A THESIS FOR THE DEGREE OF MASTER OF SCIENCE

Evaluation of Fruit Developmental Characteristics of Kiwifruit Cultivars Growing in Jeju Region

제주지역에서 재배되고 있는 참다래 품종의 과실발육 특성 평가

Pichit Luanghiran

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(Supervised by Professor **Kwan Jeong Song**, PhD)

Submitted in partial fulfillment of the requirements for the degree of Master of Science in Agriculture

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CONTENTS

ABSTRACT

Kiwifruit cultivation in Jeju region, is an emerging sector, identified to be developed further in order to expand the production and maintain the competitiveness. The present study was conducted to evaluate the fruit developmental characteristics and phenological growth stages of selected kiwifruit cultivars in detail. Three cultivars, 'Sweet Gold', 'Goldone', and 'Halla Gold' for yellow-fleshed type and one cultivar, 'Garmrok' for green-fleshed type trained to pergola system in plastic house in Jeju region were used in this study. Fruit size (length and diameter), fruit weight, dry matter, total soluble solids, acidity, and starch and sugars (fructose, glucose, sucrose, and *myo*-inositol) concentration were measured from anthesis to harvest. Some phenological growth stages were recorded based on the BBCH scale. Fruit size showed a rapid increase followed by gradual increase and then reached stable. Fruit weight of all four kiwifruit cultivars increased in a double-sigmoid curve pattern. Dry matter showed a continuous increase to full maturation stage. Starch concentration of four kiwifruit cultivars showed a gradual increase first and then decreased. In contrast, sugar concentrations started to increase as starch starts to decrease. Harvesting stage identified as BBCH stage 83 for 'Sweet Gold' and 'Hall Gold' was reached at 160 Days after anthesis (DAA) and that of 'Goldone' and 'Garmrok' was reached at 140-160 DAA.

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INTRODUCTION

The kiwifruit originated in China and belong to the genus *Actinidia* which is composed of over 50 species (Ferguson, 1999). All *Actinidia* species are perennial climbing or straggling plants. The fruit is a berry with many seeds in soft juicy flesh. Many other attributes differ between species (Ferguson, 1990).

Actinidia deliciosa cv. 'Hayward' is a green-fleshed type which are famous in the world market. Initially, *A. chinensis* Planch, a yellow-fleshed type, was classified together with *A. deliciosa*, but they were eventually separated because their fruit features are distinctly different, particularly in terms of flesh color and hairiness. *A. chinensis* was selected for cultivation in China and then spreaded out to Japan, Italy, New Zealand, and the US. Subsequently, *A. chinensis* 'Hort16A', a yellow-fleshed type, was successfully registered in New Zealand and proved it is viable in commercial market (Ferguson, 1999). Kiwifruit was introduced to Korea in 1970s. The 'Hayward' was the main cultivar and followed by 'Hort16A' in early days of kiwifruit cultivation (Park, 2009). Presently, consumers are interested in yellow-fleshed kiwifruit, particularly 'Hort16A' because of their sweetness and colour (Kwack et al., 2017). However, some farmers do not cultivate 'Hort16A' and they prefer to grow other yellow-fleshed cultivars bred by Korean researchers. Thus, to improve competitiveness of Korean kiwifruit industry, a replanting by new cultivars with high fruit quality has been a necessity. The 'Sweet Gold' is a new kiwifruit cultivar recently released by the Research Institute of Climate Change and Agriculture, National

Institute of Horticultural and Herbal Science (NIHHS), Rural Development Administration (RDA). Further, RDA breeding team in 2011 released another cultivar called ‘Goldone’ (Kwack et al., 2016). In 2013, a green-fleshed type cultivar ‘Garmrok’ was selected from a crossing between NHK0042 and NHK0041 of *A. deliciosa* by NIHHS. Also, ‘Halla Gold’ developed by NIHHS, RDA, in 2007, is still popular and being cultivated extensively in the Jeju region (Kim et al., 2012).

Many researchers have studied the development and fruit characteristics of kiwifruits. Woodward and Clearwater (2008) focused on the relationships between fruit weight and dry matter content of ‘Hayward’ kiwifruit. Burdon et al., (2016) studied fruit maturation and the soluble solids of ‘Hayward’ kiwifruit. Hopping (1976) reported a double-sigmoid curve for the development of *A. chinensis* kiwifruit and he identified three fruit development stages based on increase in fresh weight. The fruit development of *A. chinensis* ‘Hort16A’ had already been described by Richardson et al. (2011) with details from anthesis to fruit maturity based on the Biologische Bundesantalt, Bundessortenamt und Chemische Industrie (BBCH) scale and produced a sigmoidal growth curve. The BBCH scale uses a two-digit code scale to describe the growth stages in plant crops and weeds (Lancashire et al., 1991).

In addition to fruit developmental characteristics, characterization of phenological stages are essential to achieve high fruit quality and fruit weight, since management practices (pruning, application of bioregulators, fertilizers, pesticides, pollination, flower and fruit thinning, and harvest time, etc.) rely on

the recognition of certain phenological stages (Salinero et al., 2009). Phenological growth stages of several plant species have been studied and described according to the BBCH scale in *Litchi chinensis* Sonn. (Wei et al., 2013), *Persea Americana* Mill. (Alcaraz et al., 2013), *Annona squamosa* L. (Liu et al., 2014), *Hylocereus undatus* (Kishore, 2016), and *A. deliciosa* 'Hayward' kiwifruit (Salinero et al., 2009). Furthermore Richardson et al. (2011) studied the development of *A. chinensis* 'Hort16A' and related it to the BBCH scale stage 65 (fully open flower) to stage 92 (senescence).

However, four kiwifruit cultivars namely, 'Sweet Gold', 'Goldone', 'Garmrok', and 'Halla Gold' that were bred in Korea have not yet been clearly detailed with the assessment of fruit growth and development or the phenological growth stages. Hence, the objective of this particular study was to evaluate fruit developmental characteristics with some phenological growth stages based on the BBCH scale of four kiwifruit cultivars.

MATERIALS AND METHODS

1. Plant Materials

This study was conducted using four kiwifruit cultivars ‘Sweet Gold’, ‘Goldone’, ‘Garmrok’, and ‘Halla Gold’ which are trained to pergola system in non-heated plastic houses. These were cultivated in the Jeju region where seasonal kiwifruit flowering generally starts in early May and harvest in late October - November. The vines were managed based on standardized horticultural practices of the commercial orchard.

2. Fruit Assessment

Thirty fruits per cultivar (10 fruits/vine × 3 vines) were tagged and fruit size was measured. Randomly selected 9 fruits (3 fruits/vine × 3 vines) per cultivar were used for assessment of fruit characteristics. Fruits were measured from 30 days after anthesis (DAA) to harvest with 30 days interval during early growth stage, 20 days interval during late growth and early maturity stages and 10 days interval during late maturity stage. Total soluble solids (TSS) and the acidity were measured for fruit juice using a Brix-acidity meter (GMK-707R, G-won Hitech co., Ltd., Seoul, Korea). Fruit firmness was measured using a fruit hardness tester 5 kg with ø5 mm plunger (510-5 FHR-5, Japan). Fresh weight of harvested fruits was measured using a digital balance. Dry weight was

determined by oven dry method using 2-3 mm. thick transverse slices obtained from the middle part of the fruit (Burdon et al., 2016). Percentage of dry matter (DM) was calculated using the equation “DM = dry weight/fresh weight × 100” (Richardson et al., 2011). Thereafter, fruit samples were stored at -60°C.

3. Carbohydrates Measurement in Fruit

Analysis of starch and sugar concentrations were done using the methods described by Witchaya et al. (2015). Briefly, fruit samples were freeze dried at -80°C and homogenized using a blender and then stored at -60°C in powdered form before extraction. One gram of powdered sample was shaken with 10 mL, 80% ethanol for 30 min at room temperatures and then centrifuged at 10,000 rpm and 4°C for 10 min. The supernatant was filtered through 8 µm filter paper (Tokyo Roshi Kaisha, Tokyo, Japan) and kept in conical tubes. Extraction was repeated one more time using the residues. The supernatants were mixed and evaporated to dryness using rotary evaporator and re-suspended in double-distilled water (DDW). Then re-suspended samples were filtered through C18 Sep-Pak cartridge (Waters, USA) and 0.2 µm syringe filter. Sugar concentrations (fructose, glucose, sucrose, and *myo*-inositol) were analysed using high-performance liquid chromatography, HPLC (RID10A detector, Shimadzu, Japan) with carbohydrate column (5 µm, 250 × 4.6 nm). Mobile phase was 75% (v/v) acetonitrile:DDW. The residues from two extractions were used for analysis of starch concentrations by the colorimetric method as described by Magel (1991).

4. Statistical Analysis

Data was analysed by Minitab 16 software. Descriptive statistics were performed to calculate mean, standard deviation and standard error. Comparison of two years data was done using independent two samples t-test ($P \leq 0.05$).

RESULTS AND DISCUSSION

1. Scale of Phenological Growth stage.

Fruit development stages of different cultivars of kiwifruits were photographed individually and periodically. Some phenological growth stages of individual cultivars were coded based on the BBCH scale referring to Salinero et al., 2009 (Fig. 1-4). Table 1 shows BBCH stage description of kiwifruit cultivars. In line with Richardson et al. (2011), we assigned 0 DAA as stage 65. According to BBCH stage 69-70 fruit set is visible for ‘Sweet Gold’ and ‘Halla Gold’ on 11 DAA this was observed in ‘Goldone’ and ‘Garmrok’ on 8 and 4 DAA respectively. Stage 71 to 79 is the stage of fruit enlargement. Next, the BBCH stage 83 for ‘Sweet Gold’ and ‘Hall Gold’ was reached at 160 DAA and that of ‘Goldone’ and ‘Garmrok’ was reached at 140-160 DAA. Stage 87 (Start of flesh softening) in ‘Sweet Gold’ and ‘Garmrok’ reached at 170 DAA, ‘Halla Gold’ reached at 180 DAA, but that of ‘Goldone’ was unclear to determine.

Fig. 1. Phenological growth stages from stage 5 (inflorescence emergence) to stage 8 (fruit maturity) of ‘Sweet Gold’ kiwifruit.

53 69 (8 DAA) 71 (25 DAA)

78 (120 DAA) 83 (140-160 DAA)

Fig. 2. Phenological growth stages from stage 5 (inflorescence emergence) to stage 8 (fruit maturity) of ‘Goldone’ kiwifruit.

