Fruit Thinning and Physiological Disorders in Citrus Variety ‘Harumi’

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ABSTRACT

Citrus ‘Harumi’ is a mandarin-type cultivar and shows a wide range of fruit size, which affects fruit quality such as sugar and acid contents. In citrus, fruit size also affects the degree of physiological disorder which become a big problem during storage. Thus, making fruit with equal and appropriate size is very important. Fruit thinning is one of the most important techniques to adjust fruit size by controlling the fruit number. Basically, fruit thinning has been conducted using a criterion based on leaf and fruit ratio (L/F) or fruit number per canopy volume. In this review, several thinning criteria for ‘Harumi’ and other citrus varieties are compared, and the pros and cons are discussed. In some citrus varieties, storage is necessary to adjust shipping time. During the storage, some physiological disorders occurred in peel, flesh and whole fruit. The occurrence of physiological disorders was influenced by citrus variety, fruit size and environmental conditions during storage. In ‘Harumi’ which is classified to easy-peeling variety, small fruit showed serious weight loss and peel wrinkle, while rind puffing and dehydration of flesh were big problems in large fruit during storage. Polyethylene (PE) bag wrapping has been used to decrease the fruit weight loss and to prevent the occurrence of some physiological disorders in tight-skin citrus varieties. However, the influences of PE wrapping on easy-peeling citrus is unclear. In this study, the researches on storage conditions, feature, and cause of physiological disorders during storage are also reviewed, and the effects of PE wrapping are discussed to improve storage condition in ‘Harumi’.

Keywords
easy-peeling, fruit thinning, L/F ratio, physiological disorder

1. Introduction

Citrus production area in Japan reached a peak of 207.0 thousand ha in 1977 and then gradually decreased to less than 80 thousand ha in 2010’s. Area and amount of production in Satsuma mandarin, the major citrus variety in Japan, was 173.1 thousand ha in 1973 and 3,665 thousand ton in 1975. However, they gradually decreased to less than 50 thousand ha and around 800 thousand ton in 2010’s, respectively [1]. The largest production area of citrus varieties other than Satsuma mandarin was 67.4 thousand ha in 1982 and decreased gradually to less than 30 thousand ha in the 2010’s. In addition to Satsuma mandarin, Natsudaïdai, Hassaku, Iyo and Navel orange were also the main citrus varieties until 2010’s (Fig. 1). However, new citrus varieties such as ‘Harumi’, ‘Setoka’ and ‘Shiranuhi’ were released and their production area increased after the 21st century. The varieties and production area of different
citrus varieties in 2017 were ‘Shiranuhi’ (2,793 ha), Yuzu (2,244 ha), Iyo tangor (2,223 ha), Ponkan (1,701 ha), Natsudaïdaï (1,599 ha), Hassaku (1,585 ha), ‘Kiyomi’ (867 ha), Tankan (780 ha), Kabosu (534 ha), Lemon (524 ha), Pummelo (499 ha), Kawachibankan (481 ha), ‘Harumi’ (471 ha), ‘Hinoyutaka’ (449 ha) etc. (Fig. 2).

Figure 1: Production area of main citrus cultivars from 1960 to 2018 in Japan [1]

Figure 2: Citrus production area other than Satsuma mandarin in 2017 [1]
Citrus variety ‘Harumi’ was developed and released in 1996 by Okitsu branch, Fruit Tree Research Station, Ministry of Agriculture, Forestry and Fisheries (MAFF), (presently National Institute of Fruit Tree and Tea Science (NIFTS), National Agricultural Research Organization (NARO)) and was registered according to the plant variety protection law in 1999. It originates from a hybrid between ‘Kiyomi’ tangor (Citrus unshiu × C. sinensis) and ‘F-2432’ Ponkan (C. reticulata). The production area and production of ‘Harumi’ increased after 2001 and reached 471 ha and 5,626 ton in 2017, respectively [1] (Fig.3). According to Yoshida [2], ‘Harumi’ is a mandarin-type cultivar and its average fruit weight is about 190 g and fruit shape is oblate. The rind color is orange and it is easily peeling. The fruit ripens in January and is stored until the shipping time in February or March. The tree vigor is medium and has semi-upright growth habit and a strong tendency to alternate bearing. It is resistant to citrus scab and moderately resistant to citrus canker [2]. ‘Harumi’ shows a high rate of fruit bearing and this trait often results in alternate bearing and a wide range of fruit size [3]. As the fruit quality, the occurrence of physiological disorders and storage ability are closely associated with the fruit size, the control of fruit size is very important in citrus.

