Turkish Journal of Agriculture and Forestry
http://journals.tubitak.gov.tr/agriculture/
Research Article
Turk J Agric For
(2016) 40: 301-310

doi:10.3906/tar-1508-114

Labor requirements and work efficiencies of hazelnut harvesting using traditional and mechanical pick-up methods

Taner YILDIZ*
Agricultural Machinery Program, Samsun Vocational School, Ondokuz Mayıs University, İlkadım, Samsun, Turkey

Received: 30.08.2015 • **Accepted/Published Online:** 02.12.2015 • **Final Version:** 18.05.2016

Abstract: This study was completed with the aim of determining labor requirements, work efficiencies, and total costs of 6 different traditional hazelnut pick-up methods, along with 3 different mechanical harvest methods using a portable-type pneumatic hazelnut harvesting machine, on flat ground in two hazelnut orchards with linear and brush planting systems. Trials were conducted in the two different orchards in the August 2013 harvesting season. Among traditional pick-up methods, the lowest unit of human labor requirements (units of human labor power, h ha^{-1}) in an orchard with a linear planting system was obtained (180.17 h ha^{-1}) for the method involving Ethrel administration, hand-shaking, and rows gathered by garden rake (first method). For the brush-planting system orchard, the lowest value (157.39 h ha^{-1}) was obtained with the method with no Ethrel administration, hand-shaking, and rows gathered by scrub rake (fourth method). In terms of work efficiencies, the best values were obtained (0.0056 ha h^{-1}) for the first method for the linear system and for the third method for the brush system (0.0058 ha h^{-1}). In terms of time utilization coefficient, the different pick-up methods with the hazelnut harvesting machine obtained lower levels compared to the different traditional hazelnut pick-up methods. In trials of different methods of traditional pick-up, the lowest value for total harvest costs was obtained for the method with Ethrel administered and rows gathered by garden rake in the linear system (first method) (6666.29 Turkish lira (TL) ha^{-1}). For the brush-planting system the lowest value was for the fourth method with 5283.43 TL ha^{-1}. In the brush-planting system with the mechanical pick-up method, the lowest value was 1637.42 TL ha^{-1} for the pick-up method with rows gathered by garden rake (third method). Amounts of hazelnuts obtained per unit of time for traditional methods were 5.25 kg h^{-1} for the first method in linear planting and 4.49 kg h^{-1} for the third method in the brush-planting system. For hazelnut harvesting machine pick-up, the amount was 35.40 kg h^{-1} for pick-up with rows gathered by garden rake (third method). Accordingly, the hazelnut harvesting machine can collect the amount that 6.74 people can collect traditionally.

Key words: Hazelnut, labor requirements, mechanical harvesting, total costs, traditional harvesting, work efficiency

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. Hazelnut, which is one of the traditional export products of Turkey, provides foreign exchange input of nearly 1.5 billion dollars. Furthermore, this product, which is directly or indirectly related to the livelihood of nearly 400,000 hazelnut producers, has an important place in Turkey's economy (Thompson et al., 1996; KİBGS, 2008; Aktaş et al., 2011; Yıldız and Tekgüler, 2014).

Hazelnut is mainly cultivated in the Black Sea Region of Turkey and it has been reported that almost 549,000 t of hazelnut per year is produced on 422,501 ha over 13 provinces. This amount is equal to nearly 64% of the total world hazelnut production. Italy and the United States follow Turkey with 13.12% and 4.72%, respectively. (http://faostat.fao.org/). In Turkey, hazelnut orchards are typically located within 30 km of the coast and inland. In the Western Black Sea area, the growing region starts from Zonguldak (east of İstanbul) and extends east over the entire Black Sea Region and the mountains, almost until the Georgian border. The Black Sea Region is divided into three distinct growing areas: 1) the hilly region from Ordu to Trabzon, centered around Giresun, which in a normal year produces about 55% of the crop; 2) the flatter, mixed farming region west of Ordu to Samsun, which produces about 15% of the crop; and 3) the area west of Samsun, which produces the remaining 30%. Hazelnuts require relatively little effort to cultivate and inputs are low. Turkish hazelnuts usually ripen between early and late August, depending on the altitude of the orchard and climatic conditions (USDA, 2014). Harvesting takes place during several weeks in August and September. Due

* Correspondence: tyildiz@omu.edu.tr

to high temperatures, hazelnut harvesting has started 1 week earlier than normal the harvest time at the end of July at lower altitudes (0–250 m), the first week of August at middle altitudes (250–500 m), and the second week of August at higher altitudes (above 500 m). Most of these areas are not suitable for other agricultural uses, having more than 20% slope. The slope fragmentation of cultivated areas and cultivar characteristics do not allow for mechanization, except for lowlands. This leads to increases in hazelnut production costs and also in labor-intensive requirements during the harvest period.

