Pak. J. Agri. Sci., Vol. 55(4), 843-851; 2018
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
DOI: 10.21162/PAKJAS/18.5417
http://www.pakjas.com.pk

EFFECT OF ALTITUDE ON GROWTH-DEVELOPMENT AND FRUIT QUALITY ATTRIBUTES OF KIWIFRUIT (*Actinidia deliciosa* PLANCH) CULTIVATION

Hamdi Zenginbal[1,*] and Muharrem Ozcan[2]

[1]Abant Izzet Baysal University, Vocational Community College of Bolu, 14100, Bolu, Turkey; [2]Ondokuz Mayıs University, Faculty of Agriculture, Department of Horticulture, Samsun, Turkey
[*]Corresponding author's e-mail: hzenginbal@gmail.com

This study was carried out to determine the variation of vine growth-development and fruit quality characteristics of 'Hayward' and 'Matua' kiwifruit cultivars at different altitude in Ardeşen district of Rize (Turkey) province during two growing seasons in 2013-14. Significant differences in phenological dates of kiwifruit cultivars, cultivated at different altitudes were observed in both years. Generally, the kiwifruit cultivars, grown at 20 m altitude sprouted 7 days early and dropped their leaves 9-10 days later when compared to the cultivars, grown at 610 m altitude. Besides, the vegetative growth of vines was normal at all altitudes and the annual shoot diameter and length decreased with increase in altitude. With increase in altitude, the leaf area, number of leaf, bud, flower, and fruit on shoot decreased in both kiwifruit cultivars. The lowest values for leaf area, number of leaf, bud, flower, and fruit on shoot were detected in vines grown at 610 m altitude and the highest means were reached in vines grown at 20 and 210 m altitudes. The width, length index, weight, firmness, TSS, pH of fruit and yield values of 'Hayward' cultivar decreased with increase in altitude. The highest values were recorded from orchard at 20 and 210 m altitude. Acidity and firmness of fruit increased with increase in altitude and the highest acidity and firmness was taken from 610 m altitude. Effect of altitude was found non-significant for vitamin C content in both years. The results suggested that the cultivars at various altitudes were performed better but the new commercial cultivations of 'Hayward' and 'Matua' kiwifruit cultivars must be made in areas with up to 210 m altitude.

Keywords: Agro-ecology, altitude, fruit quality, growth-development, vine fruits, temperate fruits

INTRODUCTION

In ancient times, in China, kiwifruit was a remedy for a various health disorders (digestive disturbances, rheumatism, and dyspepsia) and in the recent past this fruit has gained worldwide popularity since consumers associated the consumption of kiwi-fruits were found to have health benefits (increase in antioxidants, decrease of lipids in blood, improvement of gastrointestinal laxation) (Singletary, 2012).

Originally grown in mountainous regions of China, kiwifruit belongs to *Actinidia* genus and is derived from a deciduous, woody fruiting vine. *Actinidia* species are perennial and exhibit vigorous growth and has climbing and strangling characteristics. Only four species of *Actinidia* are of interest with the purpose of fruit production: *chinensis* (golden kiwifruit), *deliciosa* (green or fuzzy kiwifruit), *kolomikta* and *arguta* (baby kiwifruit) (Singletary, 2012; Peticila *et al*., 2012).

The most widely planted kiwifruit cultivar is *A. deliciosa* 'Hayward' was selected in New Zealand in about 1925. Hayward cultivar and its associated pollinizer male plants account for about half of kiwifruit planting throughout the world and cv. 'Hayward' - fruit represent about 90-95% of the kiwifruit traded internationally (Ferguson and Seal, 2008). The 'Hayward' cultivar is easily identified by its large (80-100 g), broadly oval fruit. It is pale greenish-brown and densely covered with fairly fine and, silky hairs. This variety is superior in flavor and have shelf life better than any other variety presently available. It has delicious taste, long storage durability and high yield producing up to 50 tonnes ha^{-1}. Furthermore, it is late flowering avoiding the exposure to late spring frosts. This cultivar is recommended only for areas with mild winters. 'Matua' cultivar is male kiwifruit and it have a long and late flowering type. Though, 'Matua' cultivar was selected as a pollinator for cv. 'Hayward', but it now being considered that long flowering types are the better pollinators for cv. 'Hayward' (Sale, 1984; Strik, 2005; Marandi, 2007).

In recent years kiwifruit production and consumption has increased notably in the world. According to FAO (2015), the kiwifruit production in 22 different countries in the world was 3.3 million tonnes. China is the world's biggest producer (1.8 million tonnes), followed by Italy (448 thousand tonnes), New Zealand (382 thousand tonnes), Chile (256 thousand tonnes), Greece (162 thousand tonnes), France (56 thousand tonnes) and Turkey (42 thousand tonnes), respectively. Kiwifruit was first introduced to Turkey in the 1980s. In the last few years significant progress has been achieved. Several experiments have been conducted in different agro-ecological areas, mainly in the Black Sea, Marmara, Aegean and Mediterranean regions, and considerable information have been collected on plant-climate and plant-soil relations and the area for kiwifruit cultivation in Turkey is expanding (Basım and Uzun, 2003). Today, kiwifruit is produced commercially in 27 different cities in Turkey. Yalova is the Turkey’s biggest producer (19 thousand tonnes), followed by Ordu (6 thousand tonnes) and Rize (5 thousand tonnes), respectively. These provinces are responsible for almost 72.7% of Turkey's production. Tea cultivation makes up 91.29% of total agricultural area and 98.7% of fruit production in Rize (TUIK, 2015). The fact that tea is main crop in Rize has restrained production of other fruits. Recent problems (low yield and price) regarding tea production has resulted in seeking new plant species as alternative crop. Kiwifruit may be considered best alternative for tea. Kiwifruit production has gained acceleration during past few years as it is very suitable for local ecology and its yield per area is high. Thus, kiwifruit production has gained popularity in Turkey, especially in Eastern Black Sea Region. For that reason, further studies on increasing fruit yield and quality as well as cultivation and propagation techniques in this fruit are needed.

