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学位論文全文に代わる要約
Extended Summary in Lieu of Dissertation

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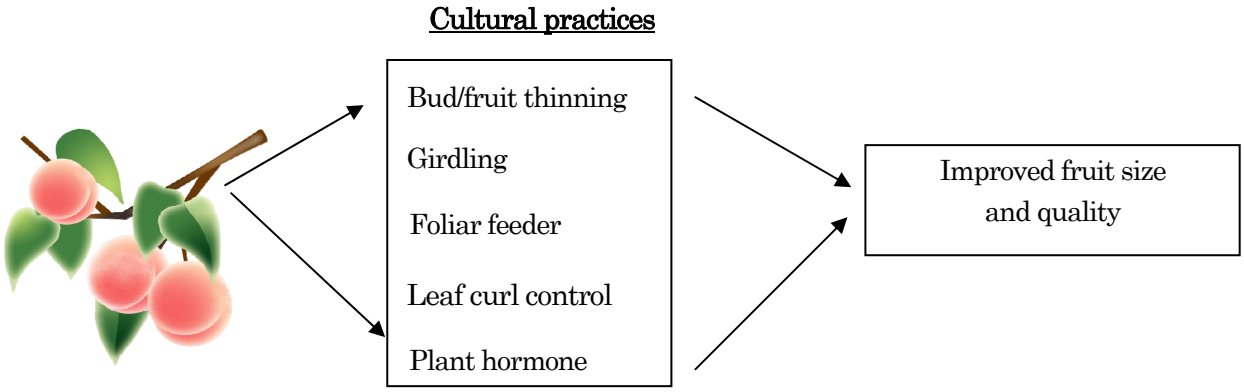
学位論文題目：
Title of Dissertation

Studies on cultural practices to improve fruit quality of low-chill, early ripening peach
(少低温要求性早生モモの果実品質向上のための栽培技術に関する研究)

学位論文要約：
Dissertation Summary

The initial steps for cultivating low-chill peaches in forcing culture as well as in natural conditions are understanding the appropriate cultural practices as well as plant growth, fruit development and fruit quality. The knowledge obtained could be used to determine the cultural practices for plant growth, which can increase plant growth and fruit quality of the low-chill peaches under forcing culture as well as natural conditions for peach growers. Besides, the proper cultural practices can prevent excessive use of cost and energy in peach production. So, I used different cultural methods such as bud/fruit thinning, spray of plant hormones, temperatures treatment, foliar fertilizer and copper agents in search of improved productions with quality improvement of these cultivars.

Effects of different cultural practices on fruit development of low-chill peach ‘KU-PP1’, ‘KU-PP2’ and HFP1 were studied in from 2018 to 2022. During the experimental seasons, we applied various cultural practices such as bud/fruit thinning, spray of plant hormones, temperatures treatment, foliar fertilizer and copper agents, and analyzed their effects on the development of fruit of these peaches (fig. 1). The application of different cultural environments expanded our understanding of fruit development and quality traits of these peaches.



(Low-chill, early ripening peach)

Fig.1. Cultural practices for fruit quality improvement of low-chill, early ripening peaches.

In the first part of my study, I thinned buds of HFP1 strain by removing 75%, 50% and 0% of total flower buds. After the treatment, I measured weekly fruit development until harvesting time. Similarly, 'KU-PP1' peach was thinned fruit with 5 cm (more fruit between fruit), 10 cm (standard fruit number) and 15 cm (fewer fruit) distance. Furthermore, I observed the weekly development of fruits measuring length and diameter. I observed heavier fruits by bud thinning treatment with 75% in HFP1 strain (Table 1). In the similar way, applying 15 cm gap in immature fruits of 'KU-PP1' resulted heavier fruits (Table 2). However, the total fruit yield will decrease by heavy removal of fruit/buds. Generally, peach grower in Japan apply fruit thinning standard near to 10 cm fruit removal treatment. These low-chill, early ripening peach have shot fruit development period (about 90 days). Thinning fruits by keeping fewer fruits (15 cm) lowers the initial nutrition competition resulting improved fruit quality with size. This is the first finding in this cultivar. During my research, there were limit number of trees for the study. In future, I suggest measuring fruit thinning with timing keeping the fruit distance 15 cm per fruits.

Table 1. Effect of fruit thinning on the fruit quality of HFP1 peach strain.