Figure 3: Annual (upper) and prefectural (below) fruit production of ‘Harumi’ [1]

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22
2. Fruit thinning

Fruit size among different citrus varieties differs drastically and standards of classification in citrus fruits were defined as shown in Table 1 [4]. The most excellent fruit quality can be attained in the specific class of its own variety. For example, generally fruit quality of S or M class is good in Satsuma mandarin. In ‘Harumi’, negative relationship between fruit size and sugar or acid concentration in juice was observed [3]. In addition, rind puffing and granulation of juice sac were mainly observed in fruits bigger than 2L, or L size, respectively. Hisamatsu [3] has comprehensively judged that fruit quality was excellent in 2L class in ‘Harumi’. During fruit thinning, fruit that are too small or too large are removed and the fruit number is adjusted. As a result, fruit size is equalized, and alternate bearing is prevented. In this section, fruit thinning criteria which can be used in ‘Harumi’ are summarized.

Table 1: National standards of citrus fruit classes [4]

| Citrus group                  | Fruit maximum diameter (mm) |
|-------------------------------|-----------------------------|
|                               | <55 | <61 | <67 | <73 | <80 | <88 | <95 | <102 | <109 | <116 | 116< |
| I. Satsuma mandarin           | 2S  | S   | M   | L   | 2L  | 3L  |
| II. Navel orange              | 2S  | S   | M   | L   | 2L  | 3L  |
| III. Iyo tangor               | 2S  | S   | M   | L   | 2L  | 3L  |
| IV. Hassaku                   | 2S  | S   | M   | L   | 2L  | 3L  |
| V. Ama-natsudaidai           | 2S  | S   | M   | L   | 2L  | 3L  |
| VI. Natsudaidai              | 2S  | S   | M   | L   | 2L  | 3L  |

I. Ponkan, Fukuhara orange, Tankan, Seminole, ‘Harehime’ etc.
II. Hyuga-natsu, ‘Kiyomi’, ‘Harumi’, ‘Setoka’ etc.

2.1 Fruit thinning based on leaf and fruit balance

As fruit develops with the supply of carbohydrates translocated from leaves, fruit development greatly depends on the amount of leaves. Thus, in order to equalize fruit size, the amount of leaves per fruit is equalized by fruit thinning. In other words, the balance between the fruit and leaf is adjusted based on fruit thinning criterion. Therefore, the factors that affect fruit and leaf balance should be considered during the fruit thinning. Characteristics relevant to leaf are individual leaf weight, leaf area per leaf, leaf number, total leaf area and leaf area index (LAI) etc. Though LAI has been measured by special equipment (plant canopy analyzer), it can be determined using digital camera equipped with a fisheye lens and image processing free software [5]. Characteristics of fruit are fruit weight, fruit growth period, dry weight percent etc. As the sugar content increases when fruit size becomes large, more carbohydrates would be required. Thus, these characteristics should be considered in defining fruit thinning criterion. Several fruit thinning criteria are listed in Table 2.
Table 2: Overview of studies on fruit thinning criterion for Satsuma mandarin and citrus variety ‘Harumi’

| Citrus type | Criterion | Definition | Range         | References |
|-------------|-----------|------------|---------------|------------|
| Satsuma mandarin (Citrus unshiu Marc.) | Leaf and fruit ratio | Leaf number / fruit number | 20–30 | [6] |
| Satsuma mandarin (Citrus unshiu Marc.) | Leaf and fruit ratio | Leaf number / fruit number | 30–40 | [7] |
| Satsuma mandarin (Citrus unshiu Marc.) | Leaf and fruit ratio | Fruit number / leaf area (m²) | 0–25 | [8] |
| Satsuma mandarin (Citrus unshiu Marc.) | Leaf and fruit ratio | Leaf number / fruit number | 35 | |
| Satsuma mandarin (Citrus unshiu Marc.) | Leaf and fruit ratio | Leaf number / fruit number | 30, 60, 100, 300 | [9] |
| Satsuma mandarin (Citrus unshiu Marc.) | Indicator of fruit load | Fruit number / kg of dry leaves | 0–70 | [11] |
| Satsuma mandarin (Citrus unshiu Marc.) | Indicator of fruit load | Leaf number / fruit number | 40–60 | |
| Satsuma mandarin (Citrus unshiu Marc.) | Fruit load index (FLI) | Fruit number / 10000 leaves | 300–1100 | [12] |
| Satsuma mandarin (Citrus unshiu Marc.) | Fruit weight per leaf area | Fruit weight (kg) / leaf area (m²) | 0–2 | [13] |
| Harumi (Kiyomi × Ponkan) (Citrus reticulata Blanco) | Fruit and leaf ratio | Fruit set / 100 leaves | 0–4 | [14] |
| Harumi (Kiyomi × Ponkan) (Citrus reticulata Blanco) | Leaf and fruit ratio | Leaf number / fruit number | 120 | [15] |
| Harumi (Kiyomi × Ponkan) (Citrus reticulata Blanco) | Leaf and fruit ratio | Leaf number / fruit number | 100 | [16] |
| Harumi (Kiyomi × Ponkan) (Citrus reticulata Blanco) | Leaf and fruit ratio | Leaf number / fruit number | 100 | [17] |
| Harumi (Kiyomi × Ponkan) (Citrus reticulata Blanco) | Fruit number per canopy volume | Fruit number / cubic meter (m³) | 20–25 | [21] |