Orchard factors known to influence fruit quality and its variability in fruit production include pollination, flowering time, irrigation, fertilizer program, altitude, plant growth regulators, and training and pruning (Woodward, 2006). Kiwifruit has been cultivated under different ecological conditions and different altitudes/directions within same ecology in Turkey and also worldwide. Thus, it is expected that cultivated plants varied with vine and fruit development, flowering, pollination and yield per tree. In the present study, it was aimed to determine the most suitable altitude(s) for kiwifruit production by exploring yield potential and fruit quality of kiwifruit plants, cultivated at different altitudes of Ardesen, the most important kiwifruit producing district of Rize.

MATERIALS AND METHODS

***Study area*:** This study was conducted at the kiwifruit orchard in the villages of the Ardeşen district, Rize (Turkey) province in 2013-14. Fruits pomological traits and chemical analyses were performed at the Abant Izzet Baysal University, Bolu Vocational Community College Laboratory. The research was carried in kiwifruit orchards grown at different altitudes (20 m, 210 m, 446 m and 610 m altitude). General information about kiwifruit orchards in this study are presented in Table 1. All orchards were established in the north-east direction and prone land. All orchards were planted at 1 male vine (cv. 'Matua') per 6 female vines (cv. 'Hayward'). The saplings used in the orchards were propagated with stem cuttings. The experimental orchards were fertilized with 5 kg/vine farmyard manure on February 20 and irrigated during summer using drip irrigation systems. There was no chemical spraying in the orchard. The vines were pruned in winter (January 20, 2013 and 2014) at all altitudes, pruning as canes on 180-200 bud levels (bud/vine), 16-18 bud per shoot, separately. No fruit thinning was applied during the experiment. Orchards at 20 and 210 m altitudes had only kiwifruit plantations whereas orchards at other altitudes had tea and kiwifruit plantations.

***Climatic data*:** The daily temperature and relative humidity for the experimental area (Ardeşen, Rize, Turkey) were recorded (1 hour’s intervals) by data loggers (HOBO U10, made in USA).

Phenological observations: Research was carried in one orchard at each altitude (20, 210, 446 and 610 m). Four vines on 'Hayward' and 'Matua' cultivars were marked in different directions of each altitude and each vine was considered as a replication. The following phenological parameters were examined to determine the effects of altitude on kiwifruit cultivation during vegetation period in kiwifruit orchard. The procedures for phenological parameters (bud swelling, bud burst, foliation, flower bud swelling, beginning of flowering, full flowering, end of flowering, fruit set, fruit harvest, and leaf fall) were followed as described earlier (Richardson *et al*., 2001; Zenginbal *et al*., 2005).

***Vines growth and development status*:** Four shoots in different directions on four vines for 'Hayward' and 'Matua' cultivars were marked to record and following measurements. All measurements of plant growth and development were carried at the vegetative growth period. Vines trunk diameter in the start (February 15) and end (December 1) of vegetative period electronic digital caliper (accuracy range of 0.01 mm) at 20 cm above the soil surface. Annual growth rate of vine trunk diameter was estimated as: vine trunk diameter in the end of vegetation - vine trunk diameter in the start of vegetation x 100 / vine trunk diameter in the start of vegetation. Shoot diameter was measured by electronic digital caliper (accuracy range of 0.01 mm) at 5 cm above the

Table 1. General information about kiwifruit orchards in this study.

The name of the place	Altitude (m)	Coordinate	Age of vine (year)	Training system	Orchard size (1000 m^2)	Planting distance (m)
Yeniyol Village	20	N: 41° 13', E: 41° 14'	8	Pergola	2.0	4,5 x 4,5
Yeniyol Village	210	N: 41° 13', E: 41° 04'	10	Pergola	2.5	4,5 x 4,5
Tunca Village	446	N: 41° 07', E: 41° 07'	6	T-bar	1.5	4 x 4
Eski Armutluk Village	610	N: 41° 07', E: 41° 09'	6	T-bar	1.5	4 x 4

junction during vegetative period at an interval of 30 days. Shoot length was measured at 5 cm above the junction with branches during vegetative period at an interval of 30 days. The number of leaves on a shoot were determined before the leaf fall (November 15). To determine leaf area, leaves on a shoot were collected in November 15 and placed on the photocopier desktop by holding flat and secure and copied on A3 sheet (at 1:1 ratio). Second, a Placom Digital Planimeter (Sokkisha Planimeter Inc., KP-90) was used to measure actual leaf area of the copy. The number of flower buds, flowers and fruits on lateral shoot were also determined.

***Pomological characteristics and chemical analyses*:** Five pieces of fruit samples were taken from previously marked shoots. The fruit pomological characteristics and chemical analyses of the kiwifruit were determined by the following methods. The fruit width (diameter) and length were measured by an electronic digital caliper (accuracy range of 0.01 mm). Fruit index was estimated as fruit width / fruit length. The fruit weight was obtained by weighing on a scale with 0.01 g sensitivity. Yield was calculated as the number of fruits on lateral shoot x mean fruit weight. The fruit firmness in harvest periods was performed on two opposite faces of the equatorial zone using a penetrometer installed on a driving column equipped with an 8 mm probe (Model FT-011). Measurements were carried out on a flat surface of the fruits and were expressed as kg. Total soluble solid contents (TSS) in fruits at harvest and eating maturity stage were measured by hand-held refractometer (Milwaukee, MR32ATC), at 20°C. Flesh firmness measurements were carried out at the same sites on fruits and were expressed as percentage. pH of fruit juice was measured by digital pH meter (WTW 526). Total titratable acidity was measured using titration method. To do that, 5 ml fruit juice was added to 25 ml distilled water plus two drops of phenolphthalein and titrated with 0.1 N NaOH up to pH 8.1 and expressed as percent citric acid. Vitamin C contents in fruits at eating maturity stage were measured using the method of Namdar and Ozcan (2006).

***Statistical analysis*:** A randomized complete block design was used with four replicates for each cultivar. Data from the analytical determinations were subjected to analysis of variance (ANOVA). Mean comparisons were performed using Duncan's test ($p<0.05$). All analyses were performed with SPSS software package.