Treatments	Fruit weight (g)	Diameter (mm)			TSS (%)	TA (%)	Skin color		
		Length	Width 1[y]	Width 2[y]			L*	a*	b*
FT5	85.1±6.1[Z]	47.8±1.5	52.3±1.3	55.9±1.0	9.6±0.3	0.36±0.05	62.4±4.0	18.7±3.0	26.6±2.0
FT10	107.1±6.1	54.2±1.0	57.5±1.1	58.3±1.2	9.8±0.6	0.32±0.07	66.7±3.0	15.8±3.7	29.0±2.0
FT15	136.7±7.1	59.2±1.6	65.8±3.2	64.1±2.1	9.8±0.5	0.48±0.05	63.7±3.5	11.4±2.8	27.7±2.2

[Z] Means data ± standard error. FT means fruit thinning. FT5, FT10 and FT15 represents 5cm, 10 cm and 15 cm gap between fruit after fruit thinning, respectively. [y] Width 1 and Width 2 mean the diameter in cheek and suture direction, respectively.

Table 2. Effect of flower bud thinning on the fruit quality to 'KU-PP1' peach cultivar.

Treatments	Fruit weight (g)	Diameter (mm)			TSS (%)	TA (%)	Skin color		
		Length	Width 1	Width 2			L*	a*	b*
BT0	105.8±5.7[Z]	49.65±1.1	58.55±1.2	56.27±1.2	13.0±0.4	0.37±0.01	45.0±2.1	25.2±1.2	16.5±1.2
BT3/4	123.9±5.9	54.7±1.3	63.2±1.0	59.90±1.2	12.7±0.2	0.30±0.01	46.7±1.3	22.4±1.0	15.6±1.0
BT1/2	114.7±5.6	51.46±1.0	60.69±1.6	58.27±1.2	12.7±0.2	0.36±0.01	47.1±2.0	25.6±1.3	17.1±1.1

[Z] Means data ± standard error. BT0, BT3/4 and BT1/2 represent control, 3/4 - part bud thinning and 1/2-part buds thinning respectively. Width 1 and Width 2 mean the diameter in cheek and suture direction, respectively.

In the second part of my study, I used GA_3 and CPPU for the fruit quality study. Generally, farmers use GA_3 and CPPU to make fruit size bigger and seedless in grapes in Japan. I hypothesis if CPPU, when combined with GA_3, would enhance fruit growth in the small-fruited 'KU-PP1' peach or have a negative effect on fruit size. This kind of research was new for this cultivar till now. I applied single, double and combined treatment using GA_3 and CPPU. The result showed the combination of CPPU and GA_3 increased average fruit weight compared with control (Table 3). The largest fruits were observed in CPPU treated fruits. TSS was the highest in GA_3 single treated fruit and reduce in double treatment. This result might be another topic for future research.

Table 3. The fruit quality of 'KU-PP1' peach cultivar treated with plant hormones.

Treatments	Weight (g)	Diameter (mm)			TSS (%)	TA (%)	Skin color		
		Length	Width 1	Width 2			L*	a*	b*
Control	98.4±9.1[Z]	49.1±2.2	58.5±2.4	54.9±1.7	11.2±0.3	0.24±0.01	50.3±0.8	27.5±1.2	20.0±0.8
CPPU	119.4±6.2	54.5±1.1	63.6±1.1	58.2±1.7	13.0±0.2	0.21±0.02	45.6±1.5	29.2±1.0	18.5±0.9
GA_3	100.9±7.4	50.6±1.0	59.1±1.6	56.7±1.3	14.4±0.5	0.30±0.01	45.5±1.5	27.9±1.2	18.7±1.0
CPPU +GA_3	101.2±8.0	50.4±1.0	59.9±1.9	56.5±1.5	13.7±0.3	0.23±0.01	45.7±1.5	28.6±1.2	18.2±1.0
GA_3+GA_3	105.7+4.3	50.7±0.8	60.1±1.0	57.4±1.0	13.0±0.4	0.21±0.01	42.4±1.8	25.4±1.5	15.8±1.0
(CPPU +GA_3)+ GA_3	94.9±4.2	49.7±1.2	57.8±0.8	55.8±1.0	13.0±0.3	0.21±0.01	47.0±2.0	25.4±1.1	19.0±1.0

[Z] Means data ± standard error. Width 1 and Width 2 mean the diameter in cheek and suture direction, respectively. CPPU: Forchlorfenuron, GA_3: Gibberellin A3

