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The Effects of Different Maturity Times of Fruit Ripening and Limb Connection Heights on the Percentages of Fruit Removal in Mechanical Harvesting of Hazelnut (Cv. Yomra)

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ABSTRACT

In this research, the effects of maturity times of fruit ripening (MTR) and limb connection heights of shaker on efficacy of eccentric type shaker which is calculated by the percentages of fruit removal (PFR) in hazelnut (*Corylus avellana* L.) harvesting were assessed. Also, work efficiency of mechanical harvesting was evaluated. Three different timing strategies were determined for shaking and collecting the maturing hazelnuts. The first harvest time was chosen as August 28th which is indicating the approximately half of the matured hazelnuts. The second harvest time (September 7th) includes the term which nearly all the hazelnuts were matured. The natural fruit dropping time was considered as third harvest time (September 15th). Experiments were performed at four different limb connecting heights from the ground (LCH, 0.5 m, 1 m, 1.5 m and 2 m). Effects of maturity times of fruit ripening, limb connecting heights of shaker and their interactions on PFR were found significantly (P<0.01). The first harvest time (26.90%) decreased (P<0.01) the PFR as compared to the second (64.13%) and the third harvest time (69.83%). The LCH of 0.5 m (40.71%) and LCH of 1 m (43.43%) had a lower PFR value as compared to the LCH of 1.5 m (53.50%) and 2 m (57.41%). The effects of harvest times and LCH on the PFR were found to be linear (P < 0.01). The obtained results have showed that for larger orchards, the third harvest time which is used in the present study could be considered to be the best of the three ones with the LHC of 2 m.

Keywords: Hazelnut; Mechanical harvesting; Hazelnut maturing; Percentage of fruit removal; Shaker; Work efficiency

Yomra Çeşidi Fındığın Mekanik Hasadında Meyve Düşürme Yüzdeleri Üzerine Farklı Olgunlaşma Dönemleri ve Dal Bağlama Yüksekliklerinin Etkileri

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ÖZET

Bu araştırmada, fındığın mekanik hasadında eksantrik tipli bir silkeleyiciyle elde edilen meyve düşürme yüzdelerinin, silkeleyicinin farklı dal bağlama yükseklikleri ve olgunlaşma dönemlerine bağlı olarak etkileri belirlenmiştir. Aynı zamanda, mekanik hasadın iş başarıları da değerlendirilmiştir. Olgunlaşan fındıkların silkelenmesi ve toplanması için üç farklı hasat dönemi belirlenmiştir. Birinci hasat zamanı olarak, fındıkların yaklaşık yarısının olgunlaştığı 28 Ağustos tarihi seçilmiştir. İkinci hasat zamanı, hemen hemen tüm fındıkların olgunlaştığı dönemi içermektedir (7 Eylül). Üçüncü hasat zamanı ise, fındıkların doğal olarak yere dökülmeye başladığı dönem olarak değerlendirilmiştir (15 Eylül). Denemeler, zeminden itibaren dört farklı dal bağlama yüksekliğinde (0.5 m, 1 m, 1.5 m and 2 m) yapılmıştır. Meyve düşürme yüzdeleri üzerine; olgunlaşma dönemleri, dal bağlama yükseklikleri ve kendi aralarındaki etkileşim çok önemli bulunmuştur ($P < 0.01$). İkinci (% 64.13) ve üçüncü hasat zamanıyla (% 69.83) karşılaştırıldığında, birinci hasat zamanında (% 26.90) meyve düşürme yüzdesi azalma göstermiştir ($P < 0.01$). Dal bağlama yüksekliklerinin 1.5 m (% 53.5) ve 2 m (% 57.41) olması durumuyla karşılaştırıldığında; 0.5 m (% 40.71) ve 1 m (% 43.43) dal bağlama yükseklikleri daha az meyve düşürme yüzdesi oluşturmuştur. Hasat zamanlarının ve dal bağlama yüksekliklerinin meyve düşürme yüzdesi üzerine etkisi lineer bulunmuştur ($P < 0.01$). Bu çalışmada elde edilen sonuçlar, daha geniş bahçeler için 2 m dal bağlama yüksekliği ve üçüncü hasat zamanın en iyi sonuçları verdiğini göstermiştir.