RESULTS AND DISCUSSION

***Climatic data*:** Experiment was carried out in Ardeşen, Rize, Turkey where daily mean temperature (°C) and daily mean relative humidity (%) were recorded from January 1 to December 31, 2013 and 2014 (Fig. 1- 2). As shown in Figure 1, daily mean temperatures varied from 0 to 25.9°C and daily mean relative humidity varied from 38.0% to 93.9% in 2013. Whereas, daily mean temperatures varied from 1.8 to 28°C and daily mean relative humidity varied from 38.4-89.8% in 2014 (Fig. 2). In both years, the highest monthly mean temperature was recorded in August, while the lowest monthly mean temperature was recorded in January. The highest monthly mean relative humidity was recorded in November, while the lowest monthly mean temperature was recorded in August. Generally, daily mean temperature increased until June 1 and reached the maximum in middle of August but decreased after middle of August. Besides, spring late frost events were not observed during both years. The year 2014 received more snow as compared to the year 2013. The climatic data were in accordance with the long-term average of Ardeşen, Rize (TUMAS, 2016), and indicated that 2013 and 2014 were average years. Thus, generalization from the study seemed possible.

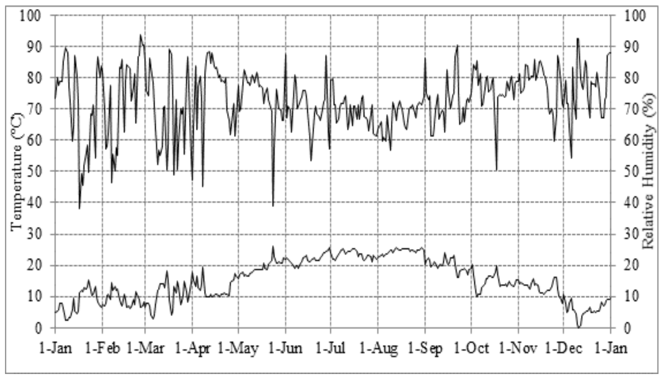

Figure 1. The daily mean temperature and relative humidity data at the experiment area in 2013.

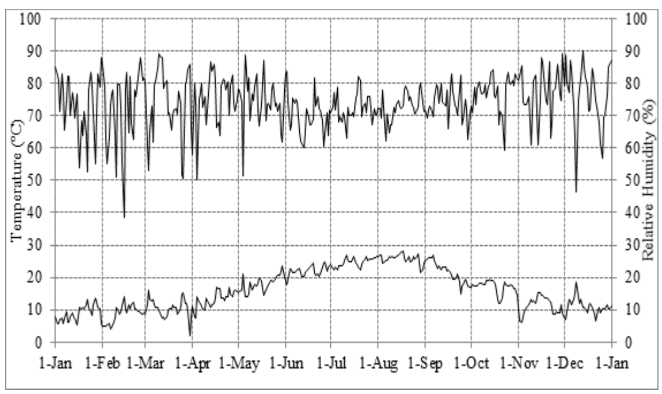

Figure 2. The daily mean temperature and relative humidity data at the experiment area in 2014.

***Phenological observations*:** Phenological observations of 'Hayward' cultivars in 2013 and 2014 are provided in Table 2. Significant differences in phenological dates of 'Hayward' cultivars, cultivated in different altitude levels were observed during both the years. In 2013, vegetative buds swelled between March 8 and 14. Bud burst started 7-8 days after while full foliation occurred 26-29 days after these dates. Flower buds swelled after 18 days from the foliation dates and flowers began to bloom between May 29 and June 1. Full flowering occurred after 4-5 days and ended after 7 days from these dates. Fruit set occurred after 2 days from the end of flowering and fruits were harvested between November 24 and December 7. Vines dropped their leaves between December 9 and 14 then entered winter dormancy. When analysed phenological observations of 2014, it was observed that buds swelled about 15 days late in 2014 than 2013, buds burst started after 4-6 days from these dates and full foliation occurred after 4 days from bud burst. Flower buds swelled after 20 days from the foliation dates and flowers began to bloom between June 2 and 8. Full flowering occurred after 4-5 days from this date and flowering lasted 7 days. Fruit set occurred after 2 days from the end of flowering and fruits were harvested between November 24 and December 1. Vines dropped their leaves between December 11 and 18 then entered into winter dormancy.

Phenological observations of 'Matua' cultivars in both years are provided in Table 3. In 2013, buds of cv. 'Matua' swelled 5 days ago as compared to cv. 'Hayward'. Bud bursting started 8-9 days after while full foliation occurred 22-23 days after these data. Flower buds swelled after 14 days from the foliation dates and flowers began to bloom between May 26 and June 1. Full flowering occurred after 5 days from these dates and flowering lasted 7 days. Vines dropped their leaves between December 6 and 12 then entered winter dormancy. When analysed phenological observations of 2014, it was observed that buds swelled about 17 days late in 2014 than 2013. Buds bursting started after 4-6 days from these dates and full foliation occurred 4 days after bud bursting. Flower buds swelled after 20 days from the foliation dates and flowers began to bloom between May 30 and June 6. Full flowering occurred after 5 days from these dates and flowering lasted 6-7 days. Vines dropped their leaves between December 7 and 16 then entered winter dormancy.

According to the results, revivals began 15 days late in 2014 than 2013 as snowed days were higher in 2014. Likewise, daily mean temperature of February and March was higher in 2013 than those of 2014 (Fig. 1-2). Chen and Zhang (1985) reported that kiwifruit buds swelled 7 days late when temperature was 10-15°C. Eris *et al*. (1997) reported that dormancy period was 151 days and chilling periods was 950 hours. The previous results are in accordance with our present results. It can be concluded that cv. 'Matua' bloomed and flowered earlier than cv. 'Hayward' as reported by Sale (1985). Korkutal *et al.* (2004) reported that flowering periods in cv. 'Matua' and cv. 'Hayward' were 4 days and 7 days, respectively, and the date of full flowering in cv. 'Hayward' was June 10 under ecological conditions of Tekirdag (Turkey). Besides, the present dates for phenological observations was similar of those reported by Zenginbal *et al*. (2005) and Eser and Ozcan (2015). It was observed that revival dates were delayed with increasing elevations and vines in high altitudes dropped their leaves early. Davison (1990) noted that there was a consistent delay in flowering

Table 2. Dates of phenological observations of kiwifruit cv. 'Hayward'.