In order to clarify the appropriate range of fruit thinning criterion, the influence of leaf and fruit ratio (L/F) in number base on the yield, alternate bearing and carbohydrates content were investigated in Satsuma mandarin. Iwasaki [6] reported that the most desirable L/F ratio for the current year’s crop was 20–25 for medium maturing Satsuma mandarin. Nishida [7] suggested that maximum yield was obtained in ‘Sugiyama’ medium maturing Satsuma mandarin when L/F ratio was 20 and that the L/F ratio for the stable yield seemed to be 20 or more. Nishida [7] also found that fruit quality increased when nitrogen supply decreased, and L/F ratio was 30–40 in this treatment. It has been reported that alternate bearing was prevented in ‘Miyagawa-wase’ early maturing Satsuma mandarin when L/F ratio was set to 35 under the no plowing and less fertilization condition [8]. Carbohydrate content of leaves at harvest time and the blossom production in the following year was increased as the L/F ratio increased [9]. Though the leaf size of Satsuma mandarin varied depending on the strain, L/F ratio as a fruit thinning criterion is set to 25–30 for early ripening Satsuma mandarin and 20–25 for standard Satsuma mandarin [10]. Other definitions which indicate the balance of leaf and fruit have been reported in Satsuma mandarin. They are fruit number per leaf dry weight kg [11], fruit number per 10,000 leaves [12], fruit number per leaf area [8] and fruit weight kg per leaf area m² [13].

As observed in Satsuma mandarin, there was also negative correlation between fruit set per 100 leaves and the fruit size at harvest or the flower index in the following season in ‘Harumi’ [14]. In ‘Harumi’, ideal fruit weight and size are larger than those of Satsuma mandarin, while the leaf size is smaller than that of Satsuma mandarin. For these reason, L/F ratio in number is set to larger value in the fruit thinning of ‘Harumi’. Generally, L/F ratio in the fruit thinning of ‘Harumi’ is set to 100–120 [15, 16, 17]. This range of in L/F ratio is also used in fruit thinning of other late-ripening citruses such as ‘Shiranuhi’ and ‘Kiyomi’ [18, 19, 20].

Practically, experienced growers conduct fruit thinning by setting appropriate L/F ratio according to their experience and intuition. If beginners in citrus farming carry out fruit thinning with their intuition, excess or insufficient fruits may be thinned. Therefore, when the beginners use L/F ratio as the thinning criterion, the task of
counting fruits and leaves may be needed. Thus, assessment of L/F ratio has the problem described above and this makes production of fruit with ideal size difficult in citrus (Table 1).

2.2 Fruit thinning based on fruit number per canopy volume

Fruit number per canopy volume is also used as a fruit bearing standard in citruses. In ‘Harumi’, Fujiwara [21] reported that excess flowers were observed when fruit number per one cubic meter of canopy volume were set to less than 10 in the previous year and that flowers were insufficient if fruit number per canopy volume were set to more than 40 in the previous year. In their study, flower setting was stable and large number of fruits of the L and 2L was obtained when fruit number per one cubic meter of canopy volume was 20–25. In fruit thinning with fruit number per canopy volume, the amount of leaf per unit volume is supposed to be identical under different tree conditions. However, according to Iwasaki [22], leaf number per canopy volume decreases when canopy volume is more than 30 m³ in Satsuma mandarin. Another study indicated that yield per unit size of a tree increases until the 12 years old when the tree size is about 10 m³ in Satsuma mandarin [23]. Both results suggest that leaf density tends to decrease in accordance with the increase of canopy volume and that the relationship between leaf number and canopy volume is not linear. This implies that fruit thinning with fruit number per canopy volume is not available in all tree conditions. In addition to this problem, it takes time and effort to measure canopy volume and count fruit number per tree in this fruit thinning method.