Anahtar Kelimeler: Fındık; Mekanik hasat; Fındığın olgunlaşması; Meyve düşürme yüzdesi; Silkeleyici; İş başarısı

1. Introduction

The hazelnut (*Corylus avellana* L.) is one of the World's major nut crops, and Turkey has long been the leading producer and exporter of hazelnut (Thompson et al 1996; Aygün et al 2009). Hazelnut, which is one of the traditional export products of Turkey, provides foreign exchange input of nearly 1.5 billion dollar. Furthermore, this product, which is directly or indirectly related to livelihood of nearly 400.000 hazelnut producers, has an important place in Turkey economy (KİBGS 2008; Aktaş et al 2011). In Turkey, hazelnuts remain multi-stemmed, are planted in brush (namely ocak in Turkish) and harvested with hand. Hazelnuts (*Corylus avellana* L.) naturally grow as a large bush, but are pruned to a single trunk in the USA to facilitate mechanical harvesting. In Italy and Spain, trees are pruned to a single trunk or several stems and then they are mechanically harvested. The USA, Italian, and Spanish cultivars drop their hazelnuts from the husk when mature mechanically harvested from orchard ground. Since hazelnuts are fruit which tends to fall spontaneously from the trees, they are mainly harvested by using pick up machines from the ground and thus hazelnuts mechanical harvesting seems to be efficient even in complex situations (Zimbalatti et al 2012). However, Turkish cultivars clasp the hazelnuts in the husk to facilitate hand harvesting. The traditional harvesting methods are generally used as the limbs are shaken with a rod; by hand or by shoving and they enable the hazelnuts to be collected from the ground (Güner et al 2003). Because hand harvesting of hazelnuts is a relatively slow and costly process and there is difficulty in finding workers and need an extensive labor (for example, nearly 306 labor unit hour per hectare) (İlkyaz 1986).

Hazelnuts mature from in early August to late September when they depend on the cultivars such as Tombul, Sivri, Palaz etc. landform and altitude of hazelnut production areas in Turkey. Therefore, the weather must also be taken into consideration in hazelnut harvesting, since rains inhibit harvest and post-harvest processes, and then it becomes much more difficult to hazelnuts drying. In many regions of Turkey, most commercial growers would rather manually shaking and collecting from ground and limbs than the hazelnuts on brush to drop on their own (Beyhan 1992; Yıldız 2000).

The most appropriate harvesting method is to pick up hazelnuts after fruit removal. In other hazelnut producing countries such as the USA, France, Italy and Spain mechanical harvesting is extensively used. The hazelnut orchards are commonly established of single-stemmed. In these countries, mechanized or partly mechanized harvesting systems (pulled harvesters with aspirating tubes or side-pickers, self-propelled vacuum harvesters and mechanical harvesters) of hazelnuts were used for last several years on flat lands (Franco & Monarca 2001). Indeed, it has been found that in the USA the sweep and pick up method is fast and best suited to larger orchards due to the fact that hazelnuts are collected by using a pick up machine after all of the hazelnuts dropped to the ground (Zoppello & Tempia 1988; Ghiotti 1989; Beyhan 1992; Beyhan & Yıldız 1996; Yıldız 2000; Franco & Monarca 2001). However, the studies related to hazelnut harvesting mechanization are scarce for hazelnut orchards with multi-stemmed and planted in brushes.

The fruit removal is commonly achieved by vibrating the limbs or by shaking the trunk of the tree via mechanical shakers (Erdoğan 1988; Erdoğan 1990). Many researchers have studied on some parameters related to shakers frequency, amplitude, shaking time, shaking direction and limb connection height and those related to fruit detachment force/fruit mass and the percentage of fruit removal on various fruits such as citrus, olive, mango, hazelnut, apricot, pistachio and almond with different operating principles of shakers (Chesson 1974; Keçecioğlu 1975; Parameswarakumar & Gupta 1991; Mamedov 1992; Beyhan 1996; Caran 1994; Gezer 1997; Polat 1999).

