26 * |
| CA1445 × CA1448 | 0.163 | -2.87 | 4.74 ** |
| CA1449 × CA683 | 0.843 * | 2.03 | 9.69 ** |
| CA1449 × CA1447 | 0.688 * | 1.25 | 2.71 |
| CA1449 × CA1448 | -1.153 ** | -3.27 | -12.39 ** |
| CA1450 × CA683 | -1.362 ** | -9.32 ** | -8.20 ** |
| CA1450 × CA1447 | -0.006 | 3.17 | 0.55 |
| CA1450 × CA1448 | 1.368 ** | 6.15 ** | 7.65 ** |

*, ** significant difference at P<0.05 and P<0.01 levels, respectively.

Table 8 General combining abilities and specific combining abilities in horticultural characteristics and physico-chemical properties of male parents, female parents and $F_1$ hybrids chilies, winter 2010 (continued)

| Variety/Lines | Fruit width (cm) | Fruit length (cm) | Pericarp thickness (mm) |
|---|---|---|---|
| ***General combining ability*** | | | |
| ***Lines*** | | | |
| CA1445 | -0.308 ** | 0.497 | -0.022 * |
| CA1449 | -0.005 | -0.326 | -0.022 * |
| CA1450 | 0.313 ** | -0.171 | 0.044 ** |
| ***Testers*** | | | |
| CA683 | -0.210 ** | -1.136 ** | -0.019 |
| CA1447 | 0.256 ** | 1.054 ** | 0.019 |
| CA1448 | -0.046 | 0.081 | 0.000 |
| ***Specific combining ability*** | | | |
| CA1445 × CA683 | -0.026 | -1.316 ** | 0.012 |
| CA1445 × CA1447 | -0.136 | -0.216 | -0.026 |
| CA1445 × CA1448 | 0.163 | 1.531 ** | 0.013 |
| CA1449 × CA683 | 0.234 ** | 3.360 ** | 0.042 * |
| CA1449 × CA1447 | 0.224 ** | -0.310 | 0.011 |
| CA1449 × CA1448 | -0.457 ** | -3.050 ** | -0.053 ** |
| CA1450 × CA683 | -0.207 * | -2.044 ** | -0.054 ** |
| CA1450 × CA1447 | -0.087 | 0.526 | 0.014 |
| CA1450 × CA1448 | 0.295 ** | 1.519 ** | 0.040 * |

*, ** significant difference at P<0.05 and P<0.01 levels, respectively.

Table 8 General combining abilities and specific combining abilities in horticultural characteristics and physico-chemical properties of male parents, female parents and $F_1$ hybrids chilies, winter 2010 (continued)

| Variety/Lines | L | Chroma | Hue angle | Total soluble solids (%) | Moisture (%) |
|---|---|---|---|---|---|
| ***General combining ability*** | | | | | |
| ***Lines*** | | | | | |
| CA1445 | -0.10 | 0.92 | 0.04 | 0.09 | -0.81 ** |
| CA1449 | 2.81 ** | 1.69 * | -1.33 * | 0.62 ** | -0.24 |
| CA1450 | -2.72 ** | -2.61 ** | 1.29 * | -0.71 ** | 1.04 ** |
| ***Testers*** | | | | | |
| CA683 | -1.96 ** | -1.59 | 1.16 * | 0.09 | -2.14 ** |
| CA1447 | 3.84 ** | 2.41 ** | -1.99 ** | -0.12 | 1.93 ** |
| CA1448 | -1.88 ** | -0.82 | 0.83 | 0.03 | 0.21 |
| ***Specific combining ability*** | | | | | |
| CA1445 × CA683 | -3.04 ** | -3.25 * | 2.44 ** | 0.42 * | -0.30 |
| CA1445 × CA1447 | 0.69 | 2.08 | -0.36 | -0.07 | -0.56 |
| CA1445 × CA1448 | 2.36 * | 1.18 | -2.08 * | -0.36 | 0.86 |
| CA1449 × CA683 | 2.94 * | 2.96 * | -2.39 ** | 0.06 | 2.16 ** |
| CA1449 × CA1447 | 1.86 | -0.11 | -0.91 | 0.43 * | 0.30 |
| CA1449 × CA1448 | -4.80 ** | -2.85 | 3.30 ** | -0.49 ** | -2.46 ** |
| CA1450 × CA683 | 0.10 | 0.29 | -0.05 | -0.48 * | -1.87 ** |
| CA1450 × CA1447 | -2.55 * | -1.97 | 1.27 | -0.37 * | 0.26 |
| CA1450 × CA1448 | 2.44 * | 1.68 | -1.22 | 0.84 ** | 1.60 ** |

*, ** significant difference at P<0.05 and P<0.01 levels, respectively.

Table 8 General combining abilities and specific combining abilities in horticultural characteristics and physico-chemical properties of male parents, female parents and $F_1$ hybrids chilies, winter 2010 (continued)

| Variety/Lines | Vitamin C (mg/100 g fresh weight) | Chlorophyll a [1] (mg/100 g fresh weight) | Chlorophyll b [1] (mg/100 g fresh weight) | Total chlorophyll [1] (mg/100 g fresh weight) | Capsaicin (Scoville unit) |
|---|---|---|---|---|---|
| ***General combining ability*** | | | | | |
| ***Lines*** | | | | | |
| CA1445 | -0.57 ** | 0.131 ** | 0.098 ** | 0.103 ** | -641.11 ** |
| CA1449 | -0.57 ** | -0.105 ** | -0.290 ** | -0.188 ** | -684.44 ** |
| CA1450 | 1.14 ** | -0.026 | 0.192 ** | 0.084 ** | 1325.56 ** |
| ***Testers*** | | | | | |
| CA683 | -0.14 | 0.086 ** | 0.024 | 0.060 ** | -927.78 ** |
| CA1447 | 0.29 | -0.031 * | 0.084 ** | 0.027 | 862.22 ** |
| CA1448 | -0.14 | -0.055 ** | -0.109 ** | -0.087 ** | 65.56 |
| ***Specific combining ability*** | | | | | |
| CA1445 × CA683 | 0.14 | 0.139 ** | 0.183 ** | 0.156 ** | 1727.78 ** |
| CA1445 × CA1447 | -0.29 | 0.207 ** | 0.237 ** | 0.222 ** | -1042.22 ** |
| CA1445 × CA1448 | 0.14 | -0.346 ** | -0.420 ** | -0.378 ** | -685.56 ** |
| CA1449 × CA683 | 0.14 | -0.259 ** | -0.312 ** | -0.267 ** | 381.11 ** |
| CA1449 × CA1447 | -0.29 | -0.127 ** | -0.152 ** | -0.153 ** | -728.89 ** |
| CA1449 × CA1448 | 0.14 | 0.386 ** | 0.464 ** | 0.420 ** | 347.78 ** |
| CA1450 × CA683 | -0.29 | 0.119 ** | 0.129 ** | 0.111 ** | -2108.89 ** |
| CA1450 × CA1447 | 0.57 | -0.080 ** | -0.084 ** | -0.069 * | 1771.11 ** |
| CA1450 × CA1448 | -0.29 | -0.040 | -0.044 | -0.042 | 337.78 ** |

[1] Transformed data by log(x)+4.