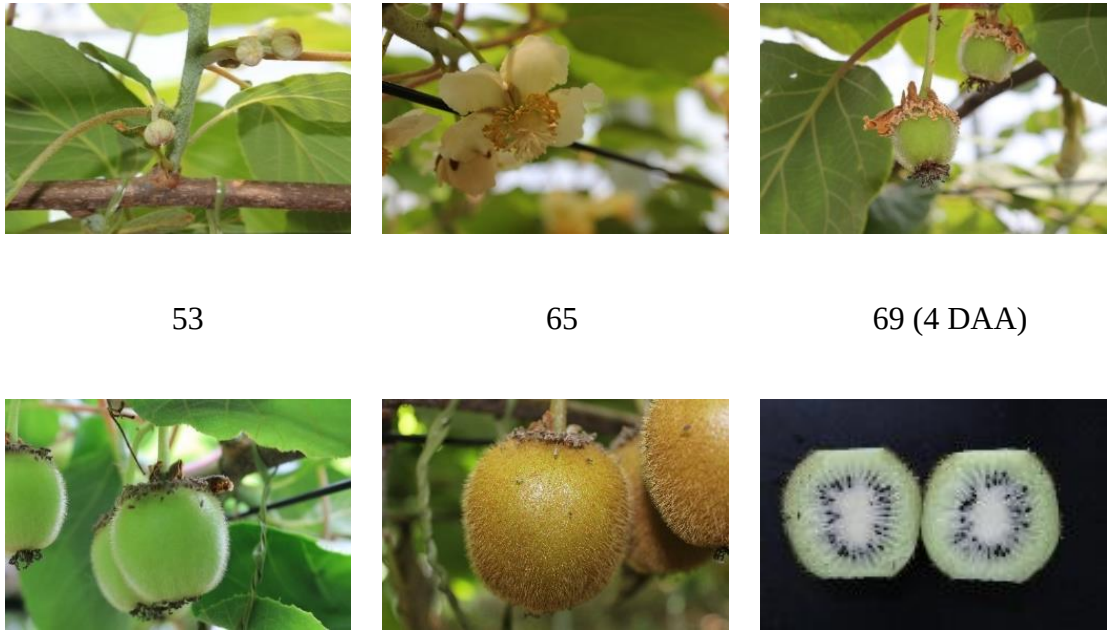
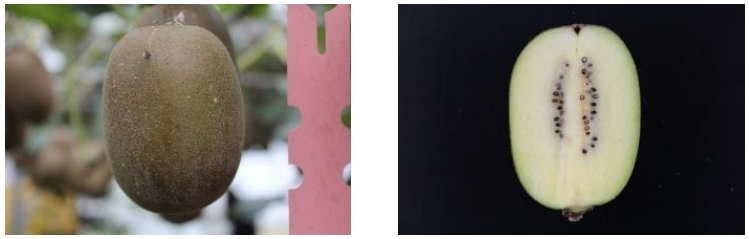


Fig. 3. Phenological growth stages from stage 5 (inflorescence emergence) to stage 8 (fruit maturity) of ‘Garmrok’ kiwifruit.

53 69 (11 DAA) 71 (25 DAA)



78-79 (150 DAA) 83 (160 DAA)

Fig. 4. Phenological growth stages from stage 5 (inflorescence emergence) to stage 8 (fruit maturity) of ‘Halla Gold’ kiwifruit.

Table 1. The BBCH growth stages of four kiwifruit cultivars.

BBCH stage	Description	Days after anthesis (DAA)			
		'Sweet Gold'	'Goldone'	'Garmrok'	'Halla Gold'
65	Fully open flower	0	0	0	0
69-70	Fruit set visible	11	8	4	11
76	60% of final fruit weight			100	
78-79	80-90% of final fruit weight	140-150	120		150
83	**Start of rapid in crease in sugar contents**	**160**	**140-160**	**140-160**	**160**
84	Maximum starch	170-180	140-160	140-160	160-180
87	Start of flesh softening	170		170	180

2. Fruit Developmental Characteristics

Increase in fruit weight during different fruit developmental stages of ‘Sweet Gold’ showed a double sigmoid curve (Fig. 5-6). This curve was similar to Hopping’s (1976) double sigmoid curve obtained for growth of *A. chinensis*. The fruit weight at 190 DAA was 128.23 ± 5.41 g in 2015 and 126.45 ± 4.69 g in 2016 (Table 2) and they did not differ significantly (P = 0.807). In both trials of 2015 and 2016, fruit size (length and diameter) has produced a similar pattern curve (a tri-phasic growth curve), where a rapid increase until 80 DAA followed by gradual increase and then stable. Theses observations were similar to the observation of ‘Mitsuko’ kiwifruit made by Kim et al., (2006). The size were recorded at 190 DAA, fruit length was 74.78 ± 0.70 mm in 2015 and 74.22 ± 1.10 mm in 2016 and fruit diameter was 49.49 ± 0.38 mm in 2015 and 50.83 ± 0.68 mm in 2016 (Table 2) and they did not differ significantly (P = 0.670 and 0.090, respectively). DM in 2016 (19.97 ± 0.37) was significantly higher than DM in 2015 (17.33 ± 0.42) (Table 2). But the pattern of change in DM in 2015 and 2016 were similar. The trend in change of TSS content, firmness, and acidity in the late maturity stage also showed a similar pattern in both years considered. Whereas, TSS content showed an increasing trend while firmness and acidity showed a decreasing trend. These results satisfied the general phenomena of parameters change in any fruit ripening. Even though, ‘Sweet Gold’ showed the same pattern of increase in TSS content compared to *A. chinensis* ‘Hort16A’, it took only 200 DAA to reach maximum TSS content. Whereas, ‘Hort16A’ took 250 DAA to reach the maximum value (Richardson et al., 2011). In addition,

Fig. 7 shows pattern curves of average data gathered in two different years to confirm the above description of all parameters including photographs with the BBCH scale.

The growth curve of developing ‘Goldone’, as measured by increasing fruit weight and DM were a double-sigmoid (Fig. 8) and they were similar to ‘Sweet Gold’ and Hopping’s (1976) observation for *A. chinensis*. Moreover, they had described the growth curve into three stages: Firstly, a rapidly increasing phase (stage I), followed by a period of slow growth (stage II) and another period of rapid growth until fruit maturity (stage III). Fruit weight at 170 DAA was 173.26 ± 6.81 g in ‘Goldone’ which became heavier and fully sized earlier than ‘Sweet Gold’. Fruit weight of ‘Goldone’ in this study differed from Kwack et al., (2016) finding where he recorded 129 g as fruit weight at 170 DAA for the fruits grown in the period of 2003-2006 under conventional field breeding orchard in Namhae region. Fruit size (length and diameter) had a similar curve compared to ‘Sweet Gold’. It represented a rapid increase until 60 DAA and followed by gradual increase and then stable. Fruit size of ‘Goldone’ at 170 DAA was 67.93 ± 1.72 mm in length and 60.69 ± 1.48 mm in diameter (Table 2). ‘Goldone’ is a tetraploid plant that produces oblong-shaped fruit (Fig. 2) and phenotype include sparse downy hairs and yellowish outer pericarp when ripe (Kwack et al., 2016). At 170 DAA, DM was recorded as 16.75 ± 0.34, TSS as 11.7 ± 0.2 °Brix (Table 2), firmness as 2.4 kgf and the acidity as 1.6% (data not shown).

Pattern of fruit weight and DM increase of ‘Garmrok’ (Fig. 9) was also similar to that of ‘Goldone’ and ‘Sweet Gold’. The time taken to reach the maximum fruit weight was shorter than ‘Sweet Gold’ with final fruit weight was recorded as 109.47 ± 4.59 g at 180 DAA which was equal to previously reported fruit weight by NIHHS in 2013. Fruit size (length and diameter) pattern of ‘Garmrok’ showed a similar pattern in both ‘Sweet gold’ and ‘Goldone’ and having maximum value of 58.42 ± 1.52 mm and 55.51 ± 1.07 mm for length and diameter respectively (Table 2). The increasing of DM was likely to ‘Goldone’, which reached as 18.30 ± 1.03 at 180 DAA (Table 2). TSS content of ‘Garmrok’ had 10.09 ± 1.22 °Brix at 180 DAA while the firmness was showing a decreasing trend during late maturity stage (Fig. 9).

‘Halla Gold’ (Fig. 10-11) showed a double-sigmoid growth curve in both years. Increase of fruit weight was similar to that of ‘Sweet Gold’. However, ‘Halla Gold’ was a selection from Jeju Island and is being cultivated since 2003 in Jeju region (Kim et al., 2012). Fruit weight was recorded at 190 DAA as 136.38 ± 5.01 g in 2015 and 145.14 ± 4.04 g in 2016 and they did not differ significantly (P = 0.194). Kim et al., (2012) reported average fruit weight as 106.3 g that was lower than value obtained in this study. This difference might be due to differences in horticultural practices. Fruit size (length and diameter) recorded at 190 DAA also showed a same pattern curve compared to other cultivars with 74.32 ± 1.01 mm length and 53.68 ± 0.56 mm diameter in 2015 and 74.89 ± 0.56 mm length and 54.02 ± 0.59 mm diameter in 2016 (Table 2) and they did not differ significantly (P = 0.621 and 0.668, respectively). DM of

‘Halla Gold’ showed an increasing pattern as same as in ‘Sweet Gold’ and recorded value for DM at 190 DAA was 15.04 ± 0.45 in 2015 and 13.86 ± 0.17 in 2016 (Table 2), differences among DM of 2015 and 2016 was siginificant (*P* = 0.033). TSS content showed an increasing pattern as same in both years. TSS was recorded at 190 DAA as 10.18 ± 0.47 °Brix in 2015 and 11.04 ± 0.32 °Brix in 2016 (Table 2) and they did not differ significantly (*P* = 0.148). Though, a continuous decreasing trend from a higher value was expected for acidity and firmness, in this experiment (2015 data), initial values of those two parameters were lower than subsequent values (Fig. 10). This unusual observation might be due to human errors. Whereas in 2016, they were gradually decreasing and then stable during fruit maturation stage (Fig. 11). Fig. 12 shows pattern curves of average data gathered in two different years to confirm the above description of all parameters including photographs with the BBCH scale. Moreover, Kim et al., (2012) also recommended ‘Halla Gold’ for cultivating in Jeju region and presently this cultivar is being planted extensively.