Gezer & Güner (2000) has determined the effects of the different connecting heights of shaker-arm to the limb on the harvesting efficiency of apricot. In the first studies that were conducted for hazelnut orchards with multi-stemmed and planted in brushes in Turkey, the highest percentage of fruit removal was achieved by vibrating the limbs or by shaking the trunk of the tree via mechanical shakers (Beyhan 1996; Beyhan & Beyhan 1998). Mamedov (1992) have suggested use of 15 Hz frequency, 35 mm amplitude and 5-6 second shaking time for hazelnut mechanical harvesting. Beyhan (1996) have determined the effects of frequency, amplitude and shaking time on the ratio of fruit removal in mechanical harvesting by using eccentric type shaker with values suggested by Mamedov (1992). However, there has been insufficient information on whether efficacy of eccentric type shaker in hazelnut harvesting affected the maturity time of fruit ripening and limb connection height of shaker. Therefore, the aims of the present study which were to assess the effects of maturity time of fruit ripening and limb connection height of shaker on efficacy of eccentric type shaker calculated by PFR in Yomra hazelnut (*Corylus avellana* L.) harvesting and work efficiency of mechanical harvesting.

2. Material and Methods

Trials have been conducted in a hazelnuts orchard of about 1.1 ha, composed of mainly by brushes of 10 years old, with a planting distances of 6x6 m between and in brushes during the harvest season of 2010 (between August 28th and September 15th) (Figure 1).

Figure 1- Hazelnut orchard in which the trials were conducted

Şekil 1- Denemelerin yürütüldüğü fındık bahçesi

The orchard is situated in the municipality of Emiryusuf village which is located in Çarşamba province of Samsun, Turkey. It is a flat area that lies through the sea level. The main cultivated variety is "Yomra" cultivar with multi-stemmed and planted in brush. Some characteristics of the orchard are presented in Table 1.

Table 1- The characteristics of the hazelnut orchard

Çizelge 1- Fındık bahçesinin özellikleri

Establishment age of the orchard (year)	10
Planting form	Brush
In and between row spacing (m x m)	6 x 3
Limb number in a brush (ave.)	13
Limb length (mm) (ave.)	298
Orchard yield (kg ha^{-1})	1800–2000
Orchard area (ha)	1.1
Total brush number (brush ha^{-1})	400

An air-cooled and single-piston manual shaker with two-stroke gasoline engine (OLEO-5 MAC 530, Italy) was used in the experiments (Figure 2). Some technical properties of the shaker are given in Table 2. Periodical shaking movements were applied to the limbs by a clamp (42 mm width) located at the boom of the shaker. Limb diameters were measured by using digital calipers with a precision of 0.01 mm. An electronic scale with a precision of 0.01 g was used for determining of fruit weights. In and between row spacing distances, brush dimensions and limb lengths were measured by using a steel measuring tape.

Three different timing strategies were used for collecting the maturing hazelnuts. For determining the harvest times, ten randomly selected brushes were shaken manually from the beginning of August with one week intervals. The date of August 28, at which approximately half of the hazelnuts were dropped, was determined as first harvest time. The second harvest time (September 7th) includes the term which nearly all the hazelnuts were matured. The natural fruit dropping time was considered as third harvest time (September 15th).