Phenological observations	Year / Altitude	2013				2014			
		20 m	**210 m**	**446 m**	**610 m**	**20 m**	**210 m**	**446 m**	**610 m**
Bud swelling		8 Mar.	10 Mar.	11 Mar.	14 Mar.	23 Mar.	24 Mar.	27 Mar.	29 Mar.
Bud burst		16 Mar.	18 Mar.	19 Mar.	21 Mar.	27 Mar.	29 Mar.	2 Apr.	5 Apr.
Foliation		4 Apr.	6 Apr.	10 Apr.	15 Apr.	8 Apr.	10 Apr.	13 Apr.	19 Apr.
Flower bud swelling		22 Apr.	24 Apr.	29 Apr.	3 May	28 Apr.	30 Apr.	2 May	7 May
Beginning of flowering		29 May	30 May	1 Jun.	4 Jun.	2 Jun.	3 Jun.	4 Jun.	8 Jun.
Full flowering		2 Jun.	3 Jun.	5 Jun.	9 Jun.	6 Jun.	7 Jun.	8 Jun.	13 Jun.
End of flowering		9 Jun.	10 Jun.	12 Jun.	16 Jun.	13 Jun.	15 Jun.	17 Jun.	20 Jun.
Fruit set		10 Jun.	12 Jun.	13 Jun.	18 Jun.	15 Jun.	17 Jun.	18 Jun.	22 Jun.
Fruit Harvest		7 Dec.	7 Dec.	25 Nov.	24 Nov.	1 Dec.	30 Nov.	26 Nov.	24 Nov.
Leaf fall		14 Dec.	15 Dec.	13 Dec.	9 Dec.	18 Dec.	18 Dec.	15 Dec.	11 Dec.

Table 3. Dates of phenological observations of kiwifruit cv. 'Matua'.

Phenological observations	Year / Altitude	2013				2014			
		20 m	**210 m**	**446 m**	**610 m**	**20 m**	**210 m**	**446 m**	**610 m**
Bud swelling		2 Mar.	3 Mar.	5 Mar.	10 Mar.	19 Mar.	20 Mar.	21 Mar.	26 Mar.
Bud burst		10 Mar.	10 Mar.	14 Mar.	19 Mar.	24 Mar.	25 Mar.	27 Mar.	2 Apr.
Foliation		2 Apr.	3 Apr.	7 Apr.	11 Apr.	6 Apr.	7 Apr.	11 Apr.	15 Apr.
Flower bud swelling		16 Apr.	18 Apr.	20 Apr.	25 Apr.	26 Apr.	28 Apr.	30 Apr.	4 May.
Beginning of flowering		26 May	27 May	29 May	1 Jun.	30 May	1 Jun.	2 Jun.	6 Jun.
Full flowering		31 May	1 Jun.	3 Jun.	6 Jun.	4 Jun.	5 Jun.	7 Jun.	11 Jun.
End of flowering		7 Jun.	8 Jun.	10 Jun.	13 Jun.	11 Jun.	13 Jun.	15 Jun.	17 Jun.
Leaf fall		12 Dec.	10 Dec.	9 Dec.	6 Dec.	16 Dec.	16 Dec.	12 Dec.	7 Dec.

time of up to 7 days along with rise in altitude of 270 m. In another study Eser and Ozcan (2015) observed significant variations in flowering, pollination and fruit development of kiwifruit from different altitudes within same ecology. Besides, Andic (1993) reported that some factors affecting tree and fruit developments namely temperature, rainfall, wind and vegetation period varied with altitude significantly. All data mentioned above supported our results.

***Vines growth and development status*:** The growth and development of vines at different altitudes is summarized in Table 4. Altitude had significant effect ($p<0.05$) on trunk diameter in the start and end of vegetation, and annual growth rate parameters for both kiwifruit cultivars in two years. The maximum diameter was obtained in kiwifruit plantation grown at 210 m altitude due to older vines (as shown Table 1). Annual growth rate of vines trunk diameter for cv. 'Hayward' varied from 8.24 to 17.01% and 9.80 to 17.43%, and for cv. 'Matua' varied from 7.74 to 17.08% and 11.61 to 22.15% with respect to years 2013 and 2014. The annual growth rates were generally high at 446 and 610 m altitudes compared to other two locations. The fact that kiwifruit plantations were established together with tea gardens which may have positively affected stem development of kiwifruit. Because, N fertilization is applied in tea cultivation to increase vegetative development and annual sprout revival (Kacar, 1984) and this application also may have positively affected vegetative development of kiwifruit trees. Gunes *et al.* (2010) reported that nitrogenous fertilizers positively effected vegetative growth of plants. Our results are in general agreement with previously research reported data.

As shown in Table 5, diameter and length of shoot showed significant differences between altitude levels. Shoot length and diameter decreased with altitude increases in parallel with the shortening of the vegetative periods. Despite this situation, generally shoot length and diameter of kiwifruit cultivars were found to be normal at all altitudes. Andic (1993) reported that, with increase in altitude, vegetative period shortened due to increase in short-wavelength rays. Thus, development of kiwifruit trees was suppressed at high elevations, as observed in this study.

All cultivars in both years showed a rapid growth of shoot diameter from June 1 to October 1. After October 1, growth of shoot diameter slowed down, finally growth of shoot diameter stopped in November 1 (Fig. 3). All cultivars in both years showed a rapid growth of shoot length from June 01 to September 1. After October 1, growth of shoot length stopped (Fig. 4).

In both kiwifruit cultivars, number of leaves per shoot and mean leaf area decreased with increase in altitude and the highest values were achieved at 20 and 210 m altitude levels

Table 4. The development of vine trunk diameters in kiwifruit cultivars at different altitudes.