In the third part of the study, I conducted temperature treatment and studied its effects on fruit quality hypothesizing there might some role of temperature for fruit quality improvement of 'KU-PP1' peach because

average temperature is lower during fruit development period of low-chill peach in Kagawa University. Temperature treatment was conducted using phytotron set at 15°C, 20°C and 25°C. The rapid growth pattern was observed from 3rd week of the treatment till harvest time at the 20°C and 25°C treatments (Fig. 1). Here, the temperature treatments of 25°C fruit was harvested earlier. However, in the fruit harvested at ripening time, the weight, length and diameter at the 15°C treatment was higher than those at the 20°C and 25°C treatments (Table 4). During the investigation, there were limited number of phytotrons and could not apply temperature more than 25°C for wider research. It will be another interesting topic for future research for forcing culture.

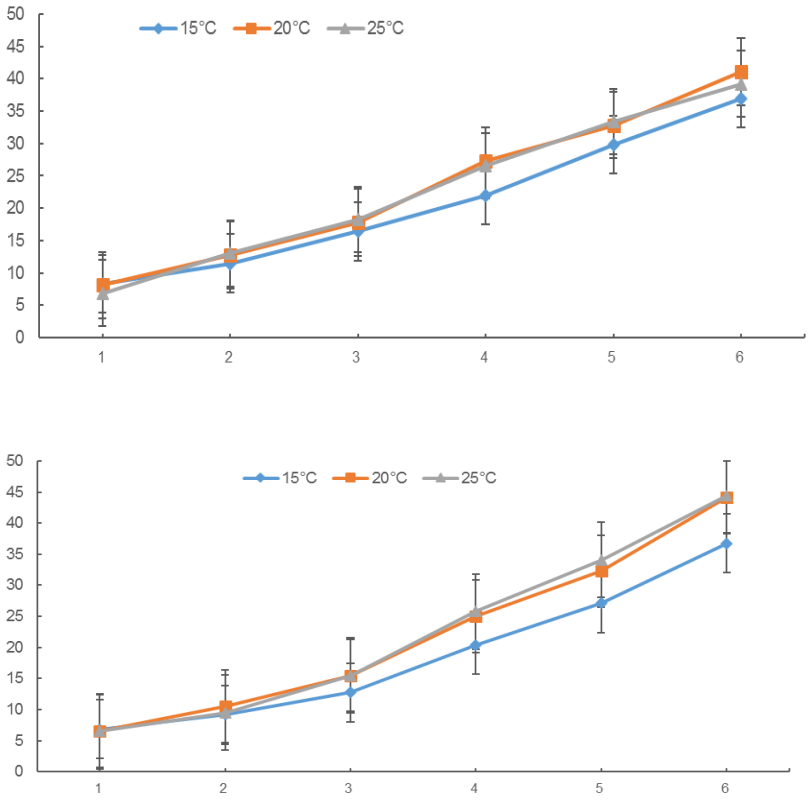


Fig. 2. The weekly development of 'KU-PP1' fruit length (upper) and width (below) at different temperature conditions after petal fall. The bar indicates the standard error value.

Table 4. The fruit quality of 'KU-PP1' peach grown at different temperature conditions.

Treatments	Weight (g)	Diameter (cm)			TSS (%)	TA (%)	Skin color		
		Length	Width1	Width2			L*	a*	b*
15°C (n=7)	83.7±5.6[z]	43.3±1.2	55.0±1.8	51.1±1.2	12.8±0.2	0.30±0.01	61.2±1.9	15.0±2.5	23.4±1.0
20°C (n=15)	60.8±5.0	41.8±0.5	48.5±1.4	46.3±0.5	11.7±0.0	0.40±0.00	62.3±2.0	12.0±2.1	24.5±1.1
25°C (n=18)	58.6±3.0	36.2±0.1	47.4±1.0	45.1±0.5	13.6±0.2	0.30±0.00	49.0±2.3	23.0±2.0	19.0±1.0

[z] Means data ± standard error. Width 1 and Width 2 mean the diameter in cheek and suture direction, respectively.

In the fifth part of study, I researched about leaf curl disease in HFP1 peach. For the research, I applied Coppersin and IC bordeaux-66D as copper compounds. Coppersin, which includes anti-biotic is expensive in market compared with IC bordeaux-66D, which does not contain antibiotic. Normally, peach grower use Coppersin to prevent from leaf curl. I assumed that if the low cost IC bordeaux-66D works in the low-chill peach like Coppersin does, fruit grower will influence for low-chill peach cultivation. However, my experiment resulted improved fruit with Coppersin treatment (Table 5).