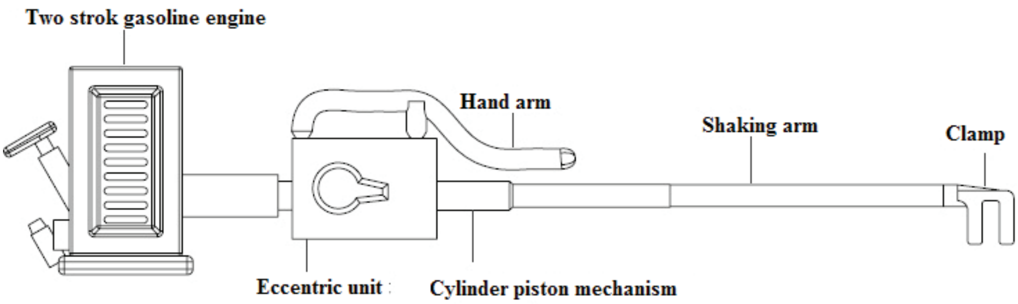

Figure 2- Eccentric type shaker used in experiments

Şekil 2- Denemelerde kullanılan eksantrik tipli silkeleyici

Table 2- Technical characteristics of the shaker

Çizelge 2- Silkeleyicinin teknik özellikleri

Cylinder volume	52.5 cc
Power	2.8 HP / 2.1 kW
Fuel capacity	1.5 liter
Extension bar length	2000–3000 mm
Weight	14.5 kg (Clamp+extension bar)
Engine	Two-stroke gasoline
Cylinder diameter x stroke	45x33 mm
Max. engine speed (unloaded)	11700 min^{-1}
Max. torque	3 Nm (5700 min^{-1})
Number of vibration per minute	900 (5295 min^{-1})
Amplitude	30 mm
Frequency	15 Hz
Fuel consumption	777 gr h-1 (5295 min^{-1})

Four different limb connecting heights from the ground (LCH, 0.5 m, 1 m, 1.5 m and 2 m) were used. The average height of the limbs was measured for determining the LCH. The limb connection heights were determined by dividing the limb heights into four parts from the upper 2/3 part of the limb (Beyhan 1996).

The pull force values were measured with a force gauge (MACRONA, capacity: 500 N, resolution: 0.1 N) for determining the spring rigidities. Limbs were pulled perpendicular to their axes at the different displacements (40, 60, 80, 100, 120, 140, 160 mm) and 1000, 1500 and 2000 mm heights above orchard ground and then maximum pull forces were recorded. A steel rule was used to measure the displacements of the limbs. Limb diameters at these points were measured with digital caliper. The calculated force (F) values and displacements of limbs (x) were put in the equation given below and spring rigidities were determined (Gezer 1999).

$$C = \frac{F}{x} \quad (1)$$

where; C, spring rigidity (N mm^{-1}); F, pull force (N); x, displacement quantity of limb (mm).

The experimental plot was composed of three rows of about 120 m of length. It is considered that each row constitutes a replicate and then, three rows replicates have been achieved. Time measurement started when the shaker was positioned at the beginning of the first row, as being ready to start shaking, and it finished at the end of the last row. The 15 Hz frequency, 30 mm amplitude and 5 second shaking time were used in experiments. Time measurements were made with a digital chronometer (CASIO).

To evaluate working efficiency, two methods such as hand harvesting and mechanical harvesting of hazelnuts were compared to the average time in hour (h) needed to harvest one hectare (ha) area, the number of brush harvested per hour and the harvested area per hour. For the hand harvesting method, the hazelnuts fruits were picked by hand individually; both the traditional and the mechanical harvesting methods. The percentage of fruit removal was determined by the following equation.

$$PFR = \frac{MFR}{MFR + MFUR} x100 \quad (2)$$

Where; PFR is percentage of fruit removal (%); MFR is the mass (g) of fruit removed by using shaker and

MFUR is the mass (g) of fruit unremoved by using shaker.

Time measurements concerned the following parameters (Beyhan & Pınar 1996; Yıldız 2000; Zimbalatti et al 2012). *ET*, effective time (necessary for harvesting); *AT*, accessory time; *TAV*, accessory time for moving to the second row; *TAC*, accessory time for handling. Thus, operative times (*OT*) for mechanical and hand harvesting were determined by the equation below

$$OT = ET + AT \quad (3)$$

Work efficiency per unit area (WPA) were determined the following equation.

$$WPA = \frac{1}{OT} \quad (4)$$

2.1. Statistical analysis

Shapiro-Wilk normality test which had been carried out previously showed that the data had a normal distribution. An analysis of variance was performed in a completely randomized design with a 2×2 factorial arrangement of treatments (Maturity time of fruit ripening and limb connecting heights):

$$Y_{ijk} = \mu + T_i + A_j + TA_{ij} + e_{ijk} \quad (5)$$

Where; Y_{ijk} is observation value (percentage of fruit removal); μ is the overall mean; T_i is the effect of the i_{th} maturity time of fruit ripening (1 = first harvest time, August 28th; 2 = Second harvest time, September 7th; 3 = Third harvest time, September 15th, 2010); A_j is the effect of the j_{th} limb connecting heights (1 = 0.5 m, 2 = 1 m, 3 = 1.5 m, 4 = 2 m); TA_{ij} is the effect of interaction between maturity time of fruit ripening and limb connecting heights; e_{ijk} represents residual error.