Varieties	Criteria	Year	Altitude (m)				P-Value
			20	210	446	610	
Hayward	Vine trunk diameter in the start of vegetation (mm)	2013	71.64 b	100.80 a	58.74 c	50.12 c	<0.05
		2014	82.08 b	107.60 a	69.19 c	57.92 d	<0.05
	Vine trunk diameter in the end of vegetation (mm)	2013	81.46 b	109.11 a	68.73 c	57.68 d	<0.05
		2014	90.13 b	119.24 a	81.25 c	66.78 d	<0.05
	Annual growth rate of vine trunk diameter (%)	2013	13.71 ab	8.24 b	17.01 a	15.08 a	<0.05
		2014	9.80 c	10.82 c	17.43 a	15.30 b	<0.05
Matua	Vine trunk diameter in the start of vegetation (mm)	2013	69.16 b	91.38 a	64.38 b	52.14 c	<0.05
		2014	77.73 b	98.81 a	74.34 b	60.52 c	<0.05
	Vine trunk diameter in the end of vegetation (mm)	2013	80.97 b	98.45 a	73.67 b	60.38 c	<0.05
		2014	94.95 b	110.28 a	86.21 c	72.38 d	<0.05
	Annual growth rate of vine trunk diameter (%)	2013	17.08 a	7.74 b	14.43 ab	15.80 a	<0.05
		2014	22.15 a	11.61 b	15.97 ab	19.60 a	<0.05

Table 5. The development of shoot in kiwifruit cultivars at different altitudes.

Varieties	Criteria	Year	Altitude (m)				P-Value
			20	210	446	610	
Hayward	Shoot diameter (mm)	2013	10.12	9.55	9.81	9.12	>0.05
		2014	12.12 a	10.77 ab	10.13 bc	8.90 c	<0.05
	Shoot length (cm)	2013	129.08	130.14	130.16	124.62	>0.05
		2014	160.73 a	153.77 a	139.75 b	128.10 b	<0.05
Matua	Shoot diameter (mm)	2013	11.27 a	9.25 b	12.20 a	10.78 ab	<0.05
		2014	11.58 a	9.55 c	11.78 a	10.62 b	<0.05
	Shoot length (cm)	2013	151.53 a	150.05 a	147.11 a	137.42 b	<0.05
		2014	166.23 a	145.00 b	145.67 b	132.50 b	<0.05

whereas the lowest values were achieved at 610 m altitude (Table 6). These results confirmed the results of Cangi and Karadeniz (1999), who reported that leaf area of kiwifruit cv. 'Hayward' decreased with increasing of altitude. Andic (1993) reported that vegetative growth slowed with increase in altitude. Our result was in accordance with the above-mentioned literature.

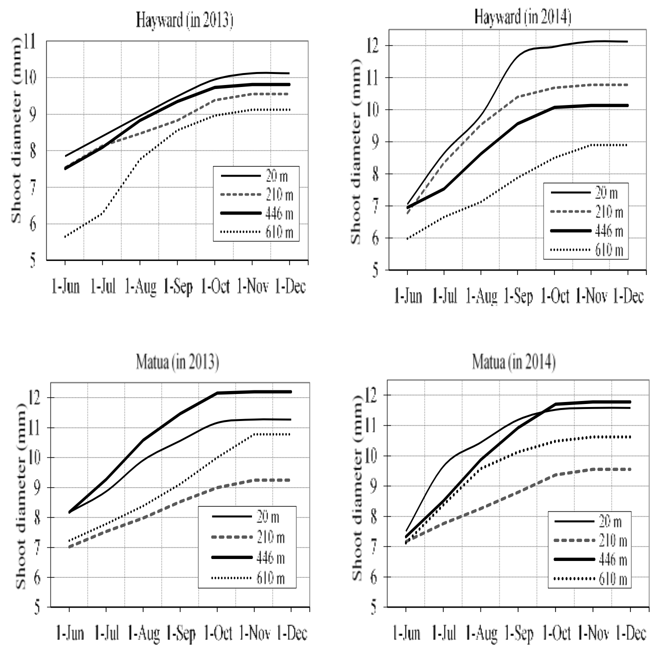

Figure 3. The development of shoot diameter at intervals of 30 days in kiwifruit cultivars at different altitudes.

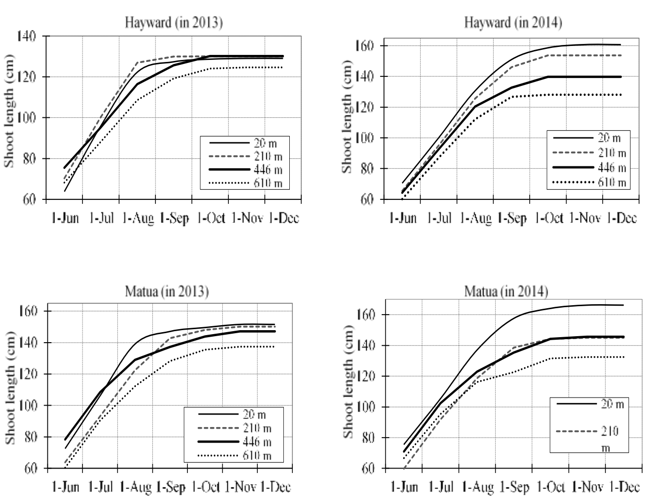

Figure 4. The development of shoot length at intervals of 30 days in kiwifruit cultivars at different altitudes.

In 'Hayward' and 'Matua' cultivars, the effects of altitude levels on number of buds and flowers per shoot were found statistically significant (p<0.05) in both years. The highest results were achieved at 210 m altitude and the lowest results were achieved at 610 m altitude (Table 7). 'Matua' cultivar produced more number of buds and flower compared of 'Hayward' cultivar. Korkutal *et al*. (2004) determined that each axis of cv. 'Matua' carried single, three and five flowers, on the other hand each axis of cv. 'Hayward' carried single or two flowers. These results confirmed the results of several researchers (Sale, 1985; Zenginbal *et al*., 2005). As shown in Table 7, altitude level had non-significant effect (p>0.05) in 2013 and significant effect (p<0.05) in 2014 on number of fruits for cv. 'Hayward'. 'Matua' cultivar does not produce fruit. Because, hermaphrodite flowers on cv. 'Matua' are physiologically male flowers (Sale, 1984). Fruit number decreased with increase in altitude and the highest number of fruits was achieved at 20 and 210 m altitudes whereas the lowest number of fruit was achieved at 610 m altitude. Andic (1993) reported that generative growth decreased with increase in altitude. Similar results were recorded by Pandey *et al.* (2004) in different kiwifruit cultivars.