Table 5. The fruit quality of HFP1 peach cultivar treated with copper agent.

Treatments	Weight (g)	Diameter (mm)			TSS (%)	TA (%)	Skin color		
		Length	Width 1	Width 2			L*	a*	b*
Control	147.8±14.3[Z]	54.9±1.1	65.4±2.7	65.5±2.1	13.1±0.7	0.30±0.00	61.2±1.9	15.0±2.5	23.4±1.0
ICB	110.8±4.5	51.5±1.2	56.6±2.0	58.2±1.0	13.5±0.4	0.36±0.01	62.3±2.0	12.0±2.1	24.5±1.1
CS	157.1±7.5	60.1±0.6	66.2±2.2	66.0±3.0	14.0±0.5	0.26±0.00	49.0±2.3	23.0±2.0	19.0±1.0

[Z] Means data ± standard error. The symbols Cont., ICB and CS represents for control, IC-Bordeaux and copper sin, respectively. Width 1 and Width 2 belongs the diameter in cheek and suture direction, respectively.

In another part of my research, I conducted fruit thinning by different timing using 'KU-PP2', a yellow flesh peach bred by Kagawa University. For the experiment, fruits were thinned with fruit distance of about 10 cm which is normal peach thinning methods of Japanese peach grower. In this experiment, the fruit quality of the

earlier thinned (first week DAFB) showed better fruit weight, size and TSS. Thinning earlies promoted the remain fruits intake of enough nutrition than fruits thinned later. Thus, the total outcome of this investigation concluded that the thinning of new low-chill peach cultivar ‘KU-PP2’ at 7 DAFB was highly effective for enhancing fruit size and TSS (Table 6).

Table 6. Effects of fruit thinning on fruit size and quality of ‘KU-PP2’ peach.

Fruit thinning time	Fruit weight (g)	TSS (°Brix)	Fruit diameter (mm)			Titratable acidity (%)	Skin color		
			Length	Cheek	Suture		L*	a*	b*
7 DAFB[Z]	178.7b	10.3 b	64.2b	70.8	65.3 b	0.32	56.6 b	15.9 b	33.9
14 DAFB	163.2 ab	10.3 b	61.8 ab	70.1	65.6 b	0.32	55.8 b	12.5 ab	33.6
21 DAFB	166.0 ab	10.0 b	62.5 ab	70	64.5 b	0.32	53.9 ab	14.5 ab	32.5
28 DAFB	176.0 b	10.3 b	63.5 b	68.9	69.4 c	0.34	48.1 a	16.0 b	36.6
Control	147.9 a	7.7 a	60.0 a	66.9	60.1a	0.32	56.8 b	8.4 a	33.9
Significance	*	*	*	NS	*	NS	*	*	NS

[Z]DAFB refers to the days after full bloom. * means significant at one-way ANOVA (P< 0.05). NS = non-significant. Different letters within the same column indicates a significant difference by Tukey`s test at the 5% level.

In the another part of my study, the effects of girdling at different growth stages on the fruit growth and quality of ‘KU-PP2’ peach was studied. Girdling was conducted at 2, 4 and 6 weeks after full bloom using four primary scaffolds from 4 different trees with 2 cm each girdle length. This girdling directly affected the fruit size and quality (Table 7). The best girdling time was 4 weeks after full bloom. In addition, TA, fruit skin firmness, and L* and b* values were not affected by the girdling treatment in ‘KU-PP2’ peach. Likewise, the effects of girdling at different size, on the fruit growth and quality of ‘KU-PP1’ peach trees directly affected the fruit size and quality. The best girdling treatment was girdle width with 0.5 cm (Table 8). This study illustrated the effects of girdling at different size, on the fruit growth and quality of ‘KU-PP1’ peach trees. Girdling treatment at different size directly affected the fruit size and quality attributes. The best girdling treatment was girdle width with 0.5 cm girdle. In addition, fruit flavour, size, fruit skin and flesh firmness, and L* and b* values were not

affected by the girdling treatment in 'KU-PP1' peach. Finally, we observed that the branches girdled with 2 cm width could not joined its bark and dried out completely in another season (data not shown).

Table 7. Effects of the girdling time on total soluble sugar (TSS), titratable acid (TA), and skin color in the peach cultivar 'KU-PP2'.