In Turkey, most hazelnuts remain multistemmed and are planted in brush. All of the hazelnut harvesting is still done entirely by hand in Turkey. The most appropriate harvesting method is to pick up the hazelnuts after fruit dropping, but fruit dropping might be delayed to the first week of September. The rainfall during this period makes the harvest and postharvest processes difficult. Furthermore, during recent years the harvest is initiated in the first week of August for fear of not finding workers. During this harvest husky fruits are picked by hand as they do not drop by themselves. Hazelnuts are generally hand-picked from the branches. This traditional harvesting method is more costly and requires more labor and exposure time during the harvest period. As usual, the higher labor requirement increases the production costs.

For harvesting this much, 306 units of human labor power in hours per hectare (UHLP h ha^{-1}) is needed in Turkey. This amount represents 71% of total working time and 55% of production costs (İlkyaz, 1986). In other research, it was found that hazelnut harvesting requires 54 UHLP h ha^{-1} in the lowland (plain) villages of Terme and Çarşamba of Samsun district (Kılıç, 1997). This represents 72.90% of total working time. This causes increases in human labor and production costs. For this reason, the labor costs must be decreased in hazelnut production, as well. It is possible to decrease production costs by mechanization (Beyhan, 1996; Beyhan and Yıldız, 1996; Yıldız, 2000; Tekgüler et al., 2015).

Traditional harvesting methods are generally used such as the branches being shaken with a rod, by hand, or by shoving, and this enables the hazelnuts to be collected from the ground (Güner et al., 2003). However, Turkish cultivars clasp the hazelnuts in the husks. Hand harvesting of hazelnuts is a relatively slow and costly process, and there is difficulty in finding workers and a need for extensive labor. Hazelnuts mature from early August to late September among cultivars such as Tombul, Sivri, Palaz, etc., depending of the 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 postharvest processes, and then it becomes much more difficult to dry hazelnuts. For this reason, most commercial growers would rather collect from branches and manually shake the branches and collect from the orchard ground than wait for the hazelnuts on brush to drop on their own in many regions of Turkey (Beyhan, 1992; Yıldız, 2000).

This study was completed with the aim of determining the labor requirements, work efficiencies, and total costs of 6 different traditional hazelnut pick-up methods, along with 3 different mechanical harvest methods using a portable-type pneumatic harvesting machine, on flat ground in two hazelnut orchards with linear and brush-planting systems.

2. Materials and methods

2.1. Material

2.1.1. Hazelnut orchards used for trials

Trials were completed in two different orchards belonging to farmers in Karacalı village linked to Terme district in the province of Samsun. The first orchard was 1.6 ha, with a brush-planting system. The orchard mainly contained Palaz-type hazelnuts, with some Tombul, Yerli, Hanım, Acı, Kalınkara, Sivri, and Ham hazelnuts present. The areas between the rows in the orchard were plowed and leveled with a rake. However, it still had an uneven surface. There were no weeds between the rows. Above the rows mowing was completed with scythes with weeds, ivy, etc. reaching about 10 cm. Within the brushes, cleaning of the bottom suckers had not been done and in some brushes blackberry brambles were found. The Palaz hazelnut drops up to 70% toward the end of the harvest, while Yerli hazelnuts drop 90% and both Yerli and Hanım hazelnuts are observed as mainly single nuts. The second orchard is 1.0 ha in size, with a linear planting system. The orchard had a 1500 ppm dose of Ethrel applied on 8 August 2013. The garden did not have bottom suckers cleared, was not plowed, and was not cleared of dried plants and leaves, and the rows were completely filled with dried leaves. The area between the rows was uneven and covered with leaves and plants. The height of the weeds varied from 15 to 20 cm. Within the rows brambles and ivy were encountered occasionally. The characteristics of the orchards used as trial areas are given in Table 1.

2.1.2. Measuring devices used for trials

To weigh hazelnuts and other foreign material, electronic scales of 750 g in capacity and 0.001 g in sensitive were used. A CASIO chronometer was used for time measurements. In order to gather dropped single and husked hazelnuts into rows, a hard-bristle scrub rake and adjustable fan rake were used.

2.1.3. Portable pneumatic hazelnut harvesting machine used for trials

The pneumatic hazelnut harvesting machine used in the trials had a 3.68 kW back-pack type, electronic ignition, two-stroke Otto motor and could also be used as a leaf blower. The leaf-blowing feature of the machine was used to gather hazelnuts into rows in both brush and linear

Table 1. The characteristics of the hazelnut orchard with linear planting system and brush-planting system.