***Pomological characteristics and chemical analyses*:** The pomological characteristic and chemical analysis of cv. 'Hayward' at various altitudes are given in Table 8. Altitude levels exhibited non-significant effects on width, length, index of fruit in both years. The effects of altitude on fruit weight was found statistically significant (p<0.05) in both years (Table 8). The fruit weight exhibited a wide range of variation at different altitudes, which varied from 80.47 to 96.62 g and 81.56 to 98.82 g, with respect to years 2013 and 2014. Fruit weight decreased with increase in altitude and the highest fruit weight was achieved from kiwifruit plants grown at 20 m whereas the lowest fruit weight was achieved at 610 m altitude. These results confirmed the results of Cangi and Karadeniz (1999) who reported that weight of kiwifruit cv. 'Hayward' decreased with increase in altitude and the fruit weight was obtained 77.05 g and 102.6 g at 600 and 350 m altitude, respectively. Bostan and Günay (2014) reported that weight of cv. 'Hayward' varied with altitude and directions and that the highest fruit weight was obtained at low altitude and from northern directions. According to the results, weight of kiwifruit (cv. 'Hayward') was found to be within normal range (80.47 to 98.82 g) at all altitudes. Beever and Hopkir (1990) reported that fruit weight varied from 80 to 120 g in 'Hayward' cultivars while it varied from 80 to 90 g according to the results of Bostan and Günay (2014). Some studies were conducted in different regions of Turkey, the fruit weight of kiwifruit cv. 'Hayward' range from 62.67 to 91.37 g (Celik *et al*., 2007; Cangi *et al*., 2011; Yildirim *et al*., 2011). Our result was in accordance with the above-mentioned literature. Fruit weight is one of the main factors for fruit quality. The research results show that fruit weight varied with altitude, growing years and cultivation conditions.

Table 6. Comparison of leaf number and leaf area at different altitude of kiwifruit cultivars.

Varieties	Criteria	Year	Altitude (m) 20	210	446	610	P-Value
Hayward	Number of leaf on shoot	2013	19.58 a	17.71 b	17.75 b	16.39 c	<0.05
	(unit/shoot)	2014	21.47 a	20.41 a	18.34 b	16.01 c	<0.05
	Mean leaf area (cm^2)	2013	161.63 a	161.50 a	107.36 b	106.36 b	<0.05
		2014	162.64 a	148.62 a	110.46 b	110.47 b	<0.05
Matua	Number of leaf on shoot	2013	21.78	21.86	19.29	17.17	>0.05
	(unit/shoot)	2014	23.21 a	19.85 b	18.12 c	16.56 d	<0.05
	Mean leaf area (cm^2)	2013	175.80	160.96	159.89	157.80	>0.05
		2014	177.41 a	162.97 ab	161.95 ab	159.21 b	<0.05

Table 7. Comparison of number of bud, flower and fruit at different altitude of kiwifruit cultivars.

Varieties	Criteria	Year	Altitude (m) 20	210	446	610	P-Value
Hayward	Number of buds on shoot	2013	17.34 b	18.82 a	17.67 ab	15.67 c	<0.05
	(unit/shoot)	2014	19.00 b	19.12 a	18.00 c	16.00 d	<0.05
	Number of flower on shoot	2013	5.00 b	10.89 a	6.56 b	5.12 b	<0.05
	(unit/shoot)	2014	6.79 b	11.00 a	7.14 b	6.52 b	<0.05
	Number of fruit on shoot	2013	3.89	5.78	5.11	4.61	>0.05
	(unit/shoot)	2014	6.00 b	6.14 a	5.58 c	4.12 d	<0.05
Matua	Number of buds on shoot	2013	30.32 b	33.00 a	26.07 c	23.00 d	<0.05
	(unit/shoot)	2014	37.87 a	35.00 b	28.00 c	25.00 d	<0.05
	Number of flower on shoot	2013	16.11 a	13.40 ab	15.67 a	12.67 b	<0.05
	(unit/shoot)	2014	18.18 c	21.00 a	19.00 b	16.00 d	<0.05
	Number of fruit on shoot	2013	-	-	-	-	-
	(unit/shoot)	2014	-	-	-	-	-

Table 8. Comparison of fruit quality characteristic at different altitude of kiwifruit cultivars.

Fruit	Year	Altitude (m) 20	210	446	610	P-Value
Width (mm)	2013	53.29	50.97	52.50	48.64	>0.05
	2014	54.62	55.14	53.52	50.12	>0.05
Length (mm)	2013	67.12	67.00	65.11	63.08	>0.05
	2014	68.00	67.14	65.78	62.12	>0.05
Fruit index (diameter/length)	2013	0.79	0.76	0.81	0.77	>0.05
	2014	0.80	0.82	0.81	0.80	>0.05
Weight (g)	2013	96.62 a	94.58 a	89.37 ab	80.47 b	<0.05
	2014	98.82 a	96.62 ab	91.11 ab	81.56 b	<0.05
Yield (kg/shoot)	2013	0.37	0.55	0.40	0.37	>0.05
	2014	0.59 a	0.59 a	0.51 a	0.34 b	<0.05
Firmness (during harvest)	2013	4.00 b	4.16 b	8.03 a	8.32 a	<0.05
(kg/8mm^2)	2014	4.12 b	4.28 b	7.35 a	7.65 a	<0.05
TSS (during harvest) (%)	2013	11.00 ab	11.97 a	10.06 bc	9.32 c	<0.05
	2014	11.12 a	11.67 a	10.76 ab	9.72 b	<0.05
TSS (during eating maturity) (%)	2013	14.97 a	14.81 a	13.78 b	13.62 b	<0.05
	2014	15.18 a	15.18 a	14.12 b	13.85 c	<0.05
pH	2013	4.02	4.01	4.01	3.98	>0.05
	2014	4.04	4.03	4.01	4.01	>0.05
Acidity (%)	2013	1.12	1.11	1.20	1.23	>0.05
	2014	1.10	1.10	1.18	1.22	>0.05
Vitamin C (mg/100ml)	2013	108.60	105.30	110.40	104.40	>0.05
	2014	106.40	102.50	107.70	102.40	>0.05