Treatments	Weight (g)	Length (L) (mm)	Diameter (D) (mm)	L/D	TSS (°Brix)	TA (%)	TSS/TA	Skin color		
								L*	a*	b*
G0	106.1a	56.9a	54.8a	1.04	7.7a	0.17	45.3a	65.2	5.3a	38.6
G1	154.6b	64.4b	64.6b	1.01	8.2b	0.16	51.3ab	62.1	10.9b	36.1
G2	184.3b	65.8b	67.7b	0.97	8.8b	0.14	62.9b	64.9	8.0b	40.2
G3	157.3b	63.1b	65.8b	0.96	8.5b	0.17	50.1ab	62.8	10.2b	40.4
Significance	*	*	*	NS	*	NS	*	NS	*	NS

*Indicates significance at the one-way ANOVA (P< 0.05); NS= non-significant. G0, G1, G2 and G3 represents control, girdled in 2,4 and 6 weeks' interval after full bloom. Different letters within the same column indicates a significant difference by Tukey`s test at the 5% level. (n=4).

Table 8. Effects of the different girdle length on fruit maturation, size, and firmness in 'KU-PP1' peach.

Treatments	Weight (g)	Length (L) (mm)	Diameter (D) (mm)	L/D	TSS (°Brix)	TA (%)	TSS/TA	Fruit skin color		
								L*	a*	b*
T0	93.8b	54.3b	62.6a	0.87	10.1b	0.25b	44.3	64.9	13.9b	29.1
T1	184.8a	62.1a	73.7a	0.84	14.9a	0.33ab	45.9	64.9	26.3ab	25.2
T2	133.1ab	55.1b	64.4ab	0.87	13.5a	0.27b	47.4	62.1	24.2a	24.9
T3	126.7ab	56.2ab	62.7a	0.89	12.8a	0.38a	46.6	60.7	25.8a	26.6
T4	95.2b	51.3b	55.9b	0.92	12.6a	0.35ab	43.8	63.9	19.2a	29.4
Significance	*	*	*	NS	*	*	NS	NS	*	NS

[Z] refers to the days from full bloom to harvest. * Indicates significance at the one-way ANOVA (P≤ 0.05); NS= non-significant. T0, T1, T2, T3 and T4 represents control, girdled with the length of 0.5, 1, 1.5 and 2 cm, respectively. Different letters within the same column indicates a significant difference by Tukey`s test at the 5% level. (n=4).

Hence, we concluded that girdling with the width less than 2 cm are safest way to apply in this cultivar. In addition, fruit flavour, size, fruit skin and flesh firmness, and L* and b* values were not affected by the girdling treatment in this cultivar. In the two years' observation of low-chill peach trees, we found the branches girdled with 2 cm width could not join its bark and dried out completely in another season. Hence, we concluded that

girdling with the width less than 2 cm are safest way to apply in this cultivar.

In the other part of my study, I used foliar feeder and observed the effects on fruit size and quality of 'KU-PP1' Peach. For the experiment, I prepared 5 $g \cdot L^{-1}$, 10 $g \cdot L^{-1}$, and 15 $g \cdot L^{-1}$ of potassium sulfate (K_2SO_4) as foliar fertilizer and sprayed three times: 30, 45 and 60 days after full bloom for each treatment. At the time of treatment, 5 g, 10 g, and 15 g of potassium sulfate were diluted with 1 L of distilled water and mixed with 3 mL of Approach BI as a cohesion agent. This experiment was conducted in 2020 and 2021 in the open field of Kagawa University.

Table 9. Effects of foliar spraying of K_2SO_4 on fruit quality and size in the peach cultivar 'KU-PP1'.

K_2SO_4 concn.($g \cdot L^{-1}$)	TSS (°Brix)		TA (%)		TSS/TA		Fruit skin color					
							L*		a*		b*	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
0	10.5a	10.7a	0.56	0.56	20.1a	21.3a	48.8	46.3	15.7a	14.1a	20.9ab	23.6a
5	10.7a	11.6ab	0.58	0.58	20.3a	21.4a	48.6	48.8	22.4b	15.1ab	19.6a	26.4ab
10	11.3b	11.7ab	0.57	0.58	23.5b	21.7a	49.6	47.6	25.6b	16.3b	21.6ab	24.5ab
15	11.4b	12.6b	0.58	0.57	21.1ab	23.6b	50.4	49.4	21.6b	17.1b	22.9b	32.8b
Significance	*	*	NS	NS	*	*	NS	NS	*	*	*	*