*, ** significant difference at P<0.05 and P<0.01 levels, respectively.

**2.4 Records of horticultural characteristics following IBPGR descriptor (1995)**

**Horticultural characteristics**

Observations on horticultural characteristics of the $F_1$ hybrids, female parents, male parents and commercial varieties of green chili were recorded according to IBPGR (1995) on plant development, inflorescence, fruit and performances; plant height, plant canopy width, plant growth habit, days to 50% flowering, flower position, corolla color, fruit weight, fruit length and fruit width fruit wall or pericarp thickness (Table 9).

Table 9 Horticultural characteristics of male parents, female parents, $F_1$ hybrid and commercial of chilies, winter 2010

| Descriptors for *Capsicum* (1995) | CA683 | CA1447 | CA1448 |
|---|---|---|---|
| **1. Plant descriptors** | | | |
| 1.1 Stem color | Green | Green | Green |
| 1.2 Nodal anthocyanin | Purple | Purple | Purple |
| 1.3 Stem shape | Cylindrical | Cylindrical | Cylindrical |
| 1.4 Stem pubescence | Sparse | Sparse | Sparse |
| 1.5 Plant growth habit | Erect | Compact | Compact |
| 1.6 Branching habit | Sparse | Sparse | Intermediate |
| 1.7 Leaf density | Dense | Intermediate | Intermediate |
| 1.8 Leaf color | Green | Green | Green |
| 1.9 Leaf shape | Lanceolate | Lanceolate | Lanceolate |
| 1.10 Lamina margin | Entire | Entire | Entire |
| 1.11 Leaf pubescence | Sparse | Sparse | Sparse |
| 1.12 Plant height (cm) | 80.89±6.74 | 62.11±5.40 | 58.56±2.22 |
| 1.13 Plant canopy width (cm) | 72.22±7.19 | 76.11±7.24 | 66.89±1.02 |
| 1.14 Stem length (cm) | 27.11±2.27 | 24.89±0.19 | 23.11±1.35 |
| 1.15 Mature leaf length (cm) | 20.52±3.62 | 18.26±1.18 | 16.97±1.52 |
| 1.16 Mature leaf width (cm) | 5.36±0.95 | 6.87±0.59 | 6.21±0.66 |
| **2. Inflorescence descriptors** | | | |
| 2.1 Days to flowering | 72 | 69 | 69 |
| 2.2 Flower position | Pendant | Pendant | Pendant |
| 2.3 Corolla color | White | White | White |
| 2.4 Corolla spot color | non | non | non |
| 2.5 Corolla shape | Rotate | Rotate | Rotate |
| 2.6 Male sterility | Absent | Absent | Absent |
| 2.7 Calyx pigmentation | Absent | Absent | Absent |
| 2.8 Calyx margin | Intermediate | Intermediate | Intermediate |
| 2.9 Calyx annular constriction | Absent | Present | Present |
| **3. Fruit descriptors** | | | |
| 3.1 Anthocyanin spots or strips | Absent | Absent | Absent |
| 3.2 Fruit color at intermediate stage | Green | Green | Green |
| 3.3 Fruit set | High | Intermediate | Intermediate |
| 3.4 Fruit color at mature stage | Red | Red | Red |
| 3.5 Fruit shape | Elongate | Elongate | Elongate |
| 3.6 Fruit shape at pedicel attachment | Obtuse | Truncate | Obtuse |
| 3.7 Neck at base of fruit | Absent | Present | Absent |
| 3.8 Fruit shape at blossom end | Pointed | Pointed | Pointed |
| 3.9 Fruit blossom end appendage | Absent) | Absent | Absent |
| 3.10 Fruit cross-sectional corrugation | Slightly corrugated | Intermediate | Slightly corrugated |
| 3.11 Fruit surface | Smooth | Semiwrinkled | Semiwrinkled |
| 3.12 Placenta length | >1/2 fruit length | >1/2 fruit length | >1/2 fruit length |
| 3.13 Number of locules | 2-3 | 2-3 | 2-3 |
| 3.14 Fruit length (cm) | 14.20±0.30 | 18.92±0.28 | 19.26±0.67 |
| 3.15 Fruit width (cm) | 2.00±0.08 | 3.16±0.10 | 3.20±0.10 |
| 3.16 Fruit weight (g) | 16.53±2.70 | 47.50±3.35 | 46.77±2.10 |
| 3.17 Fruit pedicel length (cm) | 5.92±0.04 | 5.40±0.10 | 4.99±0.20 |
| 3.18 Fruit wall thickness (mm) | 0.19±0.01 | 0.26±0.01 | 0.28±0.02 |
| **4. Seed descriptors** | | | |
| 4.1 Seed color | Straw | Straw | Straw |
| 4.2 Seed surface | Smooth | Smooth | Smooth |
| 4.3 1000-seed weight (g) | 6.66 | 6.09 | 5.03 |
| 4.4 Number of seed per fruit | >50) | >50 | >50 |