2.3 Estimation of amount of leaf

In fruit thinning with the criterion mentioned above, counting leaf number or fruit number of a tree are laborious. Consequently, developing labor saving and objective thinning criterion are of great importance to control fruit number and to produce fruit with ideal size.

The relationship among tree organs have been studied by several researchers in fruit tree. Pearce [24] studied the relationship between trunk girth and tree weight using allometric relationship W=AGᵇ, (G; trunk girth, W; tree weight, A, b; constant). The relationship between trunk cross sectional area and tree weight or yield were analyzed in apple [25, 26]. In apple, branch diameter was used to draw tree structure [27] and productivity was evaluated with tree vigor balance defined as the ratio of branches to the main stem [28]. In citrus, Hirano [29] used allometry equation to estimate leaf area based on relative growth theory. Also, leaf area was estimated by branch diameter in ‘Harumi’ cultivar [30]. By using these techniques, the amount of leaf was estimated easily. Then fruit thinning criterion would be defined as characteristic of another organ such as branch diameter, resulting in that fruit thinning can be carried out without experience or counting leaves or fruits.

3. Storage and physiological disorders in citrus

Fruits of very early and shipped Satsuma mandarin are usually shipped soon after harvest without storage. On the other hand, in some citrus varieties, such as medium maturing Satsuma mandarin or late maturing citruses, fruits need to be stored until its moderate shipping time because fruit quality at harvest isn’t suitable for shipping. In ‘Harumi’, though the maturation time is in January, fruit are harvested in December to avoid the occurrence of physiological disorders or cold injury [31]. When fruits of ‘Harumi’ are harvested earlier than the moderate time, the citric acid concentration in the juice is relatively high for marketing. Thus, fruits need to be stored until citric acid concentration decreases in the consumer’s limit. However, decay, weight loss and physiological disorders are often observed during storage.
To extend storage period, relationships between storage ability and temperature conditions or maturation stage have been studied in citrus. When fruits were pretreated at 20 °C, then duration period was shorter, fruit weight loss and the degree of decay at the later stage was less, peel color turned to deeper orange and respiration rate during storage was lower than those pretreated at 10 °C in Satsuma mandarin [32]. Matsumoto [33] found that the content of β-cryptoxanthin continued to increase following 15 days of storage in fruit harvested when β-cryptoxanthin was still being accumulated in ‘Aoshima’ Satsuma mandarin. Fruit of ‘Shiranuhi’ stored at 12 °C with MA packing showed superior rind and flesh color and eating quality. No incidence of decay and few rind oil-spots and calyx dies was observed in the long-term storage [34].

Physiological disorders of peel, flesh and whole fruit occur during the fruit growth and storage. Sunscald (sunburn) of fruit occurred in August and September under exposure to intense sunlight in ‘Setoka’ [35]. Rind color degradation was induced by exposure to sunlight in ‘Setoka’ and was prevented by fruit bagging [35, 36]. Rind color degradation in ‘Reikou’, ‘Amakusa’, ‘Nankou’, ‘Tsunonozomi’ and ‘Miho-core’ was also prevented by black, green and pink bagging [36]. Fruit suffered from these disorders have no influence on storage ability because they are rotten and drop or removed by thinning and selection before storage.

Physiological disorders which occur in mature fruit before harvest can influence storage ability. Physiological disorders of citrus during maturation or storage are listed in Table 3. In some overripened fruit, cracking of the peel was observed around calyx or surface of the peel in some specific cultivars [37]. Raindrops stayed within the cracking and this resulted in water rot (decay) before shipping. The occurrence of water rot can be prevented by GA spray (0.5 ppm for Ponkan and 0.5–1 ppm for Beni-Madonna) before harvest [38]. Fruit quality and the occurrence of physiological disorders were influenced by storing conditions. The occurrence of rind oil spots of Navel orange was low at high pretreatment temperature (20 °C). On the other hand, it was high at high storing temperature (9 °C) in Hassaku [39]. The number of decayed fruits of ‘Yoshida’ Navel orange increased during storage as the temperature increased. The rind oil spots of Hassaku and ‘Yoshida’ Navel orange were observed at the higher storage temperature than the room temperature [40]. In some cultivars, occurrence of physiological disorders was influenced by fruit size. For example, in ‘Harumi’, large weight loss, peel wrinkle or collapse of juice sack were problems in small fruit [41]. While rind puffing and granulation of juice sac were a problem in large fruits [3, 41] (Fig. 4). Thus, the storing conditions should be adjusted according to the disorder type.