	Linear planting system	Brush-planting system ('ocak' in Turkish)
Establishment age of the orchard (years)	10	11
In and between row spacing (m × m)	6	6 × 3
Limb length (mm) (avg.)	314.20	298
Orchard area (ha)	1.0	1.6
Average linear planting system width and dimensions (sizes) of brushes (m × m)	94.25	80.70 × 189.06

planting systems. Other technical characteristics of the hazelnut harvesting machine are given in Table 2.

2.2. Method

2.2.1. Traditional pick-up methods

Trials were completed 18–30 August 2013. The weather was clear and sunny with no rain. The trials used six different traditional pick-up methods. The traditional pick-up methods are listed below:

1. Traditional method: Pick-up by gathering rows with a garden rake in an orchard with linear planting system and Ethrel applied.
2. Traditional method: Pick-up without gathering rows in an orchard with linear planting system and no Ethrel applied.
3. Traditional method: Pick-up after gathering in rows with a garden rake in an orchard with brush-planting system and no Ethrel applied.
4. Traditional method: Pick-up after gathering in rows with a scrub rake in an orchard with brush-planting system and no Ethrel applied.
5. Traditional method: Pick-up only from branches and the ground in an orchard with bottom suckers and brush-planting system.
6. Traditional method: Pick-up only from branches and the ground in an orchard with no bottom suckers and brush-planting system (assessed as a control group, only collecting from branches, ground, and within brush with no harvesting aid).

Table 2. Some technical characteristics of the back-pack hazelnut harvesting machine.

Cylinder volume	70 cc
Max. engine speed (unloaded)	6000 min^{-1}
Air flow rate	640 m^3 h^{-1}
Air velocity	100 m s^{-1}
Fuel depot capacity	1.8 L
Hazelnut depot storage	15 kg
Net weight	15.5 kg

2.2.2. Mechanical pick-up methods

Pick-up trials with the back-pack pneumatic hazelnut harvesting machine were performed in the orchard with a brush-planting system. The methods were as follows:

1. Method: Mechanical pick-up from the ground after machine blowing.
2. Method: Mechanical pick-up from the ground after gathering rows with a garden rake.
3. Method: Mechanical pick-up from the ground after gathering rows with a scrub rake.

2.3. Evaluation of measurements and results

2.3.1. Time measurements

The procedures completed in the trials were divided into three labor stages and in a similar fashion the total working time for each procedure comprised three time segments (Kadayıfçılar and Dinçer, 1972; Beyhan and Pınar, 1996; Yıldız, 2000; Yıldız and Tekgüler, 2012). Pick-up trials in orchards with linear and brush-planting systems using traditional pick-up methods were evaluated in time segments of h ha^{-1} in the following way:

1. Basic time (BT_m):
   a. Time to shake branches (t_m BT_1),
   b. Time to gather rows (t_m BT_2),
   c. Time to collect from the ground by hand (t_m BT_3),
   d. Time to collect remainder from branches by hand (t_m BT_4),
   e. Time to collect within the linear and brush-planting systems (t_m BT_5).
2. Auxiliary time (AT_m): Necessary time spent, found by combining a variety of time segments. Auxiliary time was divided into subgroups (Yıldız, 2000). These are:
   a) Time to have breakfast (t_m AT_1),
   b) Journey time or time to reach the orchard (t_m AT_2),
   c) Morning break time (t_m AT_3),
   d) Lunch time (t_m AT_4),
   e) Afternoon break time (t_m AT_5)
   f) Time to move between brushes-linear planting (t_m AT_6).

3. Unavoidable time losses (UTL_m).

Pick-up trials in orchards with a linear planting system using a back-pack type pneumatic hazelnut harvesting machine were arranged in time segments of h ha^{-1} in the following way:

1. Basic time (BT_p):
   a. Time to shake branches by hand (t_p BT_1),
   b. Time to collect from the ground with hazelnut harvesting machine (t_p BT_2),
   c. Time to collect remainder from branches by hand (t_p BT_3),
   d. Time to collect from within the brush (t_p BT_4).
2. Auxiliary time (AT_p):
   a. Time to move between rows-brushes (t_p AT_1),
   b. Time to fill tank (t_p AT_2),
   c. Time to shoulder hazelnut harvesting machine (t_p AT_3),
   d. Time to gather rows by blowing/using scrub rake/using garden rake (t_p AT_4),
   e. Time to start motor (t_p AT_5),
   f. Time for fuel and oil to mix (t_p AT_6),
   g. Time to empty storage (hazelnut depot) (t_p AT_7),
   h. Time to vacuum from the ground with machine (t_p AT_8),
   i. Time to have breakfast (t_p AT_9),
   j. Journey time - time to reach orchard (t_p AT_{10}),
   k. Morning break time (t_p AT_{11}),
   l. Lunch time (t_p AT_{12}),
   m. Afternoon break time (t_p AT_{13}).
3. Unavoidable time losses (UTL_p).