Table 9 Horticultural characteristics of male parents, female parents, $F_1$ hybrid and commercial of chilies, winter 2010 (continued)

| **Descriptors for *Capsicum* (1995)** | **CA1445** | **CA1449** | **CA1450** |
|---|---|---|---|
| **1. Plant descriptors** | | | |
| 1.1 Stem color | Green | Green | Green |
| 1.2 Nodal anthocyanin | Purple | Green | Green |
| 1.3 Stem shape | Cylindrical | Cylindrical | Cylindrical |
| 1.4 Stem pubescence | Sparse | Sparse | Sparse |
| 1.5 Plant growth habit | Erect | Compact | Prostrate |
| 1.6 Branching habit | Intermediate | Sparse | Intermediate |
| 1.7 Leaf density | Intermediate | Intermediate | Intermediate |
| 1.8 Leaf color | Green | Green | Green |
| 1.9 Leaf shape | Lanceolate | Lanceolate | Lanceolate |
| 1.10 Lamina margin | Entire | Entire | Entire |
| 1.11 Leaf pubescence | Sparse | Sparse | Sparse |
| 1.12 Plant height (cm) | 69.33±2.40 | 72.45±8.28 | 52.89±1.02 |
| 1.13 Plant canopy width (cm) | 79.78±5.09 | 74.33±8.45 | 76.22±7.07 |
| 1.14 Stem length (cm) | 23.78±1.02 | 19.33±1.86 | 21.33±1.45 |
| 1.15 Mature leaf length (cm) | 14.83±1.56 | 17.48±1.49 | 13.86±3.50 |
| 1.16 Mature leaf width (cm) | 5.40±0.40 | 6.48±1.10 | 5.48±1.13 |
| **2. Inflorescence descriptors** | | | |
| 2.1 Days to flowering | 71 | 72 | 69 |
| 2.2 Flower position | Pendant | Pendant | Pendant |
| 2.3 Corolla color | White | White | White |
| 2.4 Corolla spot color | non | non | non |
| 2.5 Corolla shape | Rotate | Rotate | Rotate |
| 2.6 Male sterility | Absent | Absent | Absent |
| 2.7 Calyx pigmentation | Absent | Absent | Absent |
| 2.8 Calyx margin | Intermediate | Intermediate | Intermediate |
| 2.9 Calyx annular constriction | Present | Present | Present |
| **3. Fruit descriptors** | | | |
| 3.1 Anthocyanin spots or strips | Absent | Absent | Absent |
| 3.2 Fruit color at intermediate stage | Green | Green | Green |
| 3.3 Fruit set | High | High | Intermediate |
| 3.4 Fruit color at mature stage | Red | Red | Red |
| 3.5 Fruit shape | Elongate | Elongate | Elongate |
| 3.6 Fruit shape at pedicel attachment | Truncate | Truncate | Truncate |
| 3.7 Neck at base of fruit | Present | Present | Present |
| 3.8 Fruit shape at blossom end | Pointed | Blunt | Pointed |
| 3.9 Fruit blossom end appendage | Absent | Absent | Absent |
| 3.10 Fruit cross-sectional corrugation | Slightly corrugated | Intermediate | Slightly corrugated |
| 3.11 Fruit surface | Semiwrinkled | Semiwrinkled | Semiwrinkled |
| 3.12 Placenta length | >1/2 fruit length | >1/2 fruit length | >1/2 fruit length |
| 3.13 Number of locules | 2-3 | 2-3 | 2-3 |
| 3.14 Fruit length (cm) | 13.65±0.49 | 13.86±0.84 | 15.38±0.71 |
| 3.15 Fruit width (cm) | 2.12±0.06 | 3.05±0.15 | 3.26±0.16 |
| 3.16 Fruit weight (g) | 17.93±0.51 | 32.23±1.58 | 44.33±0.25 |
| 3.17 Fruit pedicel length (cm) | 4.01±0.24 | 4.60±0.12 | 5.34±0.64 |
| 3.18 Fruit wall thickness (mm) | 0.21±0.01 | 0.25±0.01 | 0.29±0.02 |
| **4. Seed descriptors** | | | |
| 4.1 Seed color | Straw | Straw | Straw |
| 4.2 Seed surface | Smooth | Smooth | Smooth |
| 4.3 1000-seed weight (g) | 4.76 | 7.22 | 5.48 |
| 4.4 Number of seed per fruit | >50 | >50 | >50 |

Table 9 Horticultural characteristics of male parents, female parents, $F_1$ hybrid and commercial of chilies, winter 2010 (continued)

| **Descriptors for *Capsicum* (1995)** | **CA1445 × CA683** | **CA1445 × CA1447** | **CA1448 × CA1448** |
|---|---|---|---|
| **1. Plant descriptors** | | | |
| 1.1 Stem color | Green | Green | Green |
| 1.2 Nodal anthocyanin | Purple | Purple | Purple |
| 1.3 Stem shape | Cylindrical | Cylindrical | Cylindrical |
| 1.4 Stem pubescence | Sparse | Sparse | Sparse |
| 1.5 Plant growth habit | Erect | Compact | Compact |
| 1.6 Branching habit | Intermediate | Intermediate | Sparse |
| 1.7 Leaf density | Dense | Intermediate | Intermediate |
| 1.8 Leaf color | Green | Green | Green |
| 1.9 Leaf shape | Lanceolate | Lanceolate | Lanceolate |
| 1.10 Lamina margin | Entire | Entire | Entire |
| 1.11 Leaf pubescence | Sparse | Sparse | Sparse |
| 1.12 Plant height (cm) | 74.89±8.92 | 63.56±4.55 | 59.89±2.50 |
| 1.13 Plant canopy width (cm) | 79.22±2.91 | 80.22±6.87 | 77.33±8.17 |
| 1.14 Stem length (cm) | 27.56±0.84 | 22.67±0.88 | 21.22±1.02 |
| 1.15 Mature leaf length (cm) | 17.44±1.50 | 17.24±1.23 | 13.55±0.88 |
| 1.16 Mature leaf width (cm) | 5.06±0.20 | 6.31±0.14 | 5.17±0.33 |
| **2. Inflorescence descriptors** | | | |
| 2.1 Days to flowering | 72 | 69 | 69 |
| 2.2 Flower position | Pendant | Pendant | Pendant |
| 2.3 Corolla color | White | White | White |
| 2.4 Corolla spot color | non | non | non |
| 2.5 Corolla shape | Rotate | Rotate | Rotate |
| 2.6 Male sterility | Absent | Absent | Absent |
| 2.7 Calyx pigmentation | Absent | Absent | Absent |
| 2.8 Calyx margin | Intermediate | Intermediate | Intermediate |
| 2.9 Calyx annular constriction | Absent | Present | Present |
| **3. Fruit descriptors** | | | |
| 3.1 Anthocyanin spots or strips | Absent | Absent | Absent |
| 3.2 Fruit color at intermediate stage | Green | Green | Green |
| 3.3 Fruit set | High | High | High |
| 3.4 Fruit color at mature stage | Red | Red | Red |
| 3.5 Fruit shape | Elongate | Elongate | Elongate |
| 3.6 Fruit shape at pedicel attachment | Obtuse | Truncate | Obtuse |
| 3.7 Neck at base of fruit | Absent | Present | Absent |
| 3.8 Fruit shape at blossom end | Pointed | Pointed | Pointed |
| 3.9 Fruit blossom end appendage | Absent | Absent | Absent |
| 3.10 Fruit cross-sectional corrugation | Slightly corrugated | Slightly corrugated | Slightly corrugated |
| 3.11 Fruit surface | Smooth | Semiwrinkled | Semiwrinkled |
| 3.12 Placenta length | >1/2 fruit length | >1/2 fruit length | >1/2 fruit length |
| 3.13 Number of locules | 2-3 | 2-3 | 2-3 |
| 3.14 Fruit length (cm) | 15.84±0.73 | 19.13±0.44 | 19.91±1.15 |
| 3.15 Fruit width (cm) | 2.16±0.13 | 2.52±0.08 | 2.52±0.07 |
| 3.16 Fruit weight (g) | 20.93±2.60 | 32.93±1.76 | 32.87±3.05 |
| 3.17 Fruit pedicel length (cm) | 5.35±0.12 | 4.79±0.25 | 4.76±0.29 |
| 3.18 Fruit wall thickness (mm) | 0.22±0.02 | 0.22±0.01 | 0.23±0.00 |
| **4. Seed descriptors** | | | |
| 4.1 Seed color | Straw | Straw | Straw |
| 4.2 Seed surface | Smooth | Smooth | Smooth |
| 4.3 1000-seed weight (g) | 4.82 | 5.51 | 5.19 |
| 4.4 Number of seed per fruit | >50 | >50 | >50 |