Figure 4: Reaction of ‘Harumi’ fruit to water loss during storage. After the storage without PE-wrapping, peel wrinkle (A), rind puffing (B) and granulation of juice sac (C) were observed [41].
Table 3: Overview of studies on physiological disorders in citrus fruit during maturation or storage

| Physiological disorder | Feature | Citrus type | Cause | References |
|------------------------|---------|-------------|-------|------------|
| Rind oil spot          | Collapse and browning of oil gland | Kawano Natsudaidai, Miyachi Iyo, Yosaka Navel orange | Non-seal-packing of PE | [40] |
| Peel wrinkle           | Occurrence of peel wrinkle | Satsuma mandarin, Harumi, Shiranuhi etc. | Fruit drying | [41][45] |
| Rind puffing           | Occurrence of space between peel and flesh | Easy peeling citrus | High humidity | [41][45][46][47][48][49] |
| Granulation            | Thickness, dehydration, whitening of juice sack | Sanbokan, Natsudaidai | Overripening | [3][42][51][57] |
| Shrinkage and Gelation | Dehydration and gelation of juice sac | Ponkan | Drought | [42] |
| Dehydration of juice sack | Shrinkage and yellowing of juice sack | Ponkan, Setoka | Unclear | [42][45] |
| Dry juice sac          | Collapse and dehydration of juice sack | Citrus species | Freezing | [42][52][53][54][55][56] |
| Degradation of flesh   | Collapse of juice sack structure | Harumi | Fruit drying | [41] |

Since 1990’s, new citrus varieties were developed and released and some of them used ‘Kiyomi’ or Ponkan as parents. Sometimes, rind oil spots occur in ‘Kiyomi’ and water rot in Ponkan after harvest. Ponkan is also susceptible to shrinkage and dehydration of juice sac in the early stage of fruit growth and granulation after maturation [42]. Both ‘Harumi’ (Kiyomi × Ponkan ‘F-2432’) and ‘Shiranuhi’ (Kiyomi × Ponkan ‘Nakano no.3’) are the descendant of ‘Kiyomi’ and Ponkan [2, 43]. In both cultivars water rot at harvest is a big problem and GA spray (0.5–1 ppm) before harvest is conducted to prevent water rot [38]. Rind puffing is a big problem in ‘Harumi’, but not in ‘Shiranuhi’. In the next section, studies on physiological disorders during storage and the effects of PE wrapping on physiological disorders are summarized.

3.1 Rind puffing

Citrus are classified into tight-skin and easy-peeling (loose skin) type according to the easiness of peeling. Natsudaidai, Hassaku, Navel orange, ‘Shiranuhi’, and ‘Setoka’ belong to tight-skin type. For easy-peeling citrus such as Satsuma mandarin, Ponkan, Iyo and ‘Harumi’, rind puffing is a big problem [44, 45]. Rind puffing is characterized by the increment of inner-fruit space. The increase of space between peel and flesh causes the decrease of specific gravity of fruit and the occurrence of rind puffing [46]. The fruits suffered from this disorder are easily injured by physical shock during harvest and shipping and the cracking of the peel causes decay [44]. Rind puffing was induced by high humidity during fruit maturation [46, 47, 48] and storage [45]. Rind puffing of Satsuma mandarin can be prevented by spraying chemicals which are registered according to the agricultural chemicals regulation law. Some of them are Ca type such as CaCO3 (0.95 %, 0.455–0.91 %), or CaCl2 (0.09 %) + CaSO4·2H2O (0.19 %) [38]. The spray of ethychlozate (67–100 ppm) or combined spray of GA (1–5 ppm) and prohydrojasmon (25–50 ppm) are registered and used for preventing rind puffing of Satsuma mandarin [38, 49, 50]. Easy-peeling citrus ‘Harumi’ has a wide range of fruit size, and in large fruit, specific gravity was low and rind puffing was a
problem [3, 41]. These results suggest that keeping fruit with high specific gravity is the key to prevent the occurrence of rind puffing.