Knowledge of the BBCH scale can be useful to understand the plant growth in many plant species. In sweet cherry, Fadon et al. (2015) studied phenological stages and connected flower development with external phenology. Apart from fruit agronomic studies, the adoption of BBCH is also useful in climates change studies and cultivars studies with different conditions (Leather, 2010). Moreover, the description of BBCH scale will not only act as a tool for standardization of phenological stages but also for various horticultural practices such as pest management, irrigation system and scheduling, nutrient and plant

regulator treatments, flower and fruit management and harvest planning. For kiwifruit production, fruit thinning is one of important procedure because lateral flowers can be grow up to fruit, but their fruit were always small and very low commercial value (Antognozzi et al., 1991). Therefore, completion of flower and fruit thinning in appropriate time are very advantageous.

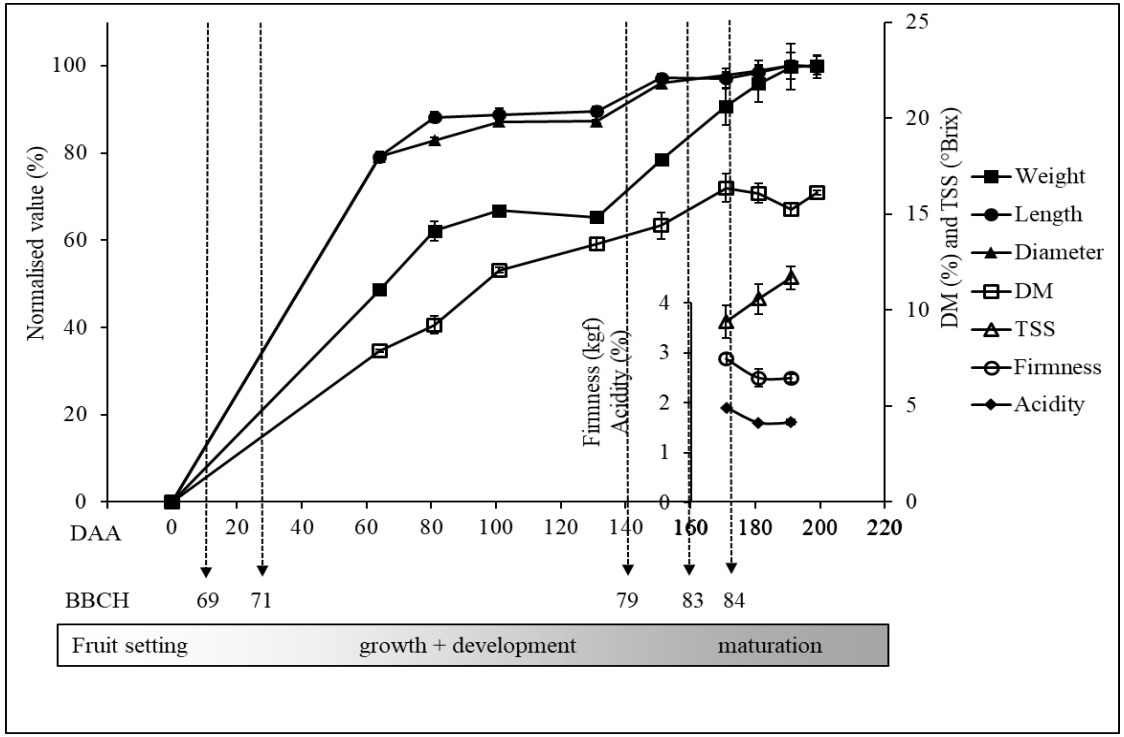


Fig. 5. Changes in fruit chracteristics of 'Sweet Gold' kiwifruit from 0 DAA to fruit maturation stage in the year 2015.

Data have been scaled to 100 arbitrary units based on maximum values. Based on fruit size (length and diameter), fruit weight, dry matter (DM), total soluble solids (TSS), acidity and firmness, the BBCH scale has been aligned.

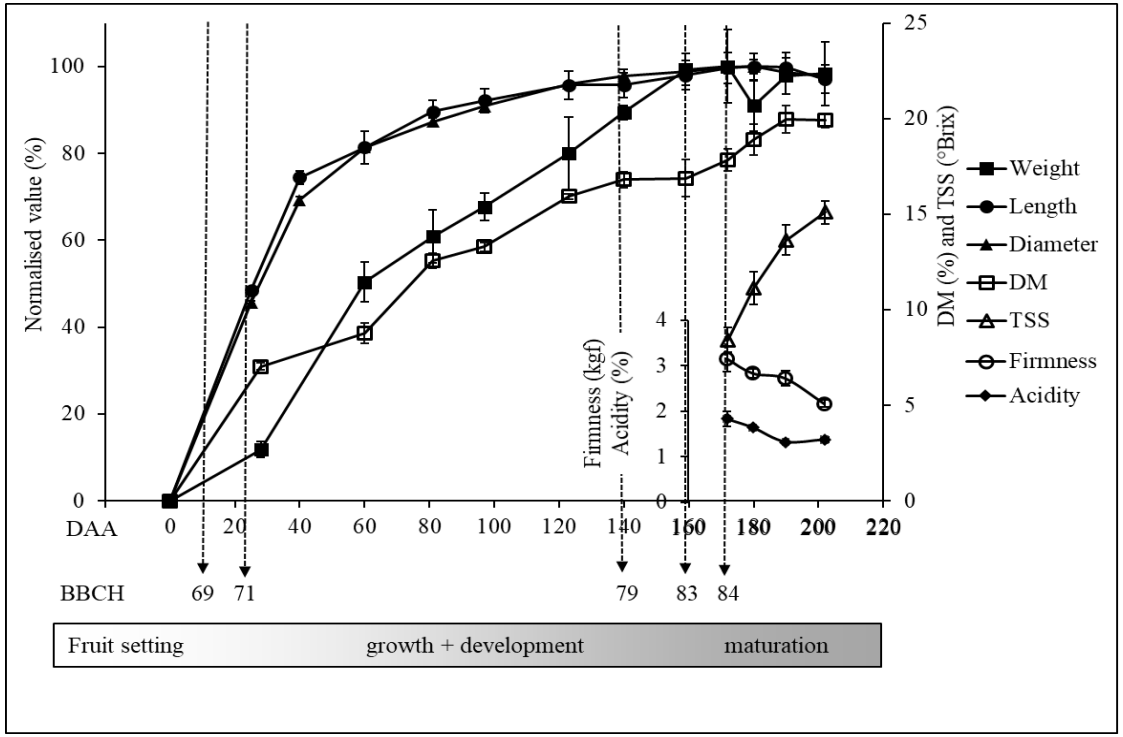


Fig. 6. Changes in fruit chracteristics of 'Sweet Gold' kiwifruit from 0 DAA to fruit maturation stage in the year 2016.

Data have been scaled to 100 arbitrary units based on maximum values. Based on fruit size (length and diameter), fruit weight, dry matter (DM), total soluble solids (TSS), acidity and firmness, the BBCH scale has been aligned.

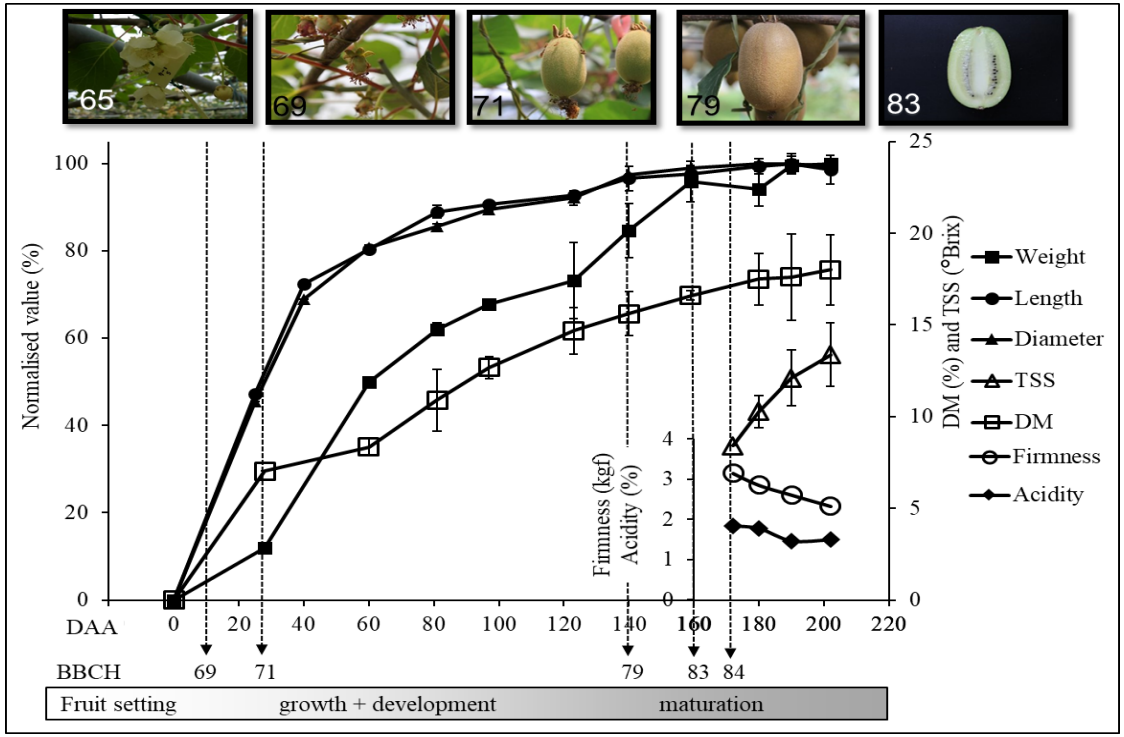


Fig. 7. Changes in fruit chracteristics of 'Sweet Gold' kiwifruit from 0 DAA to fruit maturation stage (average of 2015 and 2016 data).

Data have been scaled to 100 arbitrary units based on maximum values. Based on fruit size (length and diameter), fruit weight, dry matter (DM), total soluble solids (TSS), acidity and firmness, the BBCH scale has been aligned. Photographs of fruit in different stages with the BBCH scale were on the top.