Table 9 Horticultural characteristics of male parents, female parents, $F_1$ hybrid and commercial of chilies, winter 2010 (continued)

| **Descriptors for *Capsicum* (1995)** | **CA1449 × CA683** | **CA1449 × CA1447** | **CA1449 × CA1448** |
|---|---|---|---|
| **1. Plant descriptors** | | | |
| 1.1 Stem color | Green | Green | Green |
| 1.2 Nodal anthocyanin | Purple | Purple | Purple |
| 1.3 Stem shape | Cylindrical | Cylindrical | Cylindrical |
| 1.4 Stem pubescence | Sparse | Sparse | Sparse |
| 1.5 Plant growth habit | Erect | Compact | Erect |
| 1.6 Branching habit | Sparse | Sparse | Intermediate |
| 1.7 Leaf density | Dense | Intermediate | Dense |
| 1.8 Leaf color | Green | Green | Green |
| 1.9 Leaf shape | Lanceolate | Lanceolate | Lanceolate |
| 1.10 Lamina margin | Entire | Entire | Entire |
| 1.11 Leaf pubescence | Sparse | Sparse | Sparse |
| 1.12 Plant height (cm) | 74.45±11.42 | 62.78±3.86 | 78.78±10.42 |
| 1.13 Plant canopy width (cm) | 80.78±10.31 | 77.67±6.23 | 70.33±4.98 |
| 1.14 Stem length (cm) | 24.34±1.53 | 23.78±3.02 | 19.44±2.14 |
| 1.15 Mature leaf length (cm) | 19.15±1.02 | 19.98±0.51 | 18.49±5.27 |
| 1.16 Mature leaf width (cm) | 5.65±0.77 | 7.42±0.43 | 5.67±1.07 |
| **2. Inflorescence descriptors** | | | |
| 2.1 Days to flowering | 72 | 69 | 72 |
| 2.2 Flower position | Pendant | Pendant | Pendant |
| 2.3 Corolla color | White | White | White |
| 2.4 Corolla spot color | non | non | non |
| 2.5 Corolla shape | Rotate | Rotate | Rotate |
| 2.6 Male sterility | Absent | Absent | Absent |
| 2.7 Calyx pigmentation | Absent | Absent | Absent |
| 2.8 Calyx margin | Intermediate | Intermediate | Intermediate |
| 2.9 Calyx annular constriction | Absent | Present | Present |
| **3. Fruit descriptors** | | | |
| 3.1 Anthocyanin spots or strips | Absent | Absent | Absent |
| 3.2 Fruit color at intermediate stage | Green | Green | Green |
| 3.3 Fruit set | Intermediate | Intermediate | Intermediate |
| 3.4 Fruit color at mature stage | Red | Red | Red |
| 3.5 Fruit shape | Elongate | Elongate | Elongate |
| 3.6 Fruit shape at pedicel attachment | Truncate | Truncate | Truncate |
| 3.7 Neck at base of fruit | Present | Present | Present |
| 3.8 Fruit shape at blossom end | Pointed | Pointed | Pointed |
| 3.9 Fruit blossom end appendage | Absent | Absent | Absent |
| 3.10 Fruit cross-sectional corrugation | Slightly corrugated | Intermediate | Slightly corrugated |
| 3.11 Fruit surface | Semiwrinkled | Smooth | Semiwrinkled |
| 3.12 Placenta length | >1/2 fruit length | >1/2 fruit length | >1/2 fruit length |
| 3.13 Number of locules | 2-3 | 2-3 | 2-3 |
| 3.14 Fruit length (cm) | 19.70±1.02 | 18.22±0.91 | 14.50±1.17 |
| 3.15 Fruit width (cm) | 2.73±0.21 | 3.18±0.09 | 2.20±0.07 |
| 3.16 Fruit weight (g) | 36.90±2.19 | 43.70±3.73 | 20.53±1.80 |
| 3.17 Fruit pedicel length (cm) | 5.37±0.53 | 5.35±0.21 | 4.12±0.15 |
| 3.18 Fruit wall thickness (mm) | 0.24±0.02 | 0.24±0.02 | 0.20±0.01 |
| **4. Seed descriptors** | | | |
| 4.1 Seed color | Straw | Straw | Straw |
| 4.2 Seed surface | Smooth | Smooth | Smooth |
| 4.3 1000-seed weight (g) | 5.67 | 5.37 | 6.46 |
| 4.4 Number of seed per fruit | >50 | >50 | >50 |