3.2 Dehydration and granulation of juice sac

Dehydration of flesh is classified into four types [42]. The first is granulation of juice sacs which occurs in Sanbokan, Natsudaidai and many late maturing varieties before harvest. This disorder is characterized by thickening and whitening of juice sack [42, 51]. Granulation was also observed in large fruit of ‘Harumi’ [3].

The second is shrinkage and gelation of juice sacs of Ponkan in the early stage of fruit development [42].

The third is dehydration of juice sack in Ponkan [42], ‘Setoka’ [45] and ‘Harumi’ [41]. Dehydration of flesh is distinguishable from granulation by the lack of thickening and whitening of juice sack, but the mechanism is unclear [42]. Larger fruits of ‘Harumi’ showed low specific gravity (SG) and high degree of dehydration of flesh [41].

The fourth is the dry juice sac caused by freezing which is called cold injury [42]. In 1970’s, cold wave attacked citrus producing area in the western part of Japan. Dehydration of middle or late maturing citrus was induced by low temperature in Natsudaidai, Fukuharo orange and Sanbokan [39]. After fruit froze, dry juice sac or bitterness of juice occurred during storage in late maturing citrus such as Natsudaidai, Hassaku and sweet orange. The mechanism and conditions of cold injury were clarified [52, 53, 55, 56]. After fruit froze, large cavity appeared in the inside of flesh segment and the structure of juice sack were destroyed [52]. The decrease of specific gravity was observed corresponding to the degree of dehydration caused by freezing, and fruit storage at lower temperature soon after frost damage showed slight occurrence of dry juice sack [55].

3.3 Influences of PE wrapping on the occurrence of physiological disorders

After harvest, fruit is deprived of water rapidly by evaporation or transpiration [39]. Fruit weight decreased gradually if fruits were placed at high temperature and low humidity. Generally, PE wrapping keeps fruit in high humidity and consequently prevents fruit weight loss [39, 40]. The water loss induced different responses in fruit. In ‘Shiranuhi’, large weight loss and peel wrinkle were observed during storage. These phenomena were prevented by PE wrapping in ‘Shiranuhi’ [45] and indicate that the occurrence of peel wrinkle is induced by water loss in peel. The dehydration of juice sac of ‘Setoka’ occurred in non-wrapped storage but was prevented by PE wrapping. Thus, it was indicated that dehydration of flesh was caused by water loss in flesh [45]. In ‘Harumi’, small fruit showed peel wrinkle during storage, similar characteristic to ‘Shiranuhi’, and PE wrapping was effective to decrease fruit weight loss. Large fruit of ‘Harumi’ had the trait of ‘Setoka’ and suffered from dehydration of juice sac, and PE wrapping weakened the decrease of specific gravity during storage until March [41]. Rind oil spots of fruits occurred in the non-packed fruits but not in fruits packed with PE film in ‘Kawano’ Natsudaidai and ‘Miyauchi’ Iyo [40]. On the other hand, PE wrapping induced fruit decay of ‘Kawano’ Natsudaidai, ‘Miyauchi’ Iyo [36] and ‘Shiranuhi’ [45]. In tight skin type of citrus, the adaptability of PE wrapping was judged considering the degree of decay, rind oil spots and weight loss in each citrus. Rind puffing [45] and granulation [57] of easy peeling citrus was induced by PE wrapping. Thus, generally, PE wrapping is not recommended for easy peeling citrus. However, since peel wrinkle and dehydration were suppressed by PE wrapping in some cultivars as mentioned above, details of the effect of PE wrapping needs to be clarified and the technique to decrease the demerit is required to keep fruit quality high in easy-peeling citrus varieties.
4. Conclusions

Many new citrus varieties were released since 1970’s and the production of these varieties increased in the 21st century. In citrus, fruit size greatly affects fruit quality and storage ability. Thus, controlling fruit size and producing fruit of moderate and equalized size by fruit thinning is very important. Whereas, the present fruit thinning criteria for citrus needs laborious tasks. Few studies on the easy and objective fruit thinning criterion, which can be available to different tree conditions, have been reported. In addition, physiological disorders in peel or flesh during storage are unveiled and the favorable storing condition have not been clarified for easy-peeling citrus yet. Since producing fruit with moderate size and keeping them in high quality during storage are crucial for supplying high quality fruit, it is of great importance to develop an easily available thinning criterion and improve storing condition of citrus fruit.

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