Tukey multiple range test was then utilized to separate these differences. Results from harvesting treatment 0.5 m through 2 m and from maturity time of fruit ripening of August 28th to September 15th, 2010 were analyzed as an orthogonal polynomial. Linear, quadratic and cubic effects were determined by orthogonal polynomial contrasts (SPSS 10.0V., 1999).

3. Results and Discussion

Descriptive statistics of spring rigidity for different average limb diameters, MFR and MFUR (Mean ± SD) by shaking of different limb connection heights and maturity times of fruit ripening were presented in Table 3 and Table 4, respectively. As seen Table 3, spring rigidity values varied within large limits depending on limb diameters and LCH. And also, the PFR values at different maturity times of ripening and limb connection heights were given in Table 5. The PFR was affected by maturity time of fruit ripening and limb connecting height of shaker ($P < 0.01$) and their interaction. The first harvest time reduced ($P < 0.01$) the PFR as compared to the second and third harvest times. As seen from Table 4, the highest PFR (81.61%) was obtained at third harvest time and at the highest limb height (2 m), corresponding to the 2/3 of the average limb height (Beyhan 1996). The PFR in the mechanical harvesting related to the LCH and the time of picking the maturing hazelnuts are presented in Figure 3 and Figure 4, respectively.

Table 3- Descriptive statistics of spring rigidity for different average limb diameters (Mean ± SD)

Çizelge 3- Ortalama farklı dal çapları için yaylanma katsayılarının tanımlayıcı istatistikleri

Average limb diameter (mm)	*Limb connection height (mm)*	*Spring rigidity (N mm^{-1})*	*Standard deviation*
22.21	2000	0.140	±0.010
	1500	0.416	±0.023
	1000	0.655	±0.046
25.88	2000	0.177	±0.010
	1500	0.701	±0.051
	1000	1.230	±0.040
32.53	2000	0.380	±0.042
	1500	1.061	±0.025
	1000	2.317	±0.162

Table 4- Descriptive statistics of fruit removal by shaking for different limb connection heights and maturity times of fruit ripening (Mean ± SD)

Çizelge 4- Farklı olgunlaşma zamanları ve dal bağlama yükseklikleri için silkelemeyle düşürülen meyve yüzdesinin tanımlayıcı istatistikleri

	First harvest time (August 28th)		
LCH, m	MFR, g	MFUR, g	TFM, g
0.5	797 ± 370	2587 ± 160	3384 ± 472
1	854 ± 391	2698 ± 1174	3552 ± 1518
1.5	634 ± 438	1752 ± 899	2386 ± 1296
2	437 ± 299	917 ± 648	1354 ± 937
	Second harvest time (September 07th)		
LCH, m	MFR, g	MFUR, g	TFM, g
0.5	750 ± 110	889 ± 95	1639 ± 18
1	895 ± 266	581 ± 261	1476 ± 139
1.5	823 ± 278	224 ± 52	1046 ± 230
2	760 ± 337	261 ± 49	1021 ± 384
	Third harvest time (September 15th)		
LCH, m	MFR, g	MFUR, g	TFM, g
0.5	771 ± 182	577 ± 153	1348 ± 332
1	1333 ± 653	664 ± 223	1997 ± 875
1.5	3216 ± 833	1041 ± 204	4257 ± 722
2	2141 ± 927	511 ± 292	2652 ± 1208

Table 5- The percentages of fruit removal by eccentric type shaker in hazelnut harvesting subjected to different limb connection heights and maturity time of fruit ripening

Çizelge 5- Farklı olgunlaşma zamanları ve dal bağlama yüksekliklerine bağlı olarak fındık hasadında eksantrik tipli silkeleyiciyle düşürülen meyve yüzdeleri

	Maturity time of fruit ripening			
LCH, m	*First harvest time (August 28th)*	*Second harvest time (September 07th)*	*Third harvest time (September 15th)*	*SDM**
0.5	22.79f	45.73de	65.57abc	19.63
1.0	24.71f	60.67bcd	57.38cd	19.65
1.5	26.47ef	77.30ab	74.76abc	26.98
2.0	33.64ef	72.82abc	81.61a	23.48
SDM	7.35	15.56	10.44	

Means in the same row not sharing a common letter are significantly different ($P<0.05$). *, SDM, standart deviation of the mean; CV, 47.03%