Table 9 Horticultural characteristics of male parents, female parents, $F_1$ hybrid and commercial of chilies, winter 2010 (continued)

| **Descriptors for *Capsicum* (1995)** | **CA1450 × CA683** | **CA1450 × CA1447** | **CA1450 × CA1448** |
|---|---|---|---|
| **1. Plant descriptors** | | | |
| 1.1 Stem color | Green | Green | Green |
| 1.2 Nodal anthocyanin | Purple | Green | Purple |
| 1.3 Stem shape | Cylindrical | Cylindrical | Cylindrical |
| 1.4 Stem pubescence | Sparse | Sparse | Sparse |
| 1.5 Plant growth habit | Erect | Compact | Compact |
| 1.6 Branching habit | Sparse | Intermediate | Sparse |
| 1.7 Leaf density | Intermediate | Intermediate | Intermediate |
| 1.8 Leaf color | Green | Green | Green |
| 1.9 Leaf shape | Lanceolate | Lanceolate | Lanceolate |
| 1.10 Lamina margin | Entire | Entire | Entire |
| 1.11 Leaf pubescence | Sparse | Sparse | Sparse |
| 1.12 Plant height (cm) | 64.78±6.36 | 59.11±4.43 | 57.33±3.76 |
| 1.13 Plant canopy width (cm) | 64.22±11.22 | 77.11±7.03 | 79.78±6.52 |
| 1.14 Stem length (cm) | 23.67±0.67 | 23.00±0.58 | 23.33±0.88 |
| 1.15 Mature leaf length (cm) | 15.08±2.79 | 17.30±1.22 | 15.05±0.30 |
| 1.16 Mature leaf width (cm) | 4.52±0.68 | 6.41±0.73 | 5.63±0.24 |
| **2. Inflorescence descriptors** | | | |
| 2.1 Days to flowering | 72 | 69 | 70 |
| 2.2 Flower position | Pendant | Pendant | Intermediate |
| 2.3 Corolla color | White | White | White |
| 2.4 Corolla spot color | non | non | non |
| 2.5 Corolla shape | Rotate | Rotate | Rotate |
| 2.6 Male sterility | Absent | Absent | Absent |
| 2.7 Calyx pigmentation | Absent | Absent | Absent |
| 2.8 Calyx margin | Intermediate | Intermediate | Intermediate |
| 2.9 Calyx annular constriction | Absent | Present | Present |
| **3. Fruit descriptors** | | | |
| 3.1 Anthocyanin spots or strips | Absent | Absent | Absent |
| 3.2 Fruit color at intermediate stage | Green | Green | Green |
| 3.3 Fruit set | Intermediate | High | High |
| 3.4 Fruit color at mature stage | Red | Red | Red |
| 3.5 Fruit shape | Elongate | Elongate | Elongate |
| 3.6 Fruit shape at pedicel attachment | Obtuse | Truncate | Truncate |
| 3.7 Neck at base of fruit | Present | Present | Present |
| 3.8 Fruit shape at blossom end | Pointed | Pointed | Pointed |
| 3.9 Fruit blossom end appendage | Absent | Absent | Absent |
| 3.10 Fruit cross-sectional corrugation | Slightly corrugated | Slightly corrugated | Slightly corrugated |
| 3.11 Fruit surface | Semiwrinkled | Semiwrinkled | Semiwrinkled |
| 3.12 Placenta length | >1/2 fruit length | >1/2 fruit length | >1/2 fruit length |
| 3.13 Number of locules | 2-3 | 2-3 | 2-3 |
| 3.14 Fruit length (cm) | 14.45±0.09 | 19.21±1.18 | 19.23±0.42 |
| 3.15 Fruit width (cm) | 2.60±0.13 | 3.19±0.25 | 3.27±0.18 |
| 3.16 Fruit weight (g) | 28.63±2.58 | 51.17±1.10 | 50.20±5.31 |
| 3.17 Fruit pedicel length (cm) | 5.59±0.32 | 5.69±0.34 | 5.67±0.14 |
| 3.18 Fruit wall thickness (mm) | 0.22±0.01 | 0.28±0.03 | 0.29±0.01 |
| **4. Seed descriptors** | | | |
| 4.1 Seed color | Straw | Straw | Straw |
| 4.2 Seed surface | Smooth | Smooth | Smooth |
| 4.3 1000-seed weight (g) | 5.87 | 5.49 | 5.36 |
| 4.4 Number of seed per fruit | >50 | >50 | >50 |

Table 9 Horticultural characteristics of male parents, female parents, $F_1$ hybrid and commercial of chilies, winter 2010 (continued)