2.3.2. Calculation of labor requirements and work efficiencies

To calculate labor requirements and work efficiencies, arithmetic means of measurements of the time segments for each process were used (Beyhan and Pınar, 1996). To determine work efficiency in the orchard, effective working time (EWT) was noted. To determine EWT, first basic time (BT) and auxiliary time (AT) were added to calculate principal time (PT).

$$PT = BT + AT \text{ (h ha}^{-1}\text{)} \quad (1)$$

Effective working time (EWT) was calculated from the following equation.

$$EWT = BT + AT + UTL \text{ (h ha}^{-1}\text{)} \quad (2)$$

Unavoidable time loss (UTL) was determined as a percentage of the principal time obtained by adding basic and auxiliary time (Caran, 1994, Beyhan and Pınar, 1996; Yıldız, 2000).

$$UTL = \frac{P}{100} PT \quad (3)$$

Here, P is a multiplication factor showing variations according to the hazelnut harvesting machine used and labor power. In this study, for labor power P was 1, while for machine power P was 6 (Caran, 1994; Beyhan, 1996; Yıldız and Tekgüler, 2012).

The working efficiency per unit area (WPA) in the study with the hazelnut harvesting machine was determined with the following equation, linked to the EWT.

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

The utilization coefficient (UC_z) was calculated from the following equation using total time.

$$UC_z(\%) = \frac{BT}{EWT} 100 \quad (5)$$

The trials were completed on 3 rows of hazelnuts of 120 m in length in the linear hazelnut orchard and in groups of 10 brushes in the brush hazelnut orchard. Here, each hazelnut row was assessed as a repeat. To measure time segments, the chronometer was started when the laborer began on the first row and stopped when the end of the row was reached (Bolli and Scotton, 1987; Zimbalatti et al., 2012).

2.3.3. Determination of harvest expenses by traditional methods and mechanical pick-up

The study collated expenses related to using the hazelnut harvesting machine into two groups: fixed expenses (interest, depreciation, and protection costs) and variable expenses (fuel costs, oil costs, personnel costs, and repair and maintenance costs) (Dinçer, 1976; Kadayıfçılar and Erdoğan, 1988; Yıldız, 2000). Fixed expenses are not linked to the use of tools and machines; even if the machine is not used, these costs must be calculated. Yearly fixed expenses vary depending on the hazelnut harvesting machine, but the mean is about 22%–28% of the sale price of the machine. For the hazelnut harvesting machine this value was taken as 25%. Variable expenses are linked to the working duration of tools and machines within 1 year (Keskin and Erdoğan, 1992).

Fuel costs are calculated from hourly fuel consumption. The amount of fuel consumed was identified from the full tank method for three repeats. The amount of oil consumed was taken as 4% of the fuel amount and multiplied by the unit cost of oil to calculate oil costs. The fuel unit cost was taken as 4.58 Turkish lira (TL) L^{-1} while the oil unit cost was 12.75 TL L^{-1}. Oil costs were determined as 4% of fuel consumption. The fee paid to laborers for 10 h of work on the hazelnut harvest in the region was taken as the basis to determine human labor costs. Calculations assumed that hand and mechanical processes were completed by one person. The 2013 harvest fee was 37 TL day^{-1} (3.7 TL h^{-1}) Repair and maintenance costs were ignored. The yearly working hours of the hazelnut harvesting machine were accepted as 200 h, determined from 20 days of harvest with 10 working hours per day (Beyhan, 1992). The sale price of the machine was 850 TL with a mean sale price for 1 kg of hazelnuts in 2013 of 5.90 TL.

2.3.4. Evaluation of foreign material collected by hazelnut harvesting machine according to type and diameter

To assess the type and diameter of foreign material sent to the hazelnut depot together with single and husked hazelnuts, six sieves with different numbers were used for analysis. With this aim, dust, soil, dry branch fragments, husk fragments, leaf fragments, and weeds were separated from collected hazelnuts (single + husked) and weighed separately. The weight of each component of foreign material was determined as a percentage of the total material amount (Yıldız, 2000).

3. Results

3.1. Results of traditional pick-up methods

The values obtained in this research were set according to a standard parcel of 1 ha in size measuring 66.67 m × 150 m to determine labor requirements and work efficiencies (Yıldız, 2000). According to this, basic time (BT), auxiliary time (AT), principal time (PT), and unavoidable time loss (UTL) and working efficiency per unit area (WPA) are organized as h ha^{-1} and given in Table 3. As seen in Table 3, the human labor requirements for a linearly planted orchard have the lowest value of 180.17 UHLP h ha^{-1} for the first method. For the second method this value is 262.42 UHLP h ha^{-1}. In the brush-planting system the fourth method required the lowest value of 157.39 UHLP h ha^{-1}. This was followed by other values of 172.69 UHLP h ha^{-1} for the third method, 174.58 UHLP h ha^{-1} for the fifth method, and 523.46 UHLP h ha^{-1} for the sixth (control) method. Accordingly, when compared with the control group, the orchard with a linear planting system allows savings in human labor power of 65.58% for the first method and 49.87% for the second method. Within the traditional pick-up methods in a brush orchard compared to the control, or the sixth method, the fourth method provides savings of labor power of 69.93%, the third method saves 67.01%, and the fifth method saves 66.65%.