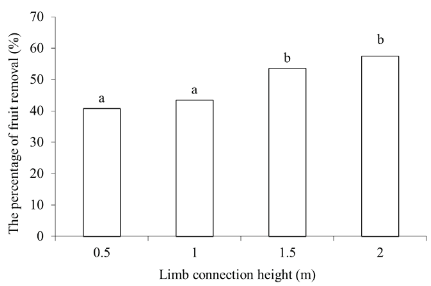

Figure 3- The percentages of fruit removal by eccentric type shaker in hazelnut harvesting subjected to different limb connection heights. Means in the same bar not sharing a common letter are significantly different ($P < 0.01$)

Şekil 3- Farklı dal bağlama yüksekliklerine bağlı olarak fındık hasadında eksantrik tipli silkeleyiciyle düşürülen meyve yüzdeleri. Aynı harfe sahip olmayan sütunlardaki ortalamalar çok önemli derecede farklıdır (P < 0.01)

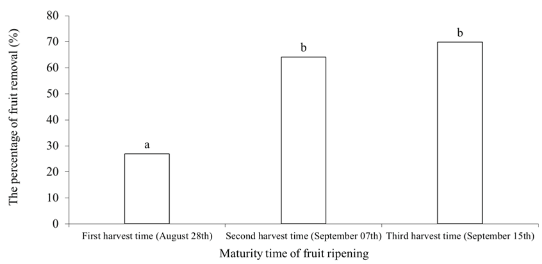

Figure 4- The percentages of fruit removal by eccentric type shaker in hazelnut harvesting subjected to maturity time of fruit ripening. Means in the same bar not sharing a common letter are significantly different ($P < 0.05$)

Şekil 4- Farklı olgunlaşma dönemlerine bağlı olarak fındık hasadında eksantrik tipli silkeleyiciyle düşürülen meyve yüzdeleri.Aynı harfe sahip olmayan sütunlardaki ortalamalark önemli derecede farklıdır (P < 0.05)

The first harvest time (26.90%) reduced ($P < 0.05$) the PFR as compared to the second (64.13%) and third harvest times (69.83%). The LCH of 0.5 m (40.71%) and LCH of 1 m (43.43%) had a lower PFR value compared to the LCH of 1.5 m (53.50%) and 2 m (57.41%). Therefore, the effects of harvest times and LCH on the PFR were found to be a linear trend ($P<0.01$). Changes in the percentage of fruit removal, due to different limb connection heights and maturity times of fruit ripening in Yomra hazelnut cultivar determined by following equation, are given in Figure 5.

$$PFR(\%) = 11.227 + 18.633LCH + 3.838MTR - 0.104MTR^2 \quad (6)$$

Where; first harvest time, second harvest time and third harvest time values are 1 (August 28th), 11 (September 07th) and 19 (September 15th), respectively.

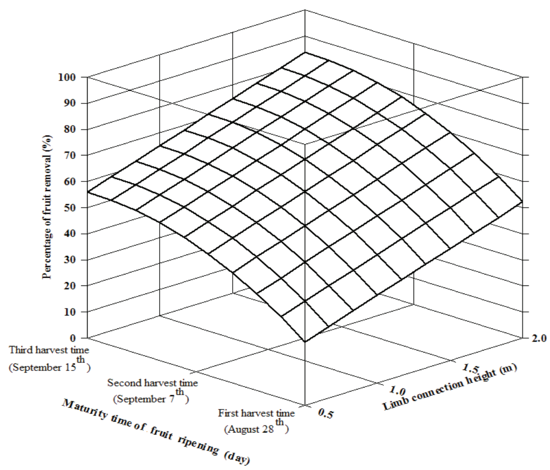

Figure 5- Changes in the percentage of fruit removal due to different limb connection heights and maturity time of fruit ripening in Yomra hazelnut cultivar

Şekil 5- Yomra çeşidi fındıkta farklı olgunlaşma dönemleri ve dal bağlama yüksekliklerine bağlı olarak düşürülen meyve yüzdelerindeki değişim