| Descriptors for *Capsicum* (1995) | Jakkrapat | JomThong 2 | YokSiam |
|---|---|---|---|
| **1. Plant descriptors** | | | |
| 1.1 Stem color | Green | Green | Green |
| 1.2 Nodal anthocyanin | Purple | Green | Purple |
| 1.3 Stem shape | Cylindrical | Cylindrical | Cylindrical |
| 1.4 Stem pubescence | Sparse | Intermediate | Intermediate |
| 1.5 Plant growth habit | Erect | Erect | Erect |
| 1.6 Branching habit | Intermediate | Intermediate | Intermediate |
| 1.7 Leaf density | Intermediate | Dense | Dense |
| 1.8 Leaf color | Green | Green | Green |
| 1.9 Leaf shape | Lanceolate | Lanceolate | Lanceolate |
| 1.10 Lamina margin | Entire | Entire | Entire |
| 1.11 Leaf pubescence | Sparse | Sparse | Sparse |
| 1.12 Plant height (cm) | 76.00±5.81 | 81.78±7.31 | 74.22±2.83 |
| 1.13 Plant canopy width (cm) | 73.67±9.70 | 78.78±5.01 | 76.22±6.68 |
| 1.14 Stem length (cm) | 22.44±0.51 | 20.56±1.71 | 24.89±1.35 |
| 1.15 Mature leaf length (cm) | 15.85±2.26 | 15.71±0.45 | 15.09±0.88 |
| 1.16 Mature leaf width (cm) | 4.94±0.48 | 5.76±0.49 | 4.94±0.17 |
| **2. Inflorescence descriptors** | | | |
| 2.1 Days to flowering | 72 | 71 | 72 |
| 2.2 Flower position | Pendant | Pendant | Pendant |
| 2.3 Corolla color | White | White | White |
| 2.4 Corolla spot color | non | non | non |
| 2.5 Corolla shape | Rotate | Rotate | Rotate |
| 2.6 Male sterility | Absent | Absent | Absent |
| 2.7 Calyx pigmentation | Absent | Absent | Absent |
| 2.8 Calyx margin | Intermediate | Intermediate | Intermediate |
| 2.9 Calyx annular constriction | Present | Absent | Present |
| **3. Fruit descriptors** | | | |
| 3.1 Anthocyanin spots or strips | Absent | Absent | Absent |
| 3.2 Fruit color at intermediate stage | Green | Green | Green |
| 3.3 Fruit set | High | High | High |
| 3.4 Fruit color at mature stage | Red | Red | Red |
| 3.5 Fruit shape | Elongate | Elongate | Elongate |
| 3.6 Fruit shape at pedicel attachment | Obtuse | Obtuse | Obtuse |
| 3.7 Neck at base of fruit | Present | Present | Present |
| 3.8 Fruit shape at blossom end | Point | Point | Point |
| 3.9 Fruit blossom end appendage | Absent | Absent | Absent |
| 3.10 Fruit cross-sectional corrugation | Slightly corrugated | Slightly corrugated | Slightly corrugated |
| 3.11 Fruit surface | Semiwrinkled | Semiwrinkled | Smooth |
| 3.12 Placenta length | >1/2 fruit length | >1/2 fruit length | >1/2 fruit length |
| 3.13 Number of locules | 2-3 | 2-3 | 2-3 |
| 3.14 Fruit length (cm) | 18.74±0.56 | 17.79±0.53 | 17.09±0.24 |
| 3.15 Fruit width (cm) | 2.15±0.04 | 2.20±0.06 | 2.07±0.02 |
| 3.16 Fruit weight (g) | 30.23±0.85 | 27.67±2.01 | 24.83±0.35 |
| 3.17 Fruit pedicel length (cm) | 6.38±0.57 | 5.40±0.09 | 6.24±0.19 |
| 3.18 Fruit wall thickness (mm) | 0.23±0.01 | 0.24±0.01 | 0.19±0.01 |
| **4. Seed descriptors** | | | |
| 4.1 Seed color | Straw | Straw | Straw |
| 4.2 Seed surface | Smooth | Smooth | Smooth |
| 4.3 1000-seed weight (g) | 4.63 | 6.08 | 6.03 |
| 4.4 Number of seed per fruit | >50 | >50 | >50 |

## 2.5 Postharvest quality assessment of fresh chili fruits

### Physico-chemical properties of chili fruits

Color of the nine $F_1$ hybrid chili fruits at green maturity but not yet fully ripen stage varied in L values indicative of bright-dark shades of fruit skin in the 46.38 - 59.99 range, with differences at statistically significant level (Table 10). The $F_1$ hybrid CA1445 × CA683 had the minimum L value thus the darkest fruit skin while the $F_1$ hybrid CA1449 × CA1447 had the maximum L value therefore the brightest skin color. The $F_1$ generation appeared to have L values higher than those of their female parents except the case of CA1449, higher than those of the commercial varieties except YokSiam and higher than those of all male parents. By comparison, the two $F_1$ hybrids namely CA1445 × CA1447 and CA1449 × CA683 had the second highest L values with the differences from those of the other $F_1$ hybrids at statistically significant level, but not significantly different when compared with color skin of CA1445 and CA1449 female parents, CA1447 male parent and YokSiam commercial variety. It can be concluded that the three $F_1$ hybrids CA1449 × CA1447, CA1445 × CA1447 and CA1449 × CA683 had skin color brighter than that of any other remaining $F_1$ hybrids as indicated by the former three's relatively much higher L value (Table 10).

The nine $F_1$ hybrids had Chroma values indicative of skin color in 41.10 - 50.43 range and the differences were statistically significant. The $F_1$ hybrid CA1445 × CA683 had the minimum while the $F_1$ hybrid CA1445 × CA1447 had the maximum Chroma value. The $F_1$ hybrid having the darkest skin color however it was not statistically significantly different from the three other $F_1$ hybrids namely CA1449 × CA1447, CA1449 × CA683 and CA1445 × CA1448, most of the female parents including CA1445 and CA1449, most of the male parents including CA1447 and CA1448 and YokSiam. Meanwhile the remaining $F_1$ hybrids had Chroma values not significantly different from those of their female parents, CA1449 and CA1450, most of the male parents, CA683 and CA1448 and Jakkrapat.

The nine $F_1$ hybrids had Hue angle values of skin color in the 122.68 - 130.56 degree range with differences at statistically significant level (Table 10). The $F_1$ hybrid CA1449 × CA1447 exhibited the minimum Hue angle value while the $F_1$

hybrid CA1445 × CA683 showed the maximum Hue angle value which was however not statistically significantly different from those values of the $F_1$ hybrids CA1449 × CA1448 and CA1450 × CA683 but which was different statistically from the Hue angle values of all female parents, most of the male parents including CA1447 and CA1448, and YokSiam commercial variety. The majority of the remaining $F_1$ hybrids appeared to be not different at statistically significant level from most of the female parents, most of the male parents as well as Jakkrapat and YokSiam commercial varieties in terms of Hue angle value.

The foremost quality traits of green chili are the moisture content and peppery hotness degree. Food venders or manufacturers that process the green chili dip are generally careful to choose chili fruits having low moisture content to ensure the dip not to be too watery to satisfy consumers and having moderate degree of hotness.

The nine $F_1$ hybrids had moisture content in fruits in 83.25 - 89.72 % range, with differences at statistically significant level (Table 11). The $F_1$ hybrid CA1445 x CA683 contained the minimum moisture thus become most suitable for making green chili dip while the $F_1$ hybrid CA1450 x CA1447 had the highest percentage of moisture but not statistically significantly different from those of the $F_1$ hybrid CA1449 x CA1447. The three $F_1$ hybrids having high moisture content, however, were statistically significantly different from most of the female parents, some of the male parents, and all of the commercial varieties in this horticultural characteristics. Most of the $F_1$ hybrids appeared to contain low percentage of moisture in fruits comparable to those of commercial varieties.