K_2SO_4 concn.($g \cdot L^{-1}$)	Weight (g)		Length (mm)		Diameter (mm)		Length/Diameter	
	2021	2020	2021	2020	2021	2020	2020	2021
0	87.0a	82.0a	50.1	50.0a	54.2a	50.5a	0.94b	0.99a
5	104.8b	89.7a	50.8	51.0ab	57.5b	48.3a	0.87a	1.00a
10	100.4b	87.8a	51.1	53.1ab	57.2b	50.0a	0.88a	1.10b
15	110.0b	115.0b	53.1	55.6b	58.5b	55.4b	0.90ab	1.00a
Significance	*	*	NS	*	*	*	*	*

[Z]refers to the days from full bloom to harvest. * Indicates significance at the one-way ANOVA ($P< 0.05$); NS= non-significant. Different letters within the same column indicates a significant difference by Tukey`s test at the 5% level. (n=4).

The application of foliar potassium application had a positive effect on the red color (a* values) of 'KU-PP1' peach fruits (Table 9). The application of K_2SO_4 with concentration of 15 $g \cdot L^{-1}$ resulted in heavier fruits and

better fruit quality compared with non-treated fruits.

In the other part of my study, I sprayed foliar feeder Pentakeep-S and observed the effect on fruit quality and size of 'KU-PP1' peach. Plants were subjected to 0.2 mL (P2), 0.4 mL (P4) and 0.6 mL (P6) PentaKeep-S (a fertilizer that containing 5-ALA, 10% N, 5.7% Mn, 0.45% Mg, 0.3% B, DTPA-iron, $CuSO_4$, $ZnSO_4$ and disodium molybdate as supplied by Cosmo Oil Co. Ltd., Japan) as foliar fertilizer after 30, 45 and 60 days after full bloom (DAFB) for each treatment. At the time of the treatments, 0.2 mL, 0.4 mL and 0.6 mL of the PentaKeep-S were diluted with 1 L of distilled water and mixed with 3 ml of Approach BI as a cohesion agent. For control, 1 L distilled water was mixed with Approach BI. All the treatments and the control were sprayed on leaves using a sprayer.

Table 10. Effects of foliar spraying of PentaKeep-super on fruit quality and size in the peach 'KU-PP1'.

Treatments	Weight (g)		Length (mm)		Diameter (mm)		Length/Diameter	
	2020	2021	2020	2021	2020	2021	2020	2021
Control	97.1b	91.6b	50.3a	48.8a	59.1	48.3b	0.86	1.0
P2	124.2a	157.1a	53.4b	55.6b	64.2	54.4a	0.84	1.02
P4	114.9a	143.2a	52.9b	52.7b	61.5	52.6a	0.86	1.01
P6	122.8a	141.2a	55.4b	53.1b	63.1	52.9a	0.89	1.01
Significance	*	*	*	*	NS	*	NS	NS

Treatments	TSS (°Brix)		TA (%)		TSS/TA	
	2020	2021	2020	2021	2020	2021
Control	10.1b	11.2b	0.31	0.36	34.2ab	33.6b
P2	12.4a	12.8a	0.34	0.31	38.6a	43.3a
P4	12.1a	12.7a	0.33	0.32	37.4a	40.4a
P6	12.2a	12.1a	0.32	0.31	39.1b	39.8a
Significance	*	*	NS	NS	NS	*

[Z] refers to the days from full bloom to harvest. P2, P4 and P6 means Pentakeep treatment at the 0.2 mL, 0.4 mL and 0.6 mL, respectively. * Indicates significance at the one-way ANOVA ($P \leq 0.05$); NS= non-significant. Different letters within the same column indicate a significant difference by Tukey`s test at the 5% level. (n=4).

The foliar spraying of Pentakeep-S effected the fruit size, and fruit quality of 'KU-PP1' peach (Table 10). Low

application of Pentakeep-S fertilizer resulted in increased fruit weight, length and TSS. In addition, TA and fruit firmness was not affected by the foliar application of Pentakeep-S. Collectively, those researches conducted here (of cultural environments) contributed for the understanding various cultural practices in fruit growth and quality attributes in these low-chill early ripening peach cultivars.

(注)　要約の文量は，学位論文の文量の約１０分の１として下さい。図表や写真を含めても構いません。
(Note)　The Summary should be about 10%　of the entire dissertation and may include illustrations