Fruit maturity has an important effect on the force which is required for removal on mechanical properties (Kader 1983). Husky hazelnuts and husky stems are blushed due to their moisture losses as they are ripened and results in loss of flexibility of husky stems. The higher percentages of fruit removal at mentioned date can be attributed to flexibility losses of husky stems. Furthermore, it can be said that vibrations are distributed more evenly on the limb that results in increasing the fruit harvest ratio (Tuncer & Özgüven 1989; Beyhan 1996). Unfortunately, such machines offer work efficiency three or four times lower than hand harvesting; therefore a significant decline of working times can be reached. The reason for this low value, in the form of high non-productive time zone can be explained. One of the reasons is the low capacity of shaker's fuel tank; the fuel requirement increases quickly and runs out when it is needed (Beyhan & Pınar 1996). However, while percentages of fruit removal were found as 62.38% in the hand shaking method, these ratios were 81.61% in the trials in which shakers were used. This indicates that 20% more product can be obtained when the shaker is used in harvesting operation.

The 1.5 m and 2 m LCH led to the highest percentage of fruit removal at second and third harvest time. At this harvest time, higher PFR (81.61%) was obtained at 2 m limb connection height though there were no statistical differences between the 1.5 and 2 m limb connection heights. The similar findings were reported by Beyhan (1996) who used eccentric type shaker with 15 Hz frequency, 35 mm amplitude and 5 second shaking time. The highest PFR were found as 86.25% in Palaz variety and 83.04% in Tombul variety, respectively. Unfortunately, 100% percentage of fruit removal could not be attained by shaking. The efficiency of shaker declines because of the hazelnut fruits on even the same limb ripen at different times and also the connection forces changing widely. For this resaon, it can be beneficial to use abscission chemicals, which lead to synchronized growth of hazelnut fruits, in mechanical harvesting (Beyhan & Beyhan 1998; Yıldız 2010).

Harvesting rates of both hand and mechanical hazelnut harvesting are presented in Table 6. The highest harvesting rate was obtained by hand harvesting. Indeed, in our trial conditions, mechanical harvesting had an average value of 156.9 h ha^{-1} for OT which was higher than the hand harvesting one (99.2 h ha^{-1}).

Table 6- The comparison of work efficiencies for hand and mechanical harvesting

Çizelge 6- Mekanik hasat ve elle yapılan hasattaki iş başarılarının karşılaştırılması

	Harvesting methods	
Work efficiencies	*Hand*	*Mechanical*
Time needed to harvest one hectare area, h ha^{-1}	99.2	156.9
Number of brush harvested per hour, brush h^{-1}	4.03	2.55
Area harvested per hour, ha h^{-1}	0.0101	0.0064

4. Conclusions

The obtained results showed that for larger orchards, the third harvest time was considered to be the most suitable harvest time with the LCH of 2 m and due to the fact that the shaker can work faster with less and without damage to material on the brush, and also such a machine offer a lower work efficiency than manual harvesting. In terms of WPA and the number of brushes harvested per hour, hand harvesting had a higher value than mechanical harvesting. Therefore, the findings have indicated that labor requirements are higher and work efficiencies are lower in harvest using shakers compared to those of manually shaking. Contrarily, it was observed that use of shaker in harvesting ensured more comfortable working conditions. Also, it was performed the most fruit removal from the limbs by using of shaker.

It can be concluded that use of shaker in hazelnut harvesting is suitable in terms of agrotechnical and, also it is possible to decrease harvesting costs and labour requirements by using suitable mechanical pick up machines for collecting of hazelnuts which are dropped by shakers.

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Abbreviations and Symbols	
MTR	maturity time of fruit ripening
PFR	percentage of fruit removal, %
LCH	limb connecting height, m
MTR	the mass of fruit removed by using shaker, g
MFUR	the mass of fruit unremoved by using shaker, g
C	spring rigidity, N mm^{-1}
F	pull force, N
x	displacement quantity of limb, mm
ET	effective time (necessary for harvesting), h ha^{-1}
AT	accessory time, h ha^{-1}
TAV	accessory time for moving to the second row, h ha^{-1}
TAC	accessory time for handling, h ha^{-1}
OT	operative times, h ha^{-1}
WPA	work efficiency per unit area, ha h^{-1}
TFM	total fruit mass, g
SD	standard deviation
CV	coefficient of variation, %
SDM	standard deviation of mean

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