The nine $F_1$ hybrids had total soluble solids in fruit flesh in the range of 4.07 - 6.2 % with differences at statistically significant level (Table 11). The $F_1$ hybrid CA1450 × CA1447 contained the lowest percentage of total soluble solids in contrast to the $F_1$ hybrid CA1449 × CA1447 which had the highest total soluble solids content but which was not different statistically significantly from the $F_1$ hybrids CA1449 × CA683 and CA1445 × CA683 in this horticultural characteristics. The latter three $F_1$ hybrids were found to contain higher percentage of total soluble solids at statistically significant level of differences in comparison with most female parents namely the CA1449 and CA1450 varieties, the CA683 male parent, and the commercial varieties. The high percentage of total soluble solids in fruit flesh is the desirable quality trait of

green chili reflecting the availability of sugar as well as other solids. The other $F_1$ hybrids not discussed above all contained total soluble solids at percentages not different at statistically significant level from those of the commercial varieties.

All nine $F_1$ hybrids under study had vitamin C content in fruit flesh in the range of 5.13 - 7.69 mg per 100 gram fresh fruit weight with statistically significant variation (Table 11). The $F_1$ hybrid CA1445 × CA683 contained the lowest vitamin C content whereas the $F_1$ hybrid CA1450 × CA1447 had the highest content of vitamin C which was higher, at statistically significant level of difference, than any other $F_1$ hybrids as well as its female parent, its male parent and all commercial varieties. Next to the $F_1$ hybrid CA1450 × CA1447, the $F_1$ hybrid having high vitamin C content were $F_1$ hybrids CA1450 × CA683 and CA1450 × CA1448 but they were not statistically significantly different in this characteristics from such female parent as CA1450, such male parents as CA1447 and CA1448, and most commercial varieties including YokSiam and JomThong 2. The other $F_1$ hybrids generally had vitamin C content rather low but not statistically significantly different from Jakkrapat commercial variety but lower at statistically significant level in comparison with Yok Siam and JomThong 2 varieties.

Capsaicin content of the nine $F_1$ hybrids varied in the 50 - 5,720 Scoville unit range with differences at statistically significant level (Table 11). The $F_1$ hybrid CA1450 × CA683 had the lowest while the $F_1$ hybrid CA1450 × CA1447 had the highest capsaicin content. The degree of hotness of the latter variety was higher at statistically significant level than those of all other $F_1$ hybrids, the male parents, the female parents, and commercial varieties. The next hottest $F_1$ hybrid, CA1450 × CA1448, contained capsaicin content in fruit flesh at the extent not statistically significantly different from the CA683 male parent but its capsaicin content was higher than other male parents, all female parents, and the commercial varieties at statistically significant level. The other $F_1$ hybrids not yet discussed appeared to have capsaicin content at the degree comparable to those of YokSiam and JomThong 2 commercial varieties.

Color of chili fruit is important for making green chili dip. It should not be too dark nor too light in green shades. A survey on the preference of 52 green chili dip processors (Apichartsrangkoon, 2006) revealed the respondents' opinion that the

light shades of green chili tended to make the dip look not attractive while the overly dark shades was also not desirable for consumers. The L, Chroma and Hue angle values, contents of chlorophyll a, b, and total chlorophyll are all indicative of the colors of chili fruit skin and flesh. From the color criterion, the male parents, the commercial varieties and the $F_1$ hybrids involved in the present study are suitable for making green chili dip while the female parent varieties and the maintainer varieties are generally not used for the purpose.

Chlorophyll a contents of the nine $F_1$ hybrids ranged from 0.0020 - 0.0197 mg per 100 gram fresh fruit weight and were different at statistically significant level (Table 12). The $F_1$ hybrid CA1449 × CA683 had the lowest chlorophyll a content while the $F_1$ hybrid CA1445 × CA683 contained the highest level. However, this highest estimate was not statistically significantly different from those of $F_1$ hybrids CA1445 × CA1447 and CA1449 × CA1448, as well as the two commercial varieties namely JomThong 2 and Jakkrapat. These three high chlorophyll a content $F_1$ hybrids nevertheless were superior to the female parents, most of the male parents, and the YokSiam variety, at statistically significant level. Most of the remaining $F_1$ hybrids were found to have chlorophyll a content at levels not statistically significant different from those of the female parents, most of the male parents, and YokSiam variety.

Chlorophyll b contents appeared to vary at statistically significant level among various varieties whether $F_1$ hybrids, the female parents, the male parents or commercial ones (Table 12). Those of the nine $F_1$ hybrids varied in the range of 0.0007 - 0.0200 mg per 100 gram fresh fruit weight (Table 12). The $F_1$ hybrid CA1449 × CA683 contained the lowest chlorophyll b content while the $F_1$ hybrid CA1445 × CA1447 contained the highest but was not statistically significantly different from the other two $F_1$ hybrids' levels: CA1450 × CA683 and CA1445 × CA683; however, higher with the differences at statistically significant level compared with the female parents, the male parents, and all commercial varieties. The remaining $F_1$ hybrids had chlorophyll b content at levels comparable to those of the female parents, the male parents, and the commercial varieties.

The total chlorophyll content of various $F_1$ hybrids ranged from 0.0087 - 0.0390 mg per 100 gram fresh fruit weight which varied at statistically significantly different level. The $F_1$ hybrid CA1445 × CA1448 contained the least total

chlorophyll content. The maximum total chlorophyll content was found in the $F_1$ hybrid CA1445 × CA1447 but the level was not different statistically significant from that of $F_1$ hybrid CA1445 × CA683. These two hybrids had total chlorophyll content far higher, at statistically significantly different level, than most of the other $F_1$ hybrids, the female parents, the male parents and all of the commercial varieties. Meanwhile, most of the other $F_1$ hybrids contained total chlorophyll lower than JomThong 2 and Jakkrapat commercial varieties when assessed the differences at statistically significant level.