The yield performance of cv. 'Hayward' at various altitudes are given Table 8. The range of variation in yield was 0.37 to 0.55 kg/shoot and 0.34 to 0.59 kg/shoot, with respect to years 2013 and 2014. The yield was generally quite low at 610 m altitude compared to other three locations. Several researchers (Cangi and Karadeniz, 1999, 2001; Pandey *et al*., 2004) reported that the yield decreased with increase in altitude. Our results agree with these findings.

Fruit firmness is one of the main factors limiting quality and post-harvest shelf life of kiwifruit. Firmness is the key criterion in the assessment of suitability of kiwifruit for export and consumption. The effects of altitude levels on fruit firmness during harvest were found statistically significant (p<0.05) in both years. Fruit firmness during harvest of cv. 'Hayward' changed from 4.0 to 8.32 kg and 4.12 to 7.65 kg, with respect to years 2013 and 2014 (Table 8). Firmness significantly increased with increase in altitude and the highest fruit firmness was achieved at 420 and 610 m altitudes. According to the results, firmness of cv. 'Hayward' was found to be within normal range at all altitudes. Similar results were reported by McDonald (1990) that fruit firmness of cv. 'Hayward' was 7 to 10 kg during harvest. In another study Zenginbal *et al*. (2005) reported that fruit firmness varied from 7.5 to 9.0 kg in 'Hayward' cultivars while it varied from 4.7 to 6.4 kg according to the results of Bostan and Gunay (2014).

Total soluble solids content (TSS) of fruits is considered an index of fruit ripening and an increase in TSS corresponds to conversion of starch to soluble sugars. As seen in Table 8, the effects of altitude on total soluble solid content (TSS) of kiwifruit were found statistically significant (p<0.05) in both years. Fruit TSS during harvest of cv. ‘Hayward’ changed from 9.32 to 11.97% and 9.72 to 11.67%, with respect to years 2013 and 2014. TSS in fruit at eating maturity stage changed from 13.62 to 14.97% and 13.85 to 15.18%, with respect to years 2013 and 2014. TSS decreased with increase in altitude and the lowest result was achieved at 610 m altitude. Temperature has been reported to have significant effects on kiwifruit maturation and the starch turned into sugars at high temperatures (Snelgar *et al*., 2005). Mean daily temperature decreased with increase in altitude and consequently effected fruit quality. Snelgar *et al*. (2005) reported that increase in temperature during summer increased rate of shoot elongation but reduced fruit growth, accumulation of dry matter and fruit firmness. In contrast, increase in temperature during late autumn increased fruit growth but also reduced soluble solids concentration (SSC) of fruit and thus, delayed commercial maturity. Poincelot (1979) reported that, the plants of high altitude began to develop at lower temperatures because the growth season was shorter which ripen the fruits before early autumn frosts. According to the results, TSS of kiwifruit (cv. 'Hayward') was found to be within normal range at all altitudes. In fact, Seker *et al*. (2003) reported that TSS varied from 11.91 to 12.74% for cv. 'Hayward' at harvesting time. Zenginbal *et al*. (2005) reported that TSS varied from 9.5 to 10.0% and 14 to 15% for cv. 'Hayward', respectively. Celik *et al*. (2007) reported that, TSS was found as 7.32% for same cultivars at physiological maturity. Cangi *et al*. (2011) reported that TSS of cv. 'Hayward' was 14.67%. According to Bostan and Günay (2014) reported that TSS varied from 12.70 to 13.88% for cv. 'Hayward' at harvest maturity. Our results are in general agreement with previously reported research data.

Effect of altitude was found non-significant for total titratable acidity and fruit pH in kiwifruit grown at different altitudes (Table 8).

It is well known that kiwifruit, as well as citrus fruits are excellent sources of vitamin C. As shown in Table 8, the vitamin C content showed non-significant differences between altitudes.

***Conclusions*:** The present results indicated that kiwifruit production can be performed economically between 20-610 m of altitudes in Ardeşen district of Rize. But, it is observed that mean values of physical fruit characters were decreased with altitude, hence lower altitudes can be recommended for kiwifruit production. In addition, trees can be damaged in locations with altitude of 400 m and higher due to higher snowfall. For that reason, trees should be lower crowned and pruning should be performed before snowfall. In such regions, chilling injury is prevalent due to early autumn frost. Thus, it is necessary to take some precautions for early fruit harvest (like culturing some varieties having lower temperature requirement) as well as chilling injury.

REFERENCES

Andic, C. 1993. Agricultural ecology, Atatürk University Faculty of Agriculture Lecture Notes, No 106, Erzurum, Turkey.

Basım, H. and H.I. Uzun. 2003. Fruit characteristics of kiwifruit in Antalya conditions. Proc. National Kiwifruit and Berries Symposium, Oct. 23-25, 2003. Karadeniz Technical University, Ordu, Turkey; pp.40-46.

Beever, D.J. and G. Hopkir. 1990. Fruit development and fruit physiology. In: I.J. Warrington and G.C. Weston (eds.), Kiwifruit science and management. New Zealand Society for Hort. Sciences, Wellington; pp.97-126.

Bostan, S.Z. and K. Gunay. 2014. The effects of altitude and direction on fruit quality of ‘Hayward’ (*Actinidia deliciosa* Planch) kiwifruit cultivar. Acad. J. Agric. 3:13-22.

Cangi, R. and T. Karadeniz. 1999. The research on yield and fruit characteristics in Hayward Kiwifruit variety (*A. Deliciosa*) different elevations in Ordu. Black Sea Region Agriculture Symposium, Jan. 4-5, 1999. Samsun, Turkey; pp.425-432.