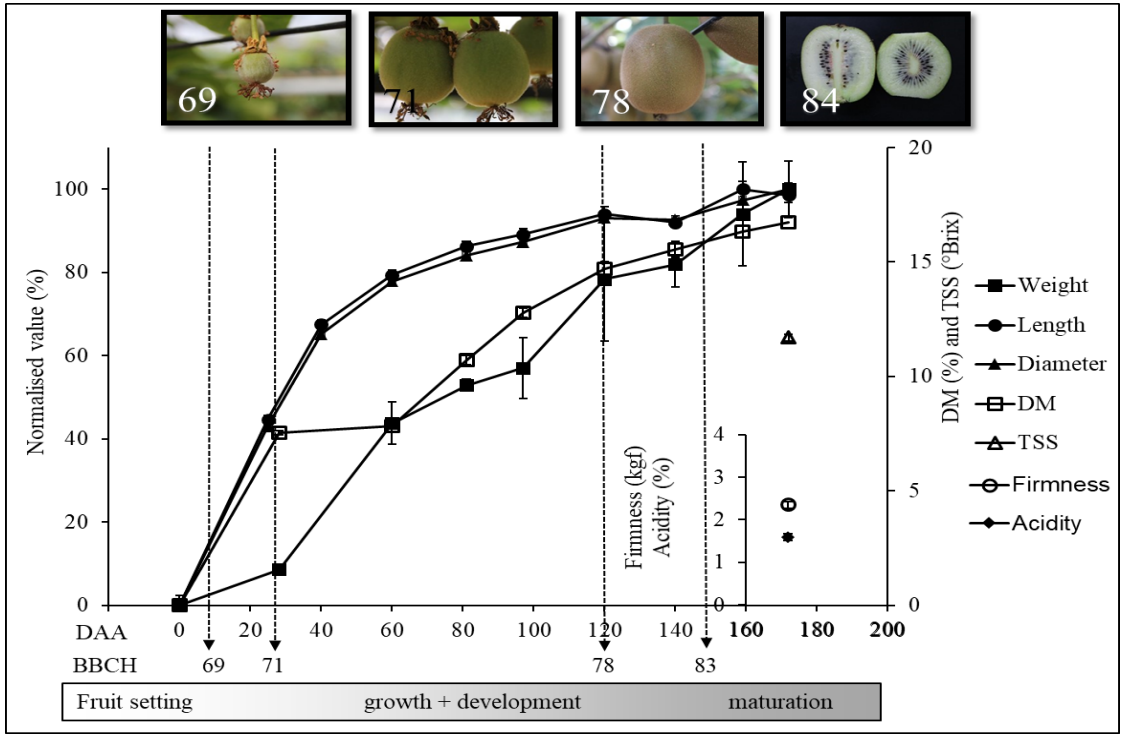


Fig. 8. Changes in fruit chracteristics of 'Goldone' kiwifruit from 0 DAA to fruit maturation stage in the year 2016.

Data have been scaled to 100 arbitrary units based on maximum values. Based on fruit size (length and diameter), fruit weight, dry matter (DM), total soluble solids (TSS), acidity and firmness, the BBCH scale has been aligned. Photographs of fruit in different stages with the BBCH scale were on the top.

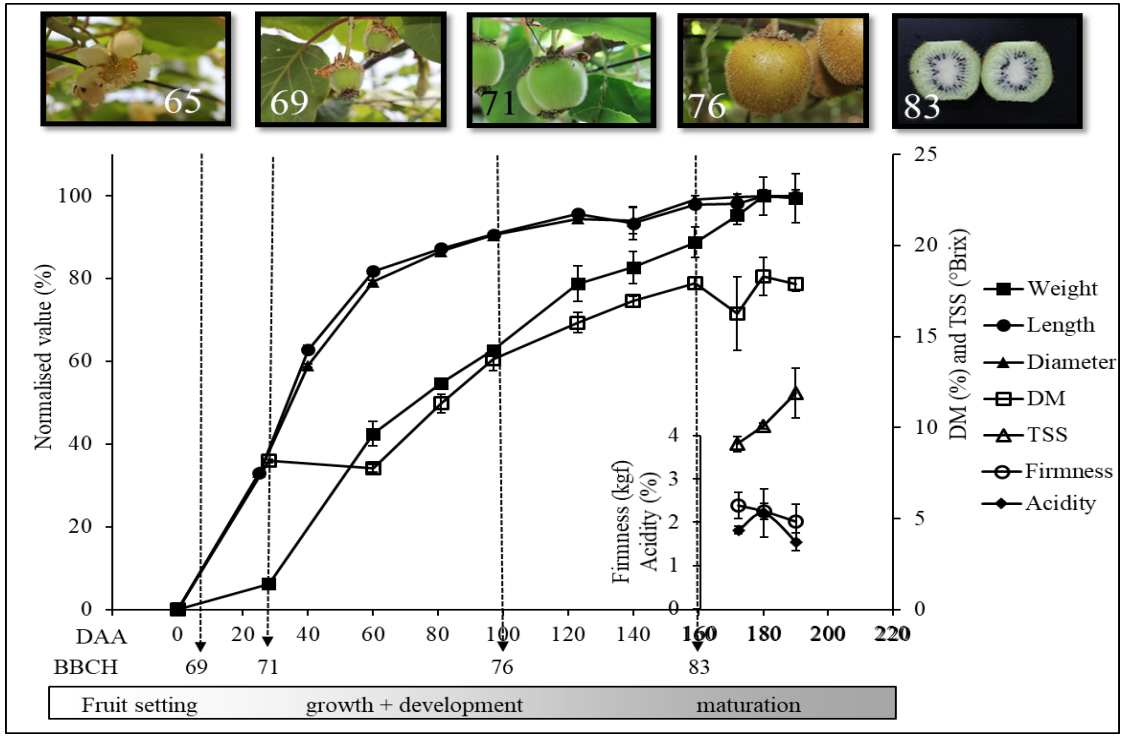


Fig. 9. Changes in fruit chracteristics of 'Garmrok' kiwifruit from 0 DAA to fruit maturation stage in the year 2016.

Data have been scaled to 100 arbitrary units based on maximum values. Based on fruit size (length and diameter), fruit weight, dry matter (DM), total soluble solids (TSS), acidity and firmness, the BBCH scale has been aligned. Photographs of fruit in different stages with the BBCH scale were on the top.

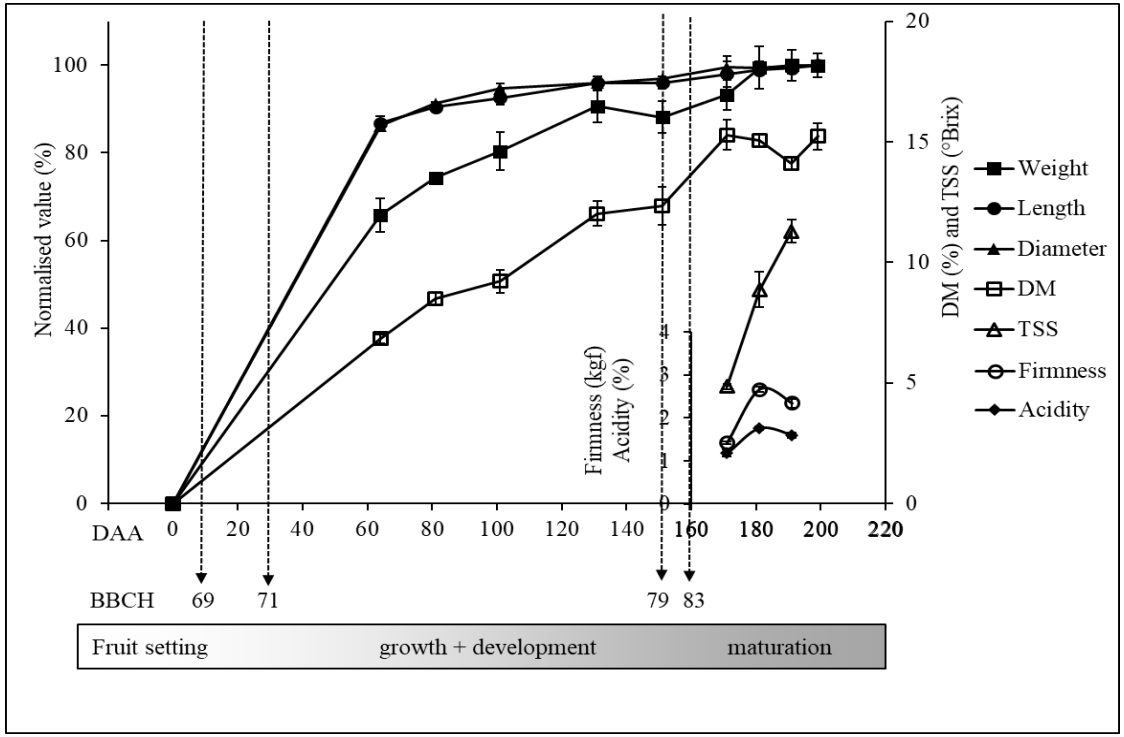


Fig. 10. Changes in fruit chracteristics of 'Halla Gold' kiwifruit from 0 DAA to fruit maturation stage in the year 2015.

Data have been scaled to 100 arbitrary units based on maximum values. Based on fruit size (length and diameter), fruit weight, dry matter (DM), total soluble solids (TSS), acidity and firmness, the BBCH scale has been aligned.