Table 10 Color of skin fruit chili of $F_1$ hybrids, male parents, female parents and commercial varieties, winter 2010

| Variety/Cultivar | L | Chroma | Hue |
|---|---|---|---|
| **$F_1$ Hybrid** | | | |
| CA1445 × CA683 | 46.38 gh | 41.10 c | 130.56 a |
| CA1445 × CA1447 | 55.91 bc | 50.43 a | 124.60 efg |
| CA1445 × CA1448 | 51.86 de | 46.29 ab | 125.70 def |
| CA1449 × CA683 | 55.27 c | 48.10 a | 124.35 fg |
| CA1449 × CA1447 | 59.99 a | 49.02 a | 122.68 g |
| CA1449 × CA1448 | 47.61 fgh | 43.04 bc | 129.71 abc |
| CA1450 × CA683 | 46.91 fgh | 41.12 c | 129.31 abc |
| CA1450 × CA1447 | 50.06 ef | 42.86 bc | 127.47 cd |
| CA1450 × CA1448 | 49.32 efg | 43.27 bc | 127.81 bcd |
| **Male Parent** | | | |
| CA683 | 48.05 fgh | 42.75 bc | 130.41 ab |
| CA1447 | 53.54 cd | 48.26 a | 125.49 def |
| CA1448 | 51.68 de | 46.30 ab | 126.40 def |
| **Female Parent** | | | |
| CA1445 | 53.83 cd | 49.48 a | 125.99 def |
| CA1449 | 58.82 ab | 46.44 ab | 122.65 g |
| CA1450 | 49.99 ef | 42.93 bc | 127.13 cde |
| **Commercial** | | | |
| Jakkrapat | 47.75 fgh | 42.15 bc | 129.60 abc |
| JomThong 2 | 44.62 h | 40.30 c | 130.70 a |
| YokSiam | 56.83 abc | 50.71 a | 126.09 def |
| **C.V. (%)** | 3.65 | 5.12 | 1.12 |

[1/] Means within column with different letters differ significantly at $P < 0.05$ according to DMRT.

Table 11 Fruit physico-chemical properties of $F_1$ hybrids, male parents, female parents and commercial varieties, winter 2010

| Variety/Cultivar | Total soluble solids | Moisture (%) | Vitamin C | Capsaicin (Scoville unit) |
|---|---|---|---|---|
| **$F_1$ Hybrid** | | | | |
| CA1445 × CA683 | 5.87 bc | 83.25 h | 5.13 c | 1920 e |
| CA1445 × CA1447 | 5.17 de | 87.05 def | 5.13 c | 940 g |
| CA1445 × CA1448 | 5.03 def | 86.75 ef | 5.13 c | 500 h |
| CA1449 × CA683 | 6.03 b | 86.28 f | 5.13 c | 530 h |
| CA1449 × CA1447 | 6.20 b | 88.47 a-d | 5.13 c | 1210 g |
| CA1449 × CA1448 | 5.43 cd | 84.00 gh | 5.13 c | 1490 f |
| CA1450 × CA683 | 4.17 h | 83.53 gh | 6.41 b | 50 i |
| CA1450 × CA1447 | 4.07 h | 89.72 a | 7.69 a | 5720 a |
| CA1450 × CA1448 | 5.43 cd | 89.34 ab | 6.41 b | 3490 b |
| **Male Parent** | | | | |
| CA683 | 4.53 fgh | 84.80 g | 3.85 d | 3530 b |
| CA1447 | 6.93 a | 89.37 ab | 6.41 b | 1700 ef |
| CA1448 | 6.23 b | 89.02 abc | 6.41 b | 190 i |
| **Female Parent** | | | | |
| CA1445 | 6.13 b | 83.50 gh | 5.13 c | 260 hi |
| CA1449 | 5.17 de | 86.58 ef | 5.13 c | 2750 c |
| CA1450 | 4.57 fgh | 88.95 abc | 6.41 b | 2370 d |
| **Commercial** | | | | |
| Jakkrapat | 4.73 efg | 87.90 b-e | 5.13 c | 2610 cd |
| JomThong 2 | 4.83 ef | 87.48 def | 6.41 b | 960 g |
| YokSiam | 4.30 gh | 87.58 c-f | 6.41 b | 1700 ef |
| **C.V. (%)** | 5.38 | 0.92 | 8.56 | 8.89 |

[1/] Means within column with different letters differ significantly at $P < 0.05$ according to DMRT.

Table 12 Chlorophyll content of $F_1$ hybrids, male parents, female parents and commercial varieties, winter 2010

| Variety/Cultivar | Chlorophyll a (mg/100 g fresh weight) | Chlorophyll b (mg/100 g fresh weight) | Total chlorophyll (mg/100 g fresh weight) |
|---|---|---|---|
| **$F_1$ Hybrid** | | | |
| CA1445 × CA683 | 0.0197 a | 0.0183 a | 0.0347 ab |
| CA1445 × CA1447 | 0.0190 a | 0.0200 a | 0.0390 a |
| CA1445 × CA1448 | 0.0047 de | 0.0007 c | 0.0087 i |
| CA1449 × CA683 | 0.0020 e | 0.0007 c | 0.0093 hi |
| CA1449 × CA1447 | 0.0047 de | 0.0013 c | 0.0093 hi |
| CA1449 × CA1448 | 0.0147 ab | 0.0097 b | 0.0210 d |
| CA1450 × CA683 | 0.0113 bc | 0.0193 a | 0.0307 bc |
| CA1450 × CA1447 | 0.0083 cd | 0.0107 b | 0.0190 de |
| CA1450 × CA1448 | 0.0090 cd | 0.0093 b | 0.0150 ef |
| **Male Parent** | | | |
| CA683 | 0.0003 e | 0.0003 c | 0.0007 j |
| CA1447 | 0.0003 e | 0.0000 c | 0.0003 j |
| CA1448 | 0.0113 bc | 0.0097 b | 0.0210 d |
| **Female Parent** | | | |
| CA1445 | 0.0093 cd | 0.0083 b | 0.0143 efg |
| CA1449 | 0.0083 cd | 0.0013 c | 0.0097 ghi |
| CA1450 | 0.0113 bc | 0.0090 b | 0.0203 d |
| **Commercial** | | | |
| Jakkrapat | 0.0193 a | 0.0097 b | 0.0290 c |
| JomThong 2 | 0.0193 a | 0.0100 b | 0.0293 c |
| YokSiam | 0.0093 cd | 0.0013 c | 0.0140 fgh |
| **C.V. (%)** | 2.47 | 2.64 | 2.16 |

[1/] Means within column with different letters differ significantly at $P < 0.05$ according to DMRT.