Cangi, R. and T. Karadeniz. 2001. The researches on changes some physıcals and chemıcals characterıstıcs ın Hayward kiwifruit variety (*A. deliciosa*) in Ordu. J. Qafgaz Univ. 7:169-176.

Cangi, R., E. Altuntaş, C. Kaya and O. Saraçoğlu. 2011. Some chemical and physical properties at physiological maturity and ripening period of kiwifruit (‘Hayward’). Afr. J. Biotechnol. 10:5304-5310.

Celik, A., S. Ercisli and N. Turgut. 2007. Some physical, pomological and nutritional properties of kiwifruit cv. Hayward. Int. J. Food Sci. Nut. 58:411-418.

Chen, K. and Z. Zhang. 1985. Growth and development of Chinese Gooseberry hardwood cuttings. Department of Horticulture, Nanjing Agricultural College, Hort. Abst. 1, China.

Davison, R.M. 1990. The physiology of the kiwifruit vine. In: I.J. Warrington and G.C. Weston (eds.), Kiwifruit Science and Management. New Zealand Soc. for Hort. Sci., Wellington; pp.127-154.

Eriş, A., T. Kamber and N. Sivritepe. 1997. Bud dormancy of kiwifruit grown in Marmara Region. Deutsch-Turkische Agrarforschung Symposium, Sep. 29-Oct. 4, 1997. Antalya, Turkey; pp.187-192.

Eser, Y. and M. Ozcan. 2015. The effect of different altitudes on fruit growth and harvest time in kiwifruit cultivation. 7th Horticultural Congress, Aug. 25-29, 2015. Canakkale Onsekiz Mart University, Çanakkale, Turkey; pp.509-514.

FAO. 2015. Food and agriculture organization of the United Nations. Available Online with updates at http://faostat3.fao.org/download/Q/QC/E.

Ferguson, A.R. and A.G. Seal. 2008. Kiwifruit. In: J.F. Hancock (eds.), Temperate Fruit Crops Breeding: Germplasm to genomics. Springer, Dordrecht, Netherlands.

Guneş, A., M. Alpaslan and A. İnal. 2010. Plant nutrition and fertilization, Ankara University Pub., No 261, Ankara, Turkey.

Kacar, B. 1984. Fertilization of tea, General Directorate of Tea Enterprises (Cay-Kur) Pub., No 4, Ankara, Turkey.

Korkutal, İ., D. Kok, E. Bahar and C. Sarıkaya. 2004. Determination of flower morphologies and phenologies in Hayward and Matua kiwifruit (*Actinidia deliciosa*) cultivars. Mediterr. Agric. Sci. 17:217-224.

Marandi, J.FR. 2007. Small Fruits. Jahad-e Daneshghahi Press, Uremia, Iran.

McDonald, B. 1990. Precooling. Storage and transport of kiwifruit. Ray Richard Publisher, Auckland.

Namdar, S. and M. Ozcan. 2006. The effect of different packing materials on cold storage of Hayward kiwifruit cultivar grown in Samsun ecological condition. Second Small Fruits Symposium; Sept. 14-16, 2006. Gaziosmanpaşa University, Tokat, Turkey; pp.348-353.

Pandey, G., J.S. Chauhan and H.S. Verma. 2004. Effect of altitude on yield and quality attributes of kiwifruit (*Actinidia deliciosa* Planch). Ind. J. Hort. 61:10-12.

Peticila, A.G., F. Stanica, O. Venat-Dumitriu and R. Madjar. 2012. Studies on the multiplication of two new fruit-growing species, *Actinidia deliciosa* and *Actinidia arguta*. An. Univ. Craiova 17:307-314.

Poincelot, P.R. 1979. Horticulture principles and practical application, Prentice Hall, Inc., Englewood Cliffs, New Jersey, USA.

Richardson, A.C., W.P. Snelgar, H.N. De Silva and H.R. Paul. 2001. Variation in flowering within *Actinidia chinensis* vines. NZ J. Crop. Hort. Sci. 29:103-110.

Sale, P.R. 1985. Kiwifruit culture. In: D.A. Williams and V.R. Ward (eds.), Government Printer, 2nd Ed. Welling, New Zealand.

Singletary, K. 2012. Kiwifruit-overview of potential health benefits. Nutr. Today 47:133-147.

Snelgar, W.P., A.J. Hall, A.R. Ferguson and P. Blattmann. 2005. Temperature influences growth and maturation of fruit on 'Hayward' kiwifruit vines. Funct. Plant Biol. 32:631-642.

Strik, B. 2005. Growing kiwifruit (revision), OSU Extension Pub. PNW 507., Washington, USA.

Şeker, M., A. Dardeniz, K. Kaynaş and H. Gacar. 2003. The effects of different pruning applications on phenological characteristics, fruit yield and quality of Hayward kiwifruit cultivar. Proc. National Kiwifruit and Berries Symposium, Oct. 23-25, 2003. Karadeniz Technical University, Ordu, Turkey; pp.61-66.

TUIK. 2015. Prime ministry Turkish statistical institute. Available online with updates at http://tuikapp.tuik.gov.tr/bitkiselapp/bitkisel.zul.

TUMAS. 2016. Turkey meteorological archive system, climate statistics. Available online with updates at http://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?m=RIZE.

Woodward, T.J. 2006. Variation in 'Hayward' kiwifruit quality characteristics. Ph.D. Diss., The Univ. of Waikato, Waikato, Japan.

Yildirim, B., T. Yeşiloğlu, M. Uysal-Kamiloglu, M. İncesu, O. Tuzcu and B. Çimen. 2011. Pomological characterisation of different kiwifruit (*Actinidia deliciosa*) cultivars in Adana (Turkey). Afr. J. Biotechnol. 6:1378-1382.

Zenginbal, H., M. Ozcan and A. Haznedar. 2005. A study on phenologic observations and pomologic analysis in kiwifruit cultivars cultivated under Rize ecological conditions. Derim 22:1-9.