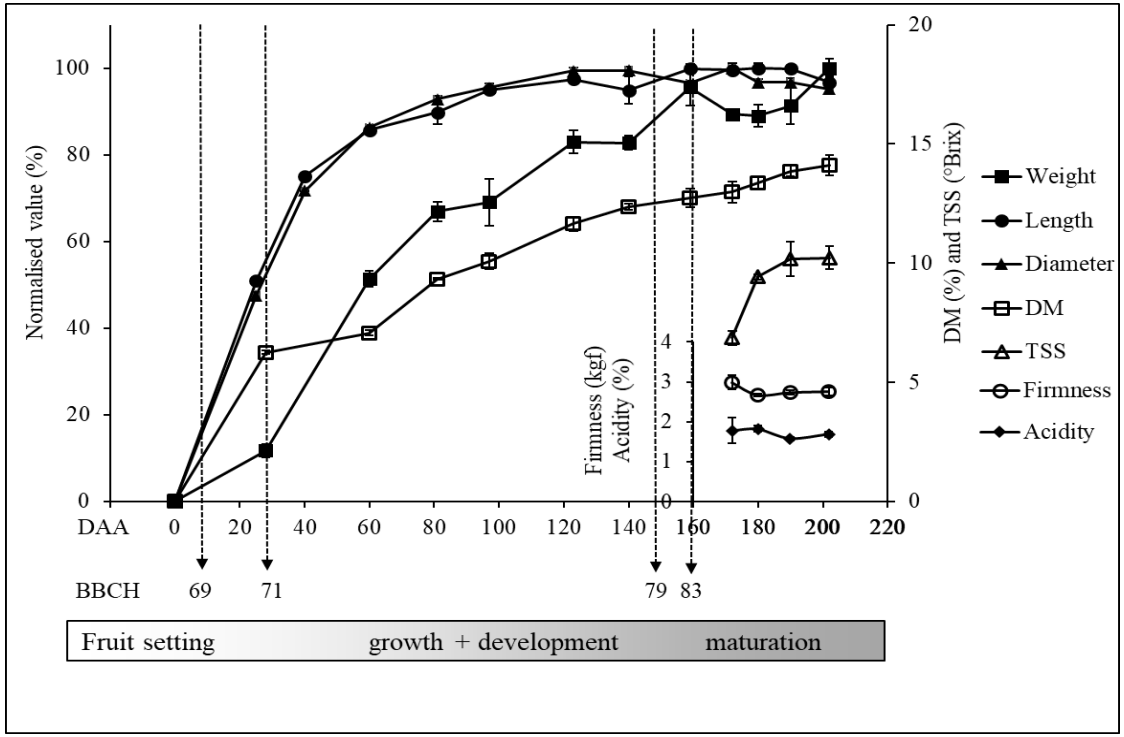


Fig. 11. Changes in fruit chracteristics of 'Halla Gold' kiwifruit from 0 DAA to fruit maturation stage in the year 2016.

Data have been scaled to 100 arbitrary units based on maximum values. Based on fruit size (length and diameter), fruit weight, dry matter (DM), total soluble solids (TSS), acidity and firmness, the BBCH scale has been aligned.

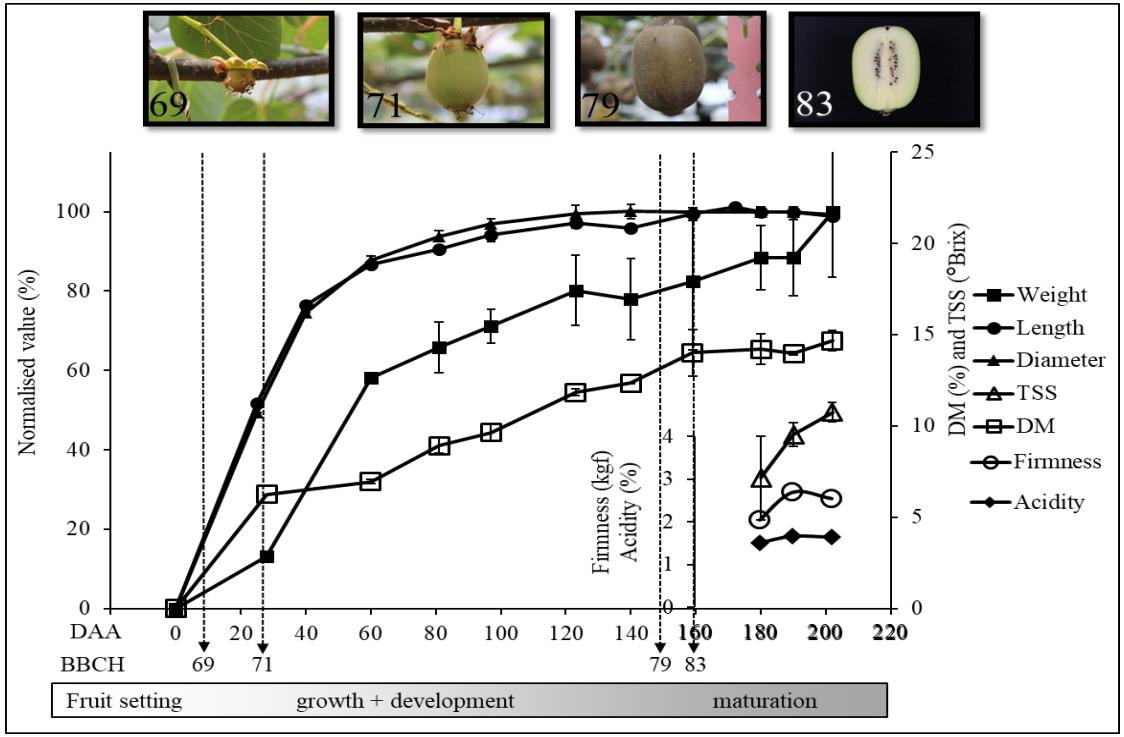


Fig. 12. Changes in fruit chracteristics of 'Halla Gold' kiwifruit from 0 DAA to fruit maturation stage (average of 2015 and 2016 data).

Data have been scaled to 100 arbitrary units based on maximum values. Based on fruit size (length and diameter), fruit weight, dry matter (DM), total soluble solids (TSS), acidity and firmness, the BBCH scale has been aligned. Photographs of fruit in different stages with the BBCH scale were on the top.

Table 2. Fruit quality characteristics of four kiwifruit cultivars in 2015 and 2016.

Cultivar	Year	Fruit size (mm)		Weight	DM	TSS	Carbohydrates (mg·g^{-1}DW)		DAA
		Length	Diameter	(g)		(°Brix)	Starch	Total Sugars	
'Sweet Gold'	2015	74.78±0.70[z]a[y]	49.49±0.38a	128.23±5.41a	17.33±0.42b	11.67±0.35b	24.59±0.22	139.04±6.67b	190
	2016	74.22±1.10a	50.83±0.68a	126.49±4.69a	19.97±0.37a	15.09±0.53a	36.22±0.19	192.12±0.44a	
'Goldone'	2016	67.93±1.72	60.69±1.48	173.26±6.81	16.75±0.34	11.7±0.15	30.94±2.00	139.40±8.42	170
'Garmrok'	2016	58.42±1.52	55.51±1.07	109.47±4.59	18.30±1.03	10.09±0.16	31.48±1.22	131.76±8.49	180
'Halla Gold'	2015	74.32±1.01a	53.68±0.56a	136.38±5.01a	15.04±0.45a	10.18±0.47a	25.89±1.09	140.30±4.30b	190
	2016	74.89±0.56a	54.02±0.59a	145.14±4.04a	13.86±0.17b	11.04±0.32a	21.35±0.75	192.60±8.60a	

[z] Value is given with mean ± standard error.

[y] Means with different letters differed significantly ($P \leq 0.05$), comparison was made between to difference sampling year.

DM: Percentage of dry matter, TSS: Total soluble solids, DAA: days after anthesis on which the comparison was made.

3. Changes of Starch and Sugar Concentrations in fruit.

In both years 2015 and 2016, starch concentrations of 'Sweet Gold' (Fig. 13-14) showed similar curves. Starch concentration was gradually increased in between 60 to 170 DAA and then rapidly decreased. This pattern had been observed in 'Hort16A' (Richardson et al., 2011) and 'Hayward' (Burdon et al., 2016) too. Beever and Hopkirk (1990) found that change in the concentrations of chemical components such as starch and sugar components are remarkable in fruits. Increase in starch accumulation occurs in early stage and rapid decrease occurs in later stage of fruit development. Among the sugars, concentrations of fructose and glucose showed a rapid increase from 160 DAA to 180 DAA. This observation was in accordance with the results of Reid et al., (1982) which was observed in *A. chinensis* 'Bruno'. Glucose and fructose declined slightly between 9 – 15 weeks after anthesis and then increased between 15 – 33 weeks. Despite gradual increase in sucrose content of 'Sweet Gold' in 2016 was observed throughout fruit development, content of *myo*-inositol showed gradual increase from 160 DAA. All of these results showed that the changes in concentrations of major sugars in 'Sweet Gold' such as glucose and fructose was similar to the reported concentrations in *A. deliciosa* and *A. chinensis* by Boldingh et al. (2000). Burdon et al., (2016) reported the increasing and decreasing pattern of starch and sugar in 'Hayward' correlates with increased accumulation of soluble solids due to starch breakdown in cooler night temperatures. Table 2 represent starch concentrations at 190 DAA as 24.59 ± 0.22 $mg \cdot g^{-1}DW$ in 2015 and 36.22 ± 0.19 $mg \cdot g^{-1}DW$ in 2016 and showed total

sugar concentrations at 190 DAA as 139.04 ± 6.67 mg·g^{-1}DW in 2015 and 192.12 ± 0.44 mg·g^{-1}DW in 2016, they are significantly different (P = 0.00). Even though, ‘Sweet gold’ and ‘Halla Gold’ fruits for this experiment was collected from the same vines in 2015 and 2016, parameters *viz*, DM, TSS, and total sugars concentration significantly differed between 2015 and 2016. This different might be due to the variation in mean monthly tempertures and Photosynthetically Active Radiation (PAR) of 2015 and 2016 (Fig. 19). Many researchers have studied the effect of temperature on fruit quality characteristics. Snelgar et al., (2007) reported that seasonal variations in temperature affects to the dry matter content (DMC) of ‘Hayward’ kiwifruit grown in New Zealand. They found cool weather in spring producing a low DMC while cool weather in summer producing high DMC in fruit. Richardson et al., (2004) found heating vines at any stage of kiwifruit development reduces carbohydrates and DMC in fruit. Moreove, Morgan et al., (1985) showed the relationship between light intensity and vegetative growth of two kiwifruit cultivars. Therefore, it can be hypothesized that light intensity can also have an effect on fruit quality by altering the vegetative growth of the kiwifruit.

Increases in starch concentrations of ‘Goldone’ (Fig. 15) and ‘Garmrok’ (Fig. 16) was gradual increase and then a decreasing trend was observed at 140-170 DAA in ‘Goldone’ and at 170-190 DAA in ‘Garmrok’. This pattern was similar to ‘Sweet Gold’. Concentration of fructose, glucose, and sucrose of ‘Goldone’ were started to increase at 120 DAA but the highest concentration was glucose followed by fructose and sucrose. At 170 DAA, starch

concentrations of ‘Goldone’ was 30.94 ± 2.00 mg·g^{-1}DW and total sugars concentration was 139.40 ± 8.42 mg·g^{-1}DW (Table 2). Changes in sugars concentration of ‘Garmrok’ showed rapid increase in glucose and fructose from 160 DAA. The main sugar of ‘Goldone’ was glucose while ‘Garmrok’ was glucose and fructose whereas *myo*-inositol was found to be lower in concentrations compared to all other sugars in all studied cultivars. At 180 DAA, starch concentrations of ‘Garmrok’ was 31.48 ± 1.22 mg·g^{-1}DW and total sugar concentration was 131.76 ± 8.49 mg·g^{-1}DW (Table 2).

Starch concentrations of ‘Halla Gold’ showed a similar curve in both years as the pattern produced by ‘Sweet Gold’ where gradual increases in concentration was observed in between 60 DAA and 160 DAA and followed by a decreasing trend (Fig. 17-18). In contrast, sugar concentrations especially glucose and fructose were gradually increased in the early developing stage (60-160 DAA) and then rapidly increased. These were same conversion of starch and sugars between ‘Halla Gold’ and ‘Sweet Gold’. Sucrose and *myo*-inositol showed a gradual increase after 160 DAA in 2016. However, they are not main sugars in kiwifruit when the concentrations of others are considered. Starch and total sugar concentrations of ‘Halla Gold’ were recorded at 190 DAA as 25.89 ± 1.09 mg·g^{-1}DW in 2015 and 21.35 ± 0.75 mg·g^{-1}DW in 2016 for starch and 140.30 ± 4.30 mg·g^{-1}DW in 2015 and 192.60 ± 8.6 mg·g^{-1}DW in 2016 for total sugars (Table 2), they are significantly different (P = 0.00).

In addition, Table 3 represents comparison of fruit developmental characteritics of four kiwifruit cultivars. In summary, four cultivars did not show

differences in terms of fruit size, fruit weight and DM. While, time at which starch and total sugar were started to decrease and increase, respectively, differed among the cultivars. Starch content of ‘Goldone’ started to decrease (140 DAA) earlier than other cultivars (170 DAA). Total sugar of ‘Goldone’ and ‘Garmrok’ started to increase (120 DAA) ealier than ‘Sweet Gold’ and ‘Halla Gold’ (160 DAA). Fig. 20 and 21 shows pattern curves of average data gathered in two different years to confirm the above description of starch and sugars concentration.

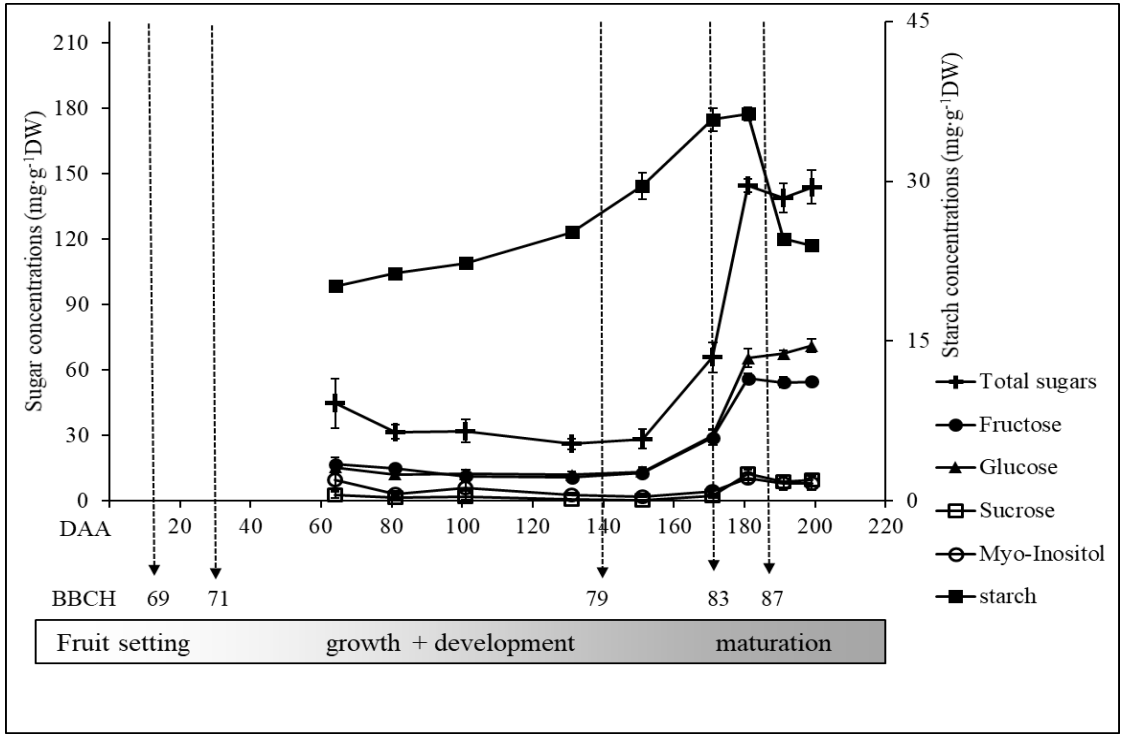


Fig. 13. Changes in starch and individual sugar concentrations of 'Sweet Gold' kiwifruit from 0 DAA to fruit maturation stage in the year 2015.

The BBCH scale has been aligned.

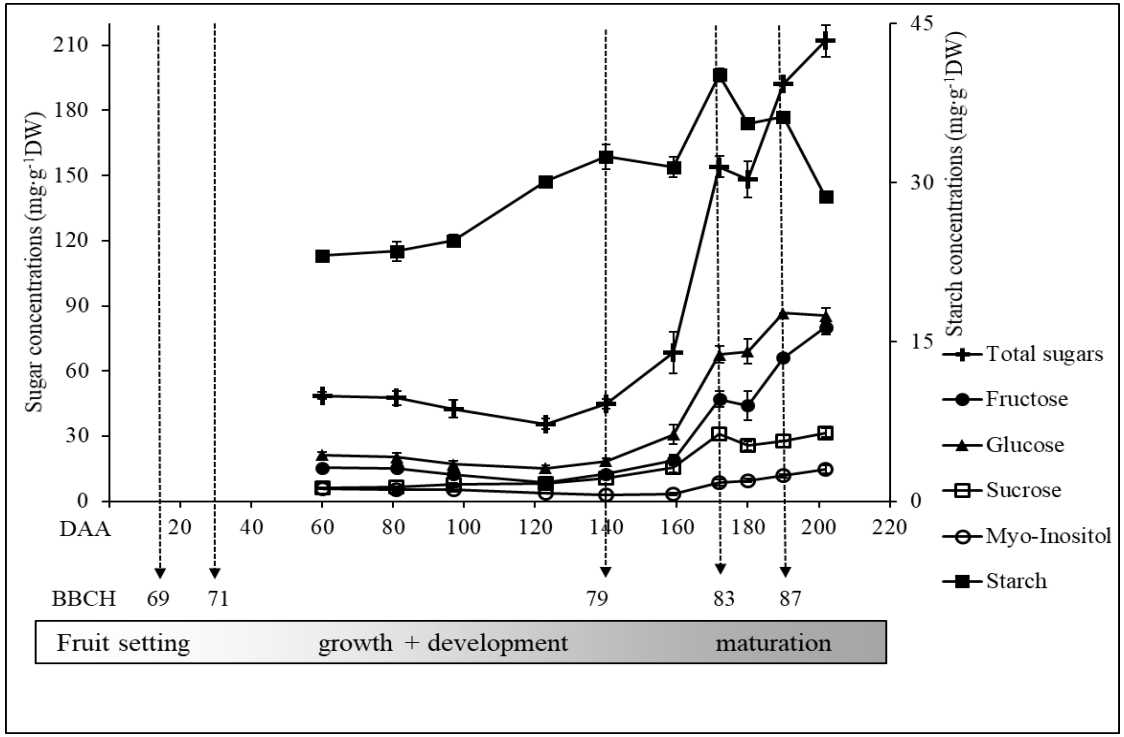


Fig. 14. Changes in starch and individual sugar concentrations of 'Sweet Gold' kiwifruit from 0 DAA to fruit maturation stage in the year 2016.

The BBCH scale has been aligned.

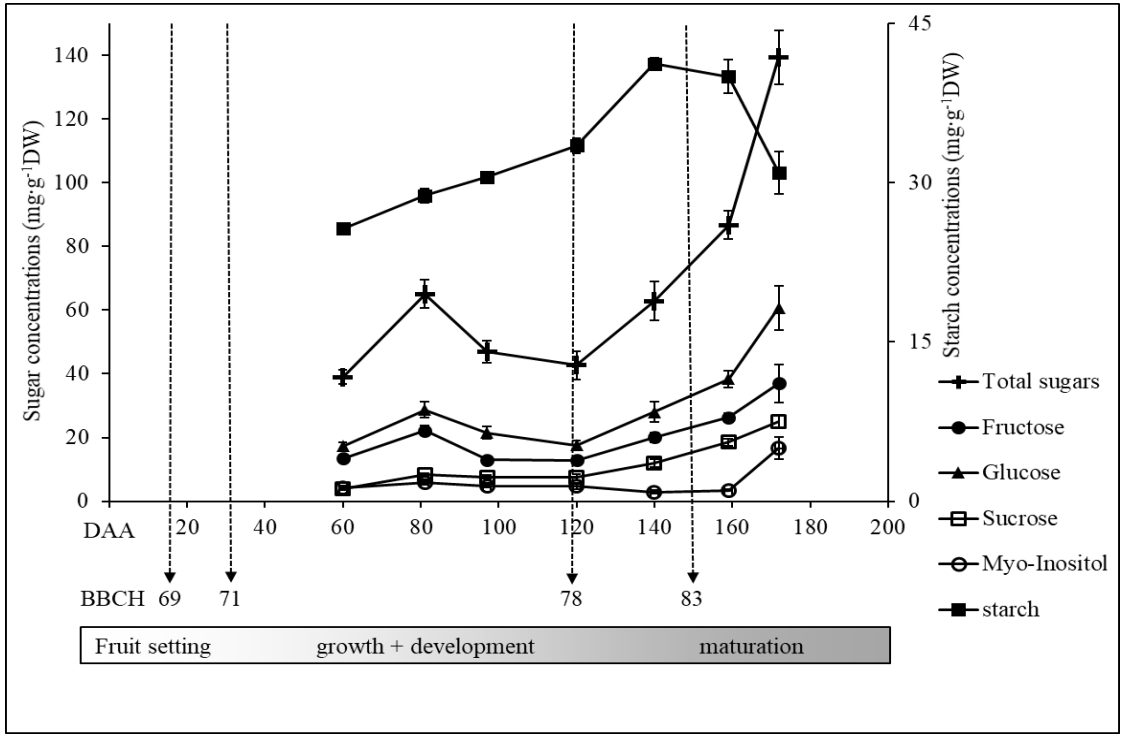


Fig. 15. Changes in starch and individual sugar concentrations of 'Goldone' kiwifruit from 0 DAA to fruit maturation stage in the year 2016.

The BBCH scale has been aligned.

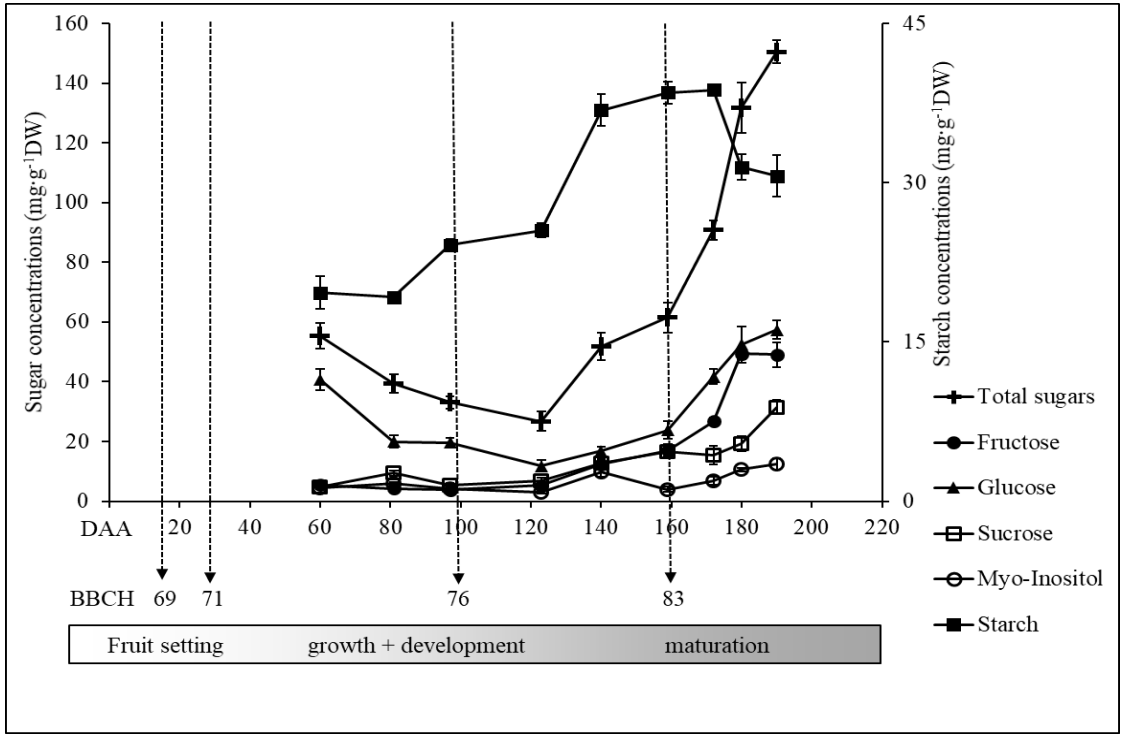


Fig. 16. Changes in starch and individual sugar concentrations of 'Garmrok' kiwifruit from 0 DAA to fruit maturation stage in the year 2016.

The BBCH scale has been aligned.

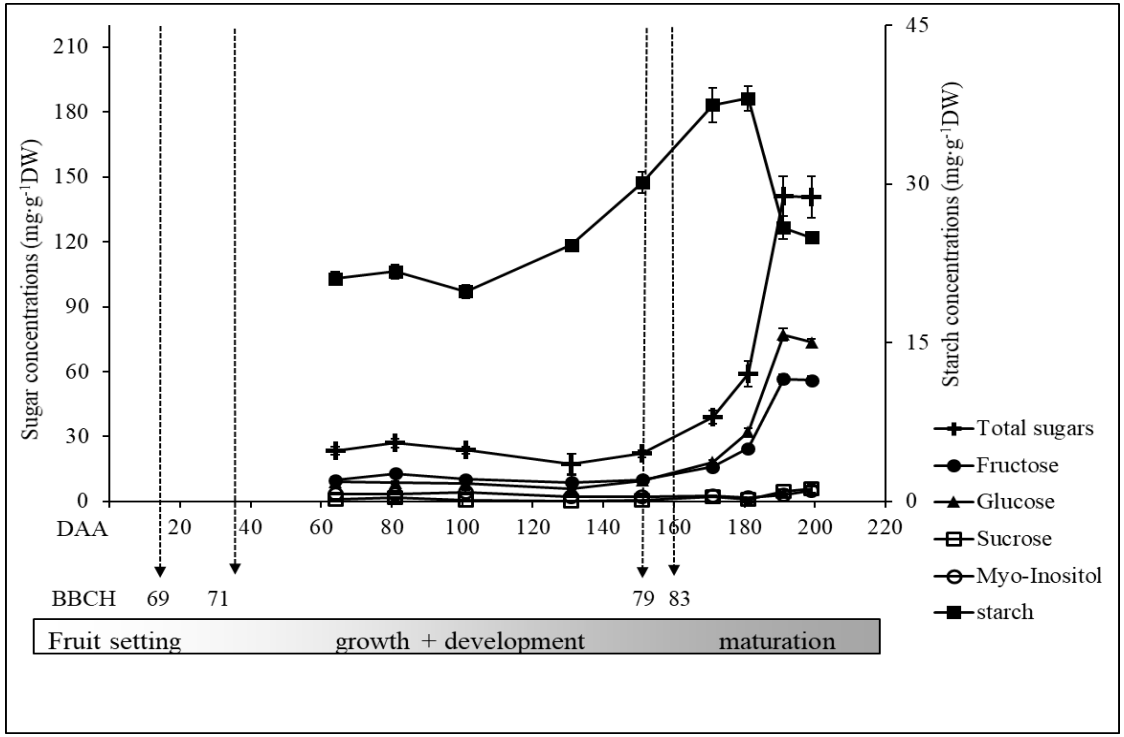


Fig. 17. Changes in starch and individual sugar concentrations of 'Halla Gold' kiwifruit from 0 DAA to fruit maturation stage in the year 2015.

The BBCH scale has been aligned.

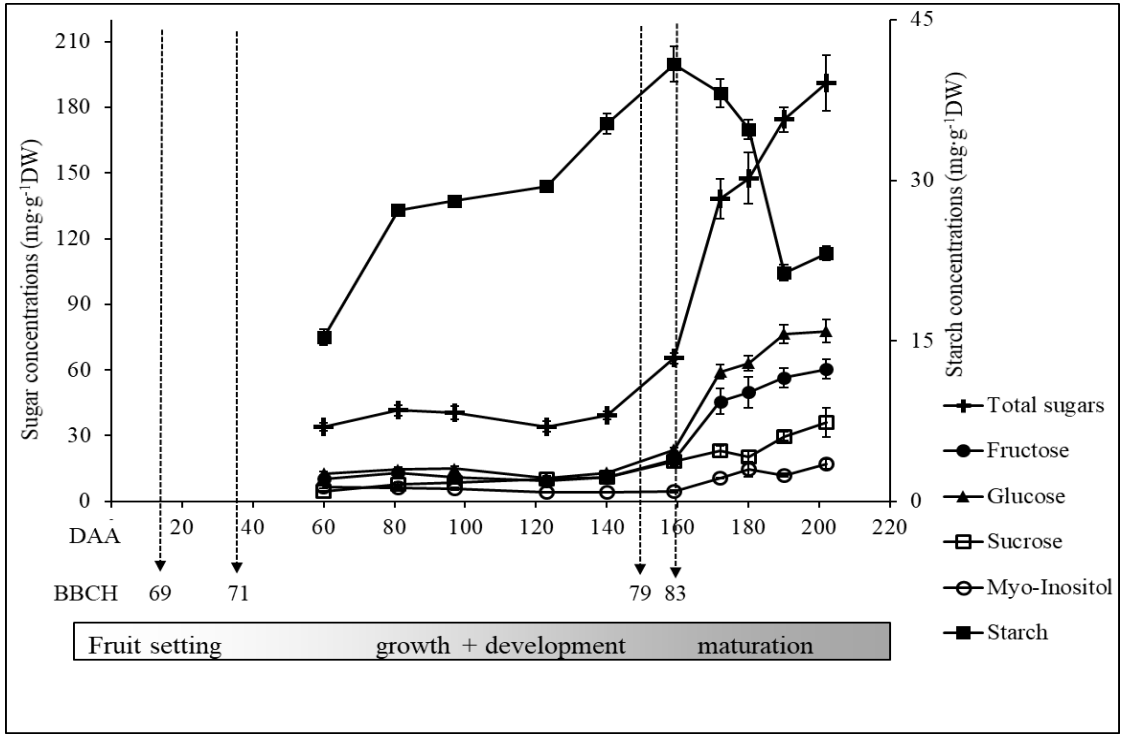


Fig. 18. Changes in starch and individual sugar concentrations of 'Halla Gold' kiwifruit from 0 DAA to fruit maturation stage in the year 2016.

The BBCH scale has been aligned.

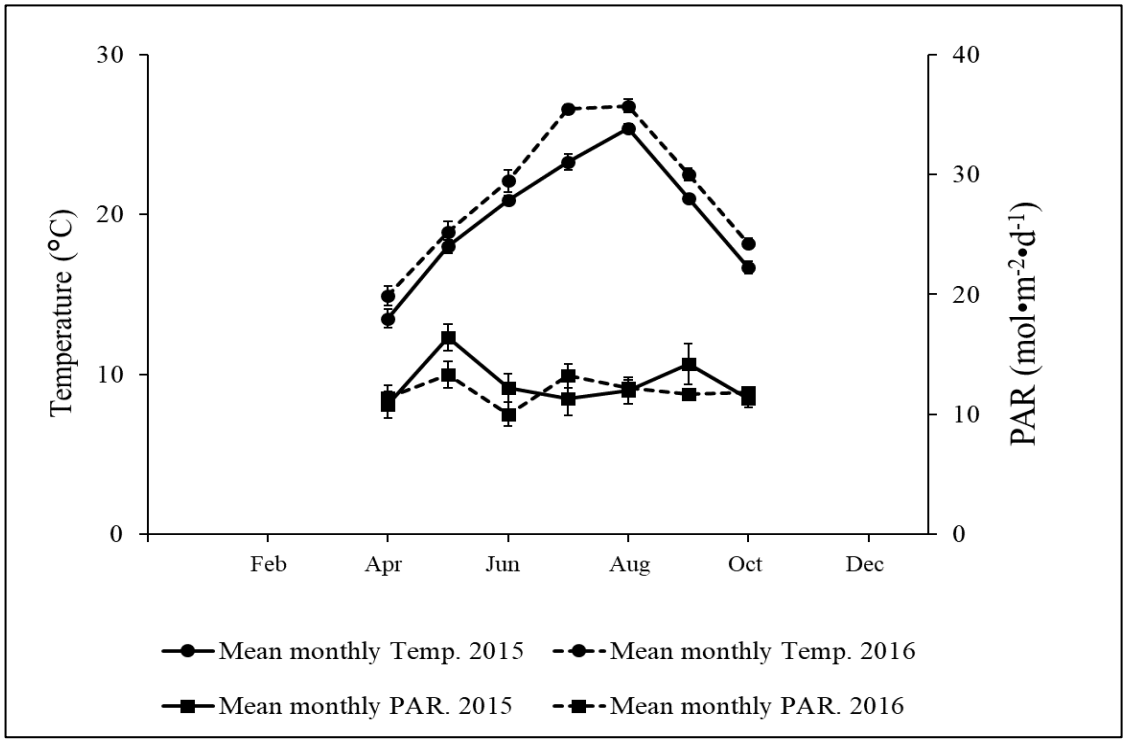


Fig. 19. Monthly mean temperatures and PAR of plastic house in which 'Sweet Gold' and 'Halla Gold' had been planted during April to October in 2015 and 2016 (from anthesis to harvest).

Table 3. Comparison of fruit developemental characteristics of four kiwifruit cultivars.

	'Sweet Gold'	'Goldone'	'Garmrok'	'Halla Gold'
Fruit size	Tri-phasic growth curve	Tri-phasic growth curve	Tri-phasic growth curve	Tri-phasic growth curve
Fruit weight, Dry matter	Double sigmoid curve	Double sigmoid curve	Double sigmoid curve	Double sigmoid curve
Starch	Start to decrease 170-200 DAA	Start to decrease 140-170 DAA	Start to decrease 170-190 DAA	Start to decrease 170-190 DAA
Sugars	Start to increase 160 DAA	Start to increase 120 DAA	Start to increase 120 DAA	Start to increase 160 DAA

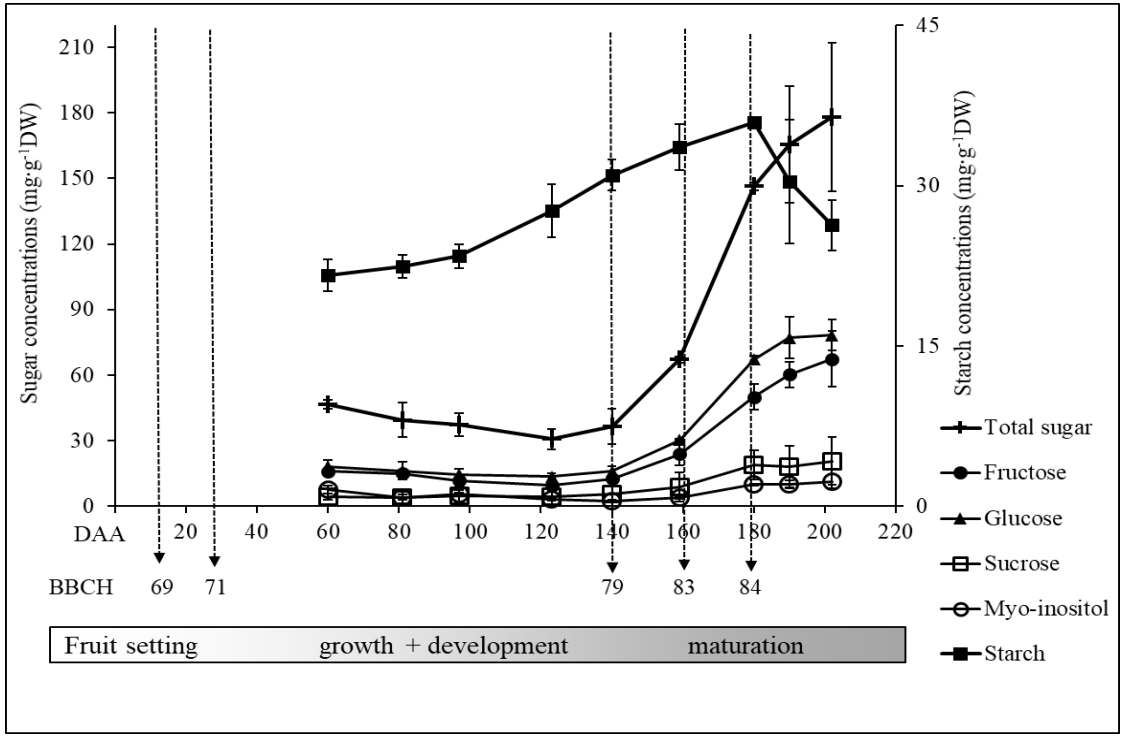


Fig. 20. Changes in starch and individual sugar concentrations of 'Sweet Gold' kiwifruit from 0 DAA to fruit maturation stage (average of 2015 and 2016 data).

The BBCH scale has been aligned.

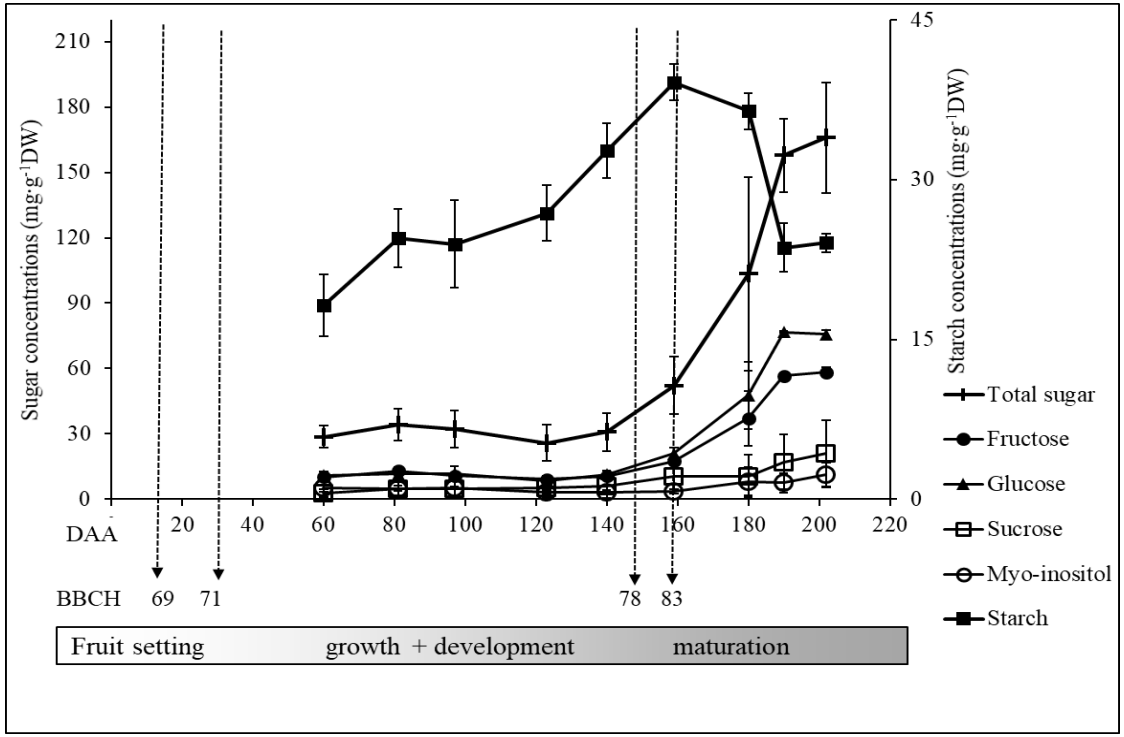


Fig. 21. Changes in starch and individual sugar concentrations of 'Halla Gold' kiwifruit from 0 DAA to fruit ripening stage (average of 2015 and 2016 data).

The BBCH scale has been aligned.

CONCLUSION

Four cultivars did not show differences growth curve in terms of fruit size, fruit weight and DM. While, time at which starch and total sugar were started to decrease and increase, respectively was differed among the cultivars. Starch content of ‘Goldone’ started to decrease earlier than others. Total sugar of ‘Goldone’ and ‘Garmrok’ started to increase ealier than ‘Sweet Gold’ and ‘Halla Gold’. Harvesting stage identified as BBCH stage 83 for ‘Sweet Gold’ and ‘Hall Gold’ was reached at 160 Days after anthesis (DAA) and that of ‘Goldone’ and ‘Garmrok’ was reached at 140-160 DAA. The generated information could be used in management of good horticultural practices in kiwifruit orchards. However, repeating this experiment at least for 1 or 2 times would helpful to confirm the results obtained in this study.

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ABSTRACT IN KOREAN

제주지역의 참다래 재배는 생산을 확대하고 경쟁력을 유지하기 위해 더욱 발전해 나갈 도약하는 분야이다. 본 연구는 새로 육성된 참다래 품종의 과실발육 특성 및 생물계절 생육단계를 상세히 평가하기 위해 수행하였다. 하우스 내 덕식 수형으로 재배되는 골드계통의 '스위트골드', '골드원', '한라골드' 3 품종과 그린계통의 '감록'이 본 연구에 이용되었다. 과실크기(종경 및 횡경), 과실무게, 건물율, 총가용성고형물, 산도 그리고 전분과 당(과당, 포도당, 자당, 미오이노시톨) 농도를 개화기부터 수확기까지 측정하였다. 생물계절 생육단계는 BBCH 척도를 기준으로 하여 조사하였다. 모든 품종의 과실무게는 이중 S 자형 곡선 패턴으로 증가하였다. 과실크기는 급격한 증가를 보인 후, 완만하게 증가한 다음 일정하게 유지되었다. 건물율은 완전한 성숙단계까지 지속적인 증가를 나타내었다. 참다래 품종의 전분농도는 4 품종 모두에서 점진적인 증가를 보이다 감소하였다. 반면, 전분이 감소하기 시작함에 따라 당 농도는 증가하기 시작했다. BBCH 83 단계인 수확기는 '골드원'과 '감록'에서 만개 후 140-160 일, '스위트골드'와 '한라골드'에서 160 일 전후로 확인되었다.

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