Table 3. Times, labor requirements, and work efficiencies of traditional pick-up methods.*

Labor requirements	Time segment	Linear planting system		Brush-planting system			
		1st method	2nd method	3rd method	4th method	5th method	6th method (control)
Standard basic time (BT) (h ha^{-1})	tBT_1 (Shaking time)	2.86	6.59	5.30	1.94	9.02	-
	tBT_2 (Row-gathering time)	27.33	-	29.33	31.88	-	-
	tBT_3 (Time to collect from the ground by hand)	54.64	70.36	34.37	36.60	40.72	110.82
	tBT_4 (Time to collect remainder from the branch by hand)	24.11	84.60	34.50	12.83	55.53	104.84
	tBT_5 (Time to collect remaining hazelnuts within brush)	24.22	33.29	25.33	29.30	24.35	173.00
Total basic time (ΣBT) (h ha^{-1})		133.16	194.84	128.83	112.55	129.62	388.66
Standard auxiliary time (h ha^{-1})	tAT_1 (Breakfast time)	9.04	12.99	8.43	8.65	8.64	25.91
	tAT_2 (Journey time)	9.04	12.99	8.43	8.65	8.64	25.91
	tAT_3 (Break time-morning)	4.52	6.49	4.21	4.33	4.32	12.96
	tAT_4 (Lunch time)	18.08	25.98	16.85	17.30	17.28	51.82
	tAT_5 (Break time-afternoon)	4.52	6.49	4.21	4.33	4.32	12.96
	tY_6 (Moving between rows-brushes)	0.03	0.04	0.02	0.02	0.02	0.06
Total auxiliary time (ΣAT) (h ha^{-1})		45.23	64.98	42.15	43.27	43.23	129.62
Principal time (PT) (h ha^{-1})		178.39	259.82	170.98	155.83	172.85	518.28
Unavoidable time losses (UTL) (h ha^{-1})		1.78	2.60	1.71	1.56	1.73	5.18
Effective working time (EWT) (UHLP h ha^{-1})**		180.17	262.42	172.69	157.39	174.58	523.46
Working efficiency per unit area (WPA) (ha UHLP h^{-1})		0.0056	0.0038	0.0058	0.0064	0.0057	0.0019
Working speed (brush h^{-1})		-	-	2.32	2.56	2.28	0.76
Utilization coefficient UC_z (%)		74.25	74.23	74.60	71.51	74.25	74.25

*All procedures accepted as being completed by one person.

**: UHLP h ha^{-1}, unit of human labor power in hour per hectare.

The efficacy of different traditional pick-up methods compared to the control group is given in Table 4. When the data in Table 4 are examined, considering the collected amount with each method and the working time to collect, it is clear that the first method for linear planting and the third method for brush planting are the most efficient pick-up methods. Especially when compared with the control group, the first method is 12.80 times more efficient for linear planting, while the third method is 10.95 times more effective for brush planting.

The area work efficiency rates of traditional methods used for hazelnut pick-up are different due to differences in effective working times. As seen in Table 3, the highest area work efficiency in the linear planting system is 0.0056 ha h^{-1} obtained using the first method. In the orchard with brush-planting system, the area work efficiency is 0.0064 ha h^{-1} with the fourth method.

Under the conditions in the orchard used for trials with the brush-planting system, when the working speeds for hazelnut pick-up using traditional methods are examined, the fourth method produced the highest speed of 2.56 brush h^{-1} and this was followed by 2.32 brush h^{-1} for the third method and 2.28 brush h^{-1} for the fifth method (Table 3).

3.2. Results of mechanical pick-up methods

In trials using the back-pack harvesting hazelnut machine and three different pick-up methods, the labor requirements and work efficiencies are evaluated according to a standard parcel of 1 ha and given in Table 5. When Table 5 is examined, the lowest value of 109.82 h ha^{-1} labor requirement is observed with the third method. This is followed by the first method with 115.54 h ha^{-1} and the third method with 128.21 h ha^{-1}.

The efficiency coefficient for pick-up by machine using different methods compared to the control group is given in Table 6. Data in Table 6 clearly show that the third method for hazelnut pick-up by machine is 86.34 times more efficient compared to the control group with collection by hand from the branches, and it is the most effective method among all pick-up methods. Comparing the machine pick-up methods with traditional pick-up methods, while the traditional pick-up methods obtained an average value of 2.79 kg h^{-1}, pick-up by machine provided a mean total amount of 27.68 kg h^{-1}. Again, when the values related to utilization coefficient (UC_z) given in Tables 3 and 5 are examined, it appears that the highest value was obtained for traditional hazelnut pick-up methods. Contrary to this, work with the pneumatic hazelnut harvesting machine was completed with lower levels of time utilization coefficient.

3.3. Results of expenses related to traditional and mechanical pick-up

Expenses related to trials of traditional methods and machine pick-up are given in Table 7. As observed in Table 7, of the traditional pick-up trials, the fourth method requires less expense compared to other methods with a value of 5283.43 TL ha^{-1}. When compared to the control group, the fourth method appears to be 3.67 times more efficient than other methods. This is followed by the third method, fifth method, first method, and second method. The fixed expenses of mechanical pick-up are 1.06 TL h^{-1}, while fuel costs are 9.76 TL h^{-1}, oil costs are 0.39 TL h^{-1}, and personnel costs are 3.7 TL h^{-1}. Accordingly the total expenses for working with the hazelnut harvesting machine are 14.91 TL h^{-1}.

For machine pick-up, the third method was the method with the lowest expenses of 1637.42 TL ha^{-1}. Compared with the control group, the first method appeared to be 16.54 times more efficient compared to other methods. The hazelnut income obtained per unit time with traditional methods was 30.98 TL h^{-1} with pick-up of 35.40 kg h^{-1} for the linear planting system and 26.49 TL h^{-1} with pick-up of 5.25 kg h^{-1} for the brush-planting system. For machine pick-up, the pick-up from rows gathered by garden rake (third method) in trials was 208.86 TL h^{-1}.

Table 4. The efficacy of different traditional pick-up methods compared to the control group.

Methods	kg ha^{-1}	EWT (h ha^{-1})	kg h^{-1}	Coefficient of efficiency compared to the control group
1st method	817.36	155.58	5.25	12.80
2nd method	471.62	221.18	2.13	5.20
3rd method	631.97	140.60	4.49	10.95
4th method	208.90	174.76	1.20	2.93
5th method	558.18	173.04	3.23	7.88
6th method (control)	182.17	446.48	0.41	1.00
Average	478.37	218.61	2.79	

Table 5. Times, labor requirements, and work efficiencies of mechanical pick-up methods.*

Labor requirements	Time segments	Pick-up from ground by machine vacuum	Pick-up from rows gathered by scrub rake	Pick-up from rows gathered by rake
Standard basic time (h ha^{-1})	tBT_1 (Shaking time)	8.66	6.89	6.44
	tBT_2 (Pick-up time by vacuuming from the ground)	26.70	24.31	21.17
	tBT_3 (Pick-up time from branches by hand)	27.22	28.29	24.65
	tBT_4 (Pick-up time within row-brush)	17.60	29.30	23.87
Total basic time (∑BT) (h ha^{-1})		80. 18	88.78	76.13
Standard auxiliary time (h ha^{-1})	tAT_1 (Time to move between row-brush)	0.0128	0.0204	0.0149
	tAT_2 (Time to fill tank)	0.7454	0.9141	0.8233
	tAT_3 (Time to shoulder hazelnut harvesting machine)	0.1722	0.2072	0.1551
	tAT_4 (Time to start motor)	0.0475	0.0592	0.0592
	tAT_5 (Time for oil and fuel to mix)	0.1169	0.1480	0.1066
	tAT_6 (Time to empty hazelnut depot)	0.2910	0.2828	0.2227
	tAT_7 (Time to gather rows by blowing/with scrub rake/with garden rake)	0.7137	0.9436	0.7173
	tAT_8 (Breakfast time)	5.3453	5.9198	5.0750
	tAT_9 (Journey time)	5.3453	5.9198	5.0750
	tAT10 (Morning break time)	2.6726	2.9594	2.5375
	tAT_{11} (Lunch time)	10.6905	11.8376	10.1501
	tAT_{12} (Afternoon break time)	2.6726	2.9594	2.5375
Total auxiliary time (∑AT) (h ha^{-1})		28.83	32.17	27.47
Principal time (PT) (h ha^{-1})		109.00	120.95	103.60
Unavoidable time losses (UTL) (h ha^{-1})		6.54	7.26	6.22
Effective working time (EWT) (MPh ha^{-1})**		115.54	128.21	109.82
Working efficiency per unit area (WPA) (ha MPh^{-1})		0.0087	0.0078	0.0091
Working speed (brush h^{-1})		3.48	3.12	3.64
Utilization coefficient UC_z (%)		69.39	69.25	69.32

*All procedures accepted as being completed by one person.
**MPh ha^{-1}, machine power hours per hectare.

Table 6. Efficiency of mechanical pick-up methods compared to control group.

Methods	kg ha^{-1}	EWT (h ha^{-1})	kg h^{-1}	Coefficient of efficiency compared to the control group
1st method	3210.90	115.54	27.79	67.78
2nd method	2545.30	128.21	19.85	48.41
3rd method	3888.10	109.82	35.40	86.34
Average	3214.77	117.86	27.68	

Table 7. Expense values for different harvest methods.

		Total costs		Coefficient of efficiency compared to the control group
		TL brush^{-1}	TL ha^{-1}	
Traditional harvest	1st method	16.67	6666.29	2.91
	2nd method	24.27	9709.54	1.99
	3rd method	15.97	6389.53	3.03
	4th method	13.21	5283.43	3.67
	5th method	16.15	6459.46	3.00
	6th method (control)	48.42	19368.02	1
Mechanical harvest	1st method	4.43	1770.70	16.54
	2nd method	4.78	1911.61	10.13
	3rd method	4.09	1637.42	11.83

3.4. Results related to foreign material collected with hazelnuts by mechanical pick-up

The distribution of collected foreign material according to diameter by the hazelnut harvesting machine is given in Table 8.

When the percentages of foreign material given in Table 8 are examined, the highest percentage was for the 12-mm-diameter group (32.41%) for the first method, the 5.5-mm-diameter group (22.55%) for the second method, and the 24-mm-diameter group (23.26%) for the third method.

Sieve analysis showed that the 2-mm-diameter and 5.5-mm-diameter groups consisted of fine dust and soil fragments, leaf fragments, thin branch fragments, and husk fragments. The 8.5-mm-diameter foreign material was soil fragments, dry branch fragments of 2–6 mm long and 2–5 mm thick, weeds, dry leaves, and green plant fragments.

The majority of 12-mm-diameter foreign material was soil and dust pieces, dry branch fragments 3–7 cm long and 1–5 mm thick, dry leaves, husks, and plant fragments. The 21-mm-diameter group was soil and dust together with dry branch fragments of 1–10 cm long and 1–10 mm in diameter, dry branch fragments 1–4 mm thick and 5–6 cm long, branch fragments 1–8 mm in diameter and 1–20 cm long, fresh and dry leaf fragments, weeds and husk fragments, and rotten hazelnuts from the previous year.

The largest diameter group (24 mm) comprised soil fragments, dry branch fragments 2–35 cm long and 2–15 mm thick, branch fragments 3–20 cm long and 1–8 mm diameter, root fragments with diameter of 1.5 cm and length of 7 cm, leaves, weeds, and husk fragments.

4. Discussion

This study researched 6 different traditional hazelnut pick-up methods and 3 different mechanical pick-up methods in terms of labor requirements, work efficiencies, and total costs. The results obtained in the study may be summarized as follows:

1) Within traditional pick-up methods, the lowest human labor requirements (180.17 h ha^{-1}) in an orchard with a linear planting system were obtained for the method

Table 8. Distribution of collected foreign material according to diameter by the hazelnut harvesting machine.

	Sieve numbers and diameters						Total
	1 (2 mm)	2 (5.5 mm)	3 (8.5 mm)	4 (12 mm)	5 (21 mm)	6 (24 mm)	
	Percentage						
Methods	(%)	(%)	(%)	(%)	(%)	(%)	(%)
1st method	8.11	11.41	14.69	32.41	29.66	3.72	100
2nd method	12.54	22.55	18.66	13.81	19.74	12.70	100
3rd method	11.96	19.00	17.86	15.82	12.10	23.26	100

involving Ethrel administration, hand-shaking, and rows being gathered by garden rake (first method). For the brush-planting system orchard the lowest value (157.39 h ha^{-1}) was obtained with the method with no Ethrel administered, hand-shaking, and rows being gathered by scrub rake (fourth method).

2) In terms of work efficiencies the best values were obtained for the first method for the linear system (0.0056 ha h^{-1}) and for the fifth method for the brush system (0.0058 ha h^{-1}).

3) In terms of time utilization coefficient, the different pick-up methods with the hazelnut harvesting machine obtained lower levels compared to the different traditional hazelnut pick-up methods. The reason for this may be explained with the nonproductive time segment; that is, high amounts of time were spent apart from hazelnut pick-up. Additionally, as the fuel tank of the hazelnut harvesting machine has low capacity, the rapid emptying of the fuel increased auxiliary time requirements.

4) In trials of different methods of traditional pick-up, the lowest value for total harvest costs was obtained for the method with Ethrel administered and rows gathered by garden rake in the linear system (first method) (6666.29 TL ha^{-1}). For the brush-planting system the lowest value was for the fourth method with 5283.43 TL ha^{-1}. In the brush system with the mechanical pick-up method, the lowest value was 1637.42 TL ha^{-1} for the pick-up method with rows gathered by garden rake (third method).

5) Amounts of hazelnuts obtained per unit time for traditional methods were 5.25 kg h^{-1} for the first method in linear planting and 4.49 kg h^{-1} for the third method in brush planting. For machine pick-up, the amount was 35.40 kg h^{-1} for pick-up with rows gathered by garden rake (third method). Accordingly, the hazelnut harvesting machine can collect the amount that 6.74 people can collect traditionally.

6) High human labor requirements are caused when bottom suckers are more plentiful and brambles and other weeds and thorny plants grow around brushes and rows.

Based on the observations during the research trials, the following may be stated. Gathering with a scrub rake is more difficult, especially in areas where weeds grow more intensely. Additionally, in areas where bottom suckers have been cleared, if brambles and other weeds are cut high it is difficult to use the brush to gather rows. Another factor preventing brushing is uneven ground, like tractor tire tracks between rows. Gathering with a garden rake is easier than with a scrub rake. However, in areas where tree branches are low, gathering with a scrub or garden rake is more difficult. Additionally, it is difficult to rake in areas with more weeds. Hazelnut suckers between brushes and rows make pick-up by hand or machine more difficult. As a result, before the harvest begins, it is necessary to first perform general clearing of the hazelnut orchards. As the region is generally rainy, density of weeds and other thorny plants grows rapidly, and just as this makes the harvest more difficult, it causes the loss of fallen hazelnuts. As a result, about 1 week before starting the harvest, clearing of the orchards should be performed to reduce human labor requirements and increase work efficiencies.

Acknowledgment
I am very grateful to Prof Dr Mehmet Arif Beyhan, who is Head of the Agricultural Machinery Department of the Agricultural Faculty of Ondokuz Mayıs University, for the generous support of this research.

References

Aktaş AR, Öztürk E, Hatırlı SA (2011). Analysis of profit inefficiencies in Turkish hazelnut agriculture. Journal of Agricultural Sciences 17: 230–240 (in Turkish with abstract in English).

Beyhan MA (1992). Ülkemiz koşullarına uygun aspiratörlü bir fındık hasat makinasının tasarım ve imalatı. PhD, Ankara University, Ankara, Turkey (in Turkish).

Beyhan MA (1996). The determination of the possibility of using an eccentric type limb shaker in the mechanical harvesting of the hazelnut. In: Proceedings of the Agricultural Education 150th Anniversary, Hazelnut and Other Nuts Symposium, 10–11 January 1996, Ondokuz Mayıs University Agriculture Faculty, Samsun, Turkey, pp. 212–225.

Beyhan MA, Pınar Y (1996). An investigation of using a mechanical scrub-clearing tool at desuckering of hazelnut. In: Proceedings of the Agricultural Education 150th Anniversary, Hazelnut and Other Nuts Symposium, 10–11 January 1996, Ondokuz Mayıs University Agriculture Faculty, Samsun, Turkey, pp. 119–133.

Beyhan MA, Yıldız T (1996). Methods in applied mechanical harvesting of hazelnut and other nuts. In: Proceedings of the Agricultural Education 150th Anniversary, Hazelnut and Other Nuts Symposium, 10–11 January 1996, Ondokuz Mayıs University Agriculture Faculty, Samsun, Turkey, pp. 183–194.

Bolli P, Scotton M (1987). Lineamenti di tecnica della meccanizzazione agricola. 1st ed. Bologna, Italy: Edagricole (in Italian).

Caran D (1994). Zeytinde mekanik hasat olanaklarının araştırılması. PhD, Ege University, İzmir, Turkey (in Turkish).

Dinçer H (1976). Tarım İşletmelerinde Makina Kullanma Masrafları. Ankara, Turkey: Türkiye Zirai Donatım Kurumu Mesleki Yayınları (in Turkish).

Güner M, Dursun E, Dursun IG (2003). Mechanical behaviour of hazelnut under compression loading. Biosyst Eng 85: 485–491.

İlkyaz H (1986). Doğu Karadeniz Bölgesi'nde Çay ve Fındığın Üretim Girdi ve Maliyetleri. Samsun, Turkey: Tarım Orman ve Köyişleri Bakanlığı, Köy Hizmetleri Araştırma Enstitüsü Müdürlüğü Yayınları (in Turkish).

Kadayıfçılar S, Dinçer H (1972). Ziraat Makinaları İşletmeciliği II. Cilt. Ankara, Turkey: Ankara Üniversitesi Ziraat Fakültesi Yayınları (in Turkