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Fruit Yield and Morphological Characters of Parental Cultivars and Intervarietal Hybrids of *Capsicum annuum* L.

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Abstract

The fruit yield and morphological characters of F_1 hybrids between *Capsicum annuum* L. 'California Wonder', four native Japanese cultivars, and three Korean F_1 cultivars were evaluated and the results compared with parental cultivars.

The F_1 hybrids obtained by crossing 'California Wonder' and native Japanese cultivars flowered 3 days earlier on average compared to parental cultivars. The yields of F_1 hybrids were higher than those of the parental cultivars, especially when one of the parents was 'California Wonder'. Also, F_1 hybrid whose one parent was 'California Wonder' showed increased fresh weight per fruit. Among the F_1 hybrids, crossing between 'California Wonder' and 'Fushimi Amanaga' gave the highest fruit yield. The number of locules and seeds per fruit from of the F_1 hybrids whose one parent was 'California Wonder' was more than that of the native Japanese cultivars. The plant height in F_1 hybrids obtained by crossing between 'California Wonder' and four native Japanese cultivars tended to be higher than that of the parental cultivars.

Key words : *Capsicum annuum, fruit yield, intervarietal hybrids, morphological characters*

Introduction

Peppers belong to the genus *Capsicum* in the family Solanaceae. Peppers have high nutritional value as a good source of vitamins, particularly vitamins C and A. In terms of economic importance, peppers are becoming increasingly popular.

In pepper, cultural factors such as transplant age and pruning[1], geographical location of transplant production [2], fertility[3,4], plant population[5,6,7], temperature[8,9,10,11], humidity[12] and delayed harvest[13] do affect yield. However, studies on fruit yield and morphological characters of fruits of intervarietal hybrids of *Capsicum* peppers as compared to parental cultivars have not yet been reported.

The objective of this study, therefore, was to characterize fruit yield of twelve F_1 hybrids obtained by crossing the bell pepper cultivar 'California Wonder' and four native Japanese cultivars, and three Korean F_1 cultivars. The morphological characters of fruits and plant height were also compared.

Materials and Methods

Plant material and growth conditions

Capsicum annuum cultivars 'California Wonder', 'Fu-

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shimi Amanaga', 'Shishitou', 'Yatsufusa', 'Taka no Tsume', twelve F_1 hybrids obtained by crossing among these cultivars in 1993, and three Korean F_1 cultivars, 'Cheongyang', 'Sinhong' and 'Geoseong' were used for the experiments.

Seeds were sown in polyester container (50.5cm long×36.0cm wide×10.0cm high) packed with vermiculite, and placed in a glasshouse at Okayama University on April 5, 1994. After germination, seedlings with 1 to 2 true leaves were transplanted into 9cm-diameter black vinyl pots containing a mixture of compost : sand (2 : 1, v/v) on April 26, 1994. Five seedlings per cultivar with 8 to 12 true leaves were planted in the field on May 29, 1994. The soil in the field had been fertilized with 'Sumika Ace' (18N−10P−14K) to provide N, P, and K at the rate of 240, 200, and 230kg/ha, respectively. Plots were 8.0m long with 1.2m between beds, on a raised bed (75cm×20cm). Within row spacings was 40cm. Twenty plants per plot were planted in single rows. Plots of each cultivar were arranged in a completely randomized design with five replications.

Climatic conditions in the field during the period of

Table 1. Environmental conditions during the culture period from April to November, 1994

Month		Mean maximum temperature (℃) 1994	Mean minimum temperature (℃) 1994	Mean temperature (℃) 1994	Mean humidity (%) 1994	Mean accumulated insolation (MJ) 1994	Mean accumulated sunshine (H) 1994	Mean accumulated rainfall (mm) 1994
April	E[z]	19.7	8.1	13.8	52.0	139.1	172.9	17.0
	M[y]	21.4	9.8	15.8	54.0	133.3	149.9	42.0
	L[x]	23.7	12.4	17.9	61.0	144.1	169.1	26.5
May	E	26.0	13.4	19.6	54.0	151.9	188.7	2.5
	M	24.7	14.0	19.2	61.0	159.0	175.6	61.0
	L	26.4	15.0	20.9	61.0	160.0	180.4	29.5
June	E	29.1	17.1	22.8	57.0	155.5	180.9	13.5
	M	27.7	18.9	23.1	70.0	130.5	137.5	78.5
	L	29.0	20.2	24.5	69.0	122.7	136.4	7.5
July	E	34.6	24.7	29.3	68.0	170.9	212.5	123.0
	M	35.9	25.0	30.2	61.0	188.1	234.2	0.0
	L	34.2	25.3	29.3	70.0	173.6	204.2	33.0
August	E	36.9	26.6	31.3	63.0	175.4	223.0	0.0
	M	34.3	25.3	29.2	65.0	170.8	208.7	38.5
	L	34.7	23.6	28.4	66.0	171.0	236.1	3.0
September	E	33.9	22.9	27.6	70.0	131.9	182.8	36.0
	M	29.9	19.2	24.0	64.0	108.4	154.4	1.0
	L	28.0	18.2	22.5	70.0	93.1	125.8	118.0
October	E	26.5	15.9	20.9	65.0	101.5	151.7	4.5
	M	25.9	15.1	20.3	68.0	86.9	146.5	9.0
	L	21.3	10.6	15.7	68.0	84.9	146.1	43.0
November	E	20.9	8.8	14.6	66.0	82.7	159.4	19.0
	M	19.4	11.5	15.1	72.0	48.6	89.5	12.0
	L	16.4	4.7	9.9	66.0	66.3	129.2	0.0

[z]Early 10 days.

[y]Middle 10 days.

[x]Last 10 days.

Observation point : Research Farm of Okayama University.

the experiment are shown in Table 1.

Determination of days to anthesis and evaluation of fruit yield and morphological characters

In all the cultivars, the number of days to anthesis of the first flower were recorded. Immature fruits of each cultivar were harvested from July 18 to August 18, for the 1994 experiments. At each harvest, all fruits were weighed and the number of fruits per plant were recorded. Fruit length, diameter, shape index (ratio of fruit length to fruit diameter), locule number and number of seeds per fruit were also recorded. Plant height was measured once per month from July 17 to September 17, for the 1994 experiments.

Results

Anthesis of the first flower

The number of days to anthesis of the first flower are shown in Table 2.

The Korean F_1 cultivars were earlier than the Japanese cultivars. The F_1 hybrids obtained by crossing 'California Wonder' and native Japanese cultivars flowered 3 days earlier on average compared to parental cultivars. Mean days to first flowering in 1994 were 77.7 for the Korean F_1 cultivars, 85.7 for the Japanese cultivars, and 82.4 days for F_1 hybrids.

Fruit yield

Yields of immature fruits for each cultivar harvested in 1994 is shown in Table 3. The highest yield was realized with Japanese hybrids followed by the Korean F_1 cultivars, and was lowest for the parental cultivars. Among the Japanese cultivars, crossing between 'California Wonder' and 'Fushimi Amanaga' gave the highest fruit yield (Table 3, Fig. 1).

The fruit yields of F_1 hybrids obtained by crossing between bell pepper 'California Wonder' and four native Japanese cultivars in 1994 is 567.1g, while for the parents they were 310.5g. The yield of Korean F_1 cultivars in 1994 was 483.8g.

Table 2. Days to first flowering in peppers after sowing, 1994

Group	No. Cultivar	1994 Apr. 5 – July 6
Bell pepper	1. California Wonder	85.3± 1.9ab[z]
Japanese cultivar	2. Fushimi Amanaga	85.0± 0.8abc
	3. Shishitou	85.4± 2.0ab
	4. Yatsufusa	85.4± 1.9abc
	5. Taka no Tsume	87.8± 3.5a
	Mean	85.7
	♀ ♂	
F_1 hybrid	6. 1×2	82.6± 1.3cd
	7. 1×3	79.5± 2.7de
	8. 1×4	83.0± 1.8bcd
	9. 1×5	83.0± 1.0bcd
	10. 2×1	82.8± 1.1bcd
	11. 2×3	83.6± 1.8bc
	12. 2×4	83.0± 0.7bcd
	13. 3×1	82.4± 4.7cd
	14. 3×2	84.6± 1.3abc
	15. 4×1	83.3± 3.4bc
	16. 4×2	82.8± 0.5bcd
	17. 5×1	78.2± 1.8ef
	Mean	82.4
Korean F_1 cultivar	18. Cheongyang	77.8± 0.8ef
	19. Sinhong	79.0± 2.6ef
	20. Geoseong	76.4± 2.5f
	Mean	77.7

[z]Mean± SD, Mean separation within columns by Duncan's multiple range test at 5% level.

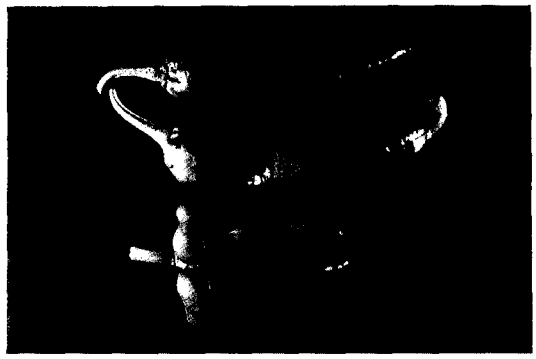

Fig. 1. Fruit of the F_1 hybrid(middle) obtained by crossing between 'California Wonder' (lower, ♀) and 'Fushimi Amanage' (upper, ♂).

Table 3. Yield of immature fruits in 1994[z]

Group	No. Cultivar	1994 (July 18 – August 18) Mean fruit yield(g/plant)	No. of fruits per plant
Bell pepper	1. California Wonder	365.9± 147.8fghij[y]	16.0± 6.6j
Japanese cultivar	2. Fushimi Amanaga	385.6± 202.7efghij	138.6± 67.4bcdefgh
	3. Shishitou	571.4± 194.5bcd	277.0± 90.9a
	4. Yatsufusa	107.4± 28.9j	109.8± 35.1fghi
	5. Taka no Tsume	122.0± 65.1ij	124.5± 62.8cdefghi
	Mean	310.5	133.2
	♀ ♂		
F_1 hybrid	6. 1×2	1037.3± 491.8a	110.6± 36.7efghi
	7. 1×3	672.5± 300.1abc	107.8± 27.9ghi
	8. 1×4	517.8± 249.4cdefgh	140.6± 53.7bcdefg
	9. 1×5	486.8± 270.5cdefghij	122.2± 44.9cdefghi
	10. 2×1	904.4± 308.0ab	106.4± 24.0hij
	11. 2×3	396.6± 217.9cdefghij	150.0± 85.6bcdef
	12. 2×4	345.1± 114.4hij	190.8± 58.1abcd
	13. 3×1	549.8± 428.9cdef	78.3± 49.7ij
	14. 3×2	502.8± 244.4cdefghi	199.0± 87.1abc
	15. 4×1	456.0± 186.0cdefghij	114.4± 44.4defghi
	16. 4×2	394.5± 146.5defghij	210.0± 46.5ab
	17. 5×1	541.8± 118.5cdefg	123.2± 14.8cdefghi
	Mean	567.1	137.8
Korean F_1 cultivar	18. Cheongyang	534.1± 112.9cdefgh	186.5± 48.8abcde
	19. Sinhong	354.8± 176.8ghij	121.3± 56.0cdefghi
	20. Geoseong	562.4± 286.9bcde	125.5± 61.1cdefghi
	Mean	483.8	144.4

[z]Fruits were harvested for a duration of 32 days in 1994.

[y]Mean± SD, Mean separation within columns by Duncan's multiple range test at 5% level.

In 1994, the number of fruits per plant for the F_1 hybrids, the parental cultivars, and Korean F_1 cultivars was 137.8, 133.2 and 144.4, respectively.

Morphological characters

Various morphological characters such as fruit length and diameter, shape index, fresh weight and the number of locules and seeds per fruit were recorded(Table 4).

In 1994, the mean fresh weight per fruit was 4.5, 5.9 and 3.4g for the F_1 hybrids, the parental cultivars, and Korean F_1 cultivars, respectively. The mean fruit length for the F_1 hybrids, the parental cultivars, and the Korean F_1 cultivars in 1994 it was 5.9, 4.5 and 6.9cm, respectively. The mean fruit diameter for the F_1 hybrids in 1994 was 1.8cm, while in the parental cultivars it was 1.8cm. For Korean F_1 cultivars in 1994 it was 1.2 cm. In 1994, the shape index (ratio of fruit length to

Table 4. Morphological characters of immature fruits harvested for a duration of 32 days in 1994

Group	No. Cultivar	1994 (July 18 – August 18) Fresh weight per fruit(g)	Fruit length(cm) a	Fruit diameter(cm) b	Shape index (a/b)	No. of locules	No. of seeds
Bell pepper	1. California Wonder	22.9± 1.7a[z]	4.0± 0.3f	4.7± 0.3a	0.9	3.4± 0.1a	71.7± 7.2a
Japanese	2. Fushimi Amanaga	2.7± 0.4efg	5.9± 0.8bcde	1.3± 0.1hi	4.5	2.2± 0.2defgh	21.8± 5.9f
cultivar	3. Shishitou	2.1± 0.2gh	4.3± 0.4ef	1.5± 0.0fg	2.9	2.2± 0.2defgh	18.1± 1.7f
	4. Yatsufusa	1.0± 0.2h	4.2± 0.5ef	0.8± 0.1k	5.3	2.1± 0.1gh	25.1± 4.0ef
	5. Taka no Tsume	1.0± 0.2h	4.0± 0.6f	0.8± 0.1k	5.0	2.2± 0.2defgh	27.4± 9.8ef
	Mean	5.9	4.5	1.8	3.7	2.4	32.8
	♀ ♂						
F_1 hybrid	6. 1×2	9.0± 1.9b	7.3± 1.4a	2.6± 0.2b	2.8	2.4± 0.3cd	66.5± 20.0a
	7. 1×3	6.0± 1.4c	5.2± 0.9def	2.4± 0.1cd	2.2	2.7± 0.1b	49.7± 20.1bc
	8. 1×4	3.6± 0.5def	5.4± 0.6bcdef	1.6± 0.1ef	3.4	2.3± 0.2cdef	57.0± 11.6ab
	9. 1×5	3.8± 0.8def	5.7± 1.0bcde	1.6± 0.1ef	3.6	2.3± 0.1cdefg	58.5± 11.0ab
	10. 2×1	8.3± 1.1b	6.8± 1.0ab	2.4± 0.1bc	2.8	2.4± 0.2cde	46.5± 3.3bcd
	11. 2×3	2.8± 0.5efg	6.2± 1.1abcd	1.4± 0.1gh	4.4	2.0± 0.0h	28.4± 8.6ef
	12. 2×4	1.8± 0.2gh	5.3± 0.6cdef	1.1± 0.1j	4.8	2.1± 0.2efgh	28.9± 6.4ef
	13. 3×1	6.0± 2.6c	5.3± 1.5cdef	2.2± 0.4d	2.4	2.5± 0.2bc	25.1± 21.1ef
	14. 3×2	2.5± 0.2fg	5.7± 0.5bcde	1.4± 0.1ghi	4.1	2.1± 0.1gh	30.4± 5.2def
	15. 4×1	3.9± 0.2de	5.9± 1.0bcde	1.7± 0.1ef	3.5	2.4± 0.1cde	56.5± 5.1ab
	16. 4×2	1.8± 0.4gh	5.6± 1.0bcde	1.0± 0.1j	5.6	2.1± 0.1fgh	40.3± 5.9cde
	17. 5×1	4.4± 0.5d	6.4± 0.8abcd	1.7± 0.1e	3.8	2.3± 0.2cdef	51.7± 11.6bc
	Mean	4.5	5.9	1.8	3.6	2.3	45.0
Korean F_1	18. Cheongyang	2.9± 0.1efg	6.6± 0.0abc	1.1± 0.0j	6.0	2.2± 0.1defgh	47.5± 6.9bcd
cultivar	19. Sinhong	2.9± 0.3efg	6.7± 0.6ab	1.2± 0.1ij	5.6	2.0± 0.1gh	39.2± 9.7cde
	20. Geoseong	4.4± 0.3d	7.5± 0.6a	1.4± 0.0gh	5.4	2.0± 0.1gh	46.3± 10.6bcd
	Mean	3.4	6.9	1.2	5.7	2.1	44.3

[z]Mean± SD, Mean separation within columns by Duncan's multiple range test at 5% level.

fruit diameter) of the F_1 hybrids was 3.6, while in the parental cultivars it was 3.7. For Korean F_1 cultivars in 1994 it was 5.7. The mean number of locules and seeds per fruit of the F_1 hybrids in 1994 was 2.3 and 45.0, respectively, while for the parental cultivars they are 2.4 and 32.8, respectively. For Korean F_1 cultivars, the number of locules and seeds per fruit were 2.1 and 44.3, respectively.

The mean height of all plants in each cultivar were recorded once a month from July to September in 1994 (Table 5).

Plant height of the F_1 hybrids as of July 1994 was 40.4cm, while in the parental cultivars it was 35.3cm. For Korean F_1 cultivars, plant height was 60.4cm. One month later, plant height of the F_1 hybrids, the parental cultivars, and Korean F_1 cultivars was 58.1, 52.3 and 95.0cm, respectively. Plant height of the F_1 hybrids and the parental cultivars as of September 1994 was 72.3 and 62.8cm, respectively, while that of Korean F_1 cultivars was 103.9cm.

Table 5. Plant height from July to September in 1994

Group	No. Cultivar	1994		
		July 17	August 17	September 17
Bell pepper	1. California Wonder	36.4± 5.3hi[z]	49.7± 9.2fgh	66.0± 10.2efgh
Japanese cultivar	2. Fushimi Amanaga	44.1± 4.1de	65.1± 5.8bcd	77.8± 7.3bcd
	3. Shishitou	41.7± 3.2defgh	58.8± 11.1bcdefg	72.7± 15.8bcdefgh
	4. Yatsufusa	26.1± 3.8j	41.5± 4.7h	45.3± 8.8i
	5. Taka no Tsume	28.1± 5.6ij	46.4± 9.0gh	52.1± 15.5hi
	Mean	35.3	52.3	62.8
	♀ ♂			
F_1 hybrid	6. 1×2	42.1± 3.5defg	54.9± 6.8bcdefgh	69.5± 6.5cdefgh
	7. 1×3	37.1± 4.3gh	52.4± 12.5efgh	61.1± 11.1ghi
	8. 1×4	38.7± 4.2defgh	53.3± 7.2cdefgh	72.2± 3.5bcdefgh
	9. 1×5	37.5± 5.7fgh	57.7± 11.4bcdefgh	77.0± 15.5bcde
	10. 2×1	40.9± 4.6defgh	62.7± 7.2bcdef	75.4± 7.7bcdef
	11. 2×3	38.4± 7.6defgh	54.9± 9.0bcdefgh	65.2± 16.1fghi
	12. 2×4	43.8± 6.6def	62.8± 10.3bcde	74.1± 18.3bcdefg
	13. 3×1	39.9± 8.7defgh	68.8± 14.0b	72.9± 26.4bcdefgh
	14. 3×2	38.2± 5.9efgh	54.1± 10.5bcdefgh	68.0± 7.9defgh
	15. 4×1	38.4± 3.7defgh	53.2± 10.0defgh	73.3± 9.8bcdefgh
	16. 4×2	47.9± 4.7cd	67.3± 8.5bc	87.3± 10.3bc
	17. 5×1	41.5± 3.0defgh	55.5± 6.7bcdefgh	71.2± 16.7bcdefgh
	Mean	40.4	58.1	72.3
Korean F_1 cultivar	18. Cheongyang	68.3± 4.1a	99.8± 14.1a	112.2± 13.5a
	19. Sinhong	58.9± 12.0b	99.8± 20.3a	109.7± 21.7a
	20. Geoseong	54.1± 14.5bc	85.3± 17.8a	89.7± 24.5b
	Mean	60.4	95.0	103.9

[z]Mean± SD, Mean separation within columns by Duncan's multiple range test at 5% level.

Discussion

In the present study, flowering of pepper appeared to have been influenced by environmental factors, such as day length and temperature(Tables 1 and 2). It has been reported that day length affects development of pepper plant[14]. Air and soil temperature also have a great influence on the development and flowering of the pepper plant[15]. In particular, temperature conditions strongly influenced the development of flowers and fruits of pepper plants[8,9,11].

The F_1 hybrid from the bell pepper cultivar 'California Wonder', and Japanese cultivar 'Fushimi Amanaga' had higher yields than the parental cultivars in 1994 (Table 3). In particular, F_1 hybrid whose one parent was 'California Wonder' gave higher yields and increased fruit number ($P \leq 0.05$). Also, F_1 hybrid whose one parent was 'California Wonder' showed increased fresh weight per fruit in 1994.

The shape index of green immature fruits (ratio of fruit length to fruit diameter) was higher for the F_1 hybrids than for fruits from the parental cultivars (Table

4). The number of locules per fruit from the 'California Wonder' and F_1 hybrids whose one parent was 'California Wonder' in 1994 was more than that of the native Japanese cultivars, such as 'Fushimi Amanaga', 'Shishitou', 'Yatsufusa', and 'Taka no Tsume'. The number of seeds per fruit of the F_1 hybrids whose one parent was 'California Wonder' was also more than that of the native Japanese cultivars. In the other F_1 hybrids, the number of seeds per fruit in 1994 tended to be slightly more than that of the parental cultivars. These characteristics were affected by factors such as one of the parent being 'California Wonder'.

The plant height in F_1 hybrids obtained by crossing between the bell pepper cultivar of 'California Wonder' and four native Japanese cultivars tended to be higher than that of the parental cultivars in 1994 (Table 5). F_1 hybrid obtained by crossing between 'Yatsufusa' and 'Fushimi Amanaga' was higher than that of parental cultivars in 1994. In particular, the height of F_1 hybrids made by crossing between 'Yatsufusa' and 'Fushimi Amanaga' was higher than that of other F_1 hybrids in 1994. This result may be attributed to the dominance of the character of 'Fushimi Amanaga' as one of the parents. The plant height of F_1 hybrids was higher than that of parental cultivars in 1994.

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초록 : 고추의 친품종 및 품종간 잡종의 과실수량과 형태적 특성

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고수량·고품질의 고추 신품종을 육성하기 위해 피만의 'California Wonder'와 일본재래종 4품종, 이들의 F_1 잡종 12조합 그리고 한국의 F_1 3품종을 공시하고, 과실수량과 형태적 특성에 관하여 검토했다.

그 결과, 'California Wonder'와 일본재래종간 교잡에 의해 얻어진 F_1 잡종은 친품종보다 3일 먼저 개화했다. F_1 잡종은 특히, 'California Wonder'가 편친이었을 때 친품종보다 고수량 이었다. 또한, 일과중도 증가하는 경향 이었다. F_1 잡종중에서 'California Wonder'와 'Fushimi Amanaga'간 잡종이 가장 고수량 이었다. 자실수와 종자수는 'California Wonder'가 편친이었을 때 친품종보다 많았다. 초장은 친품종보다 F_1 잡종이 큰 경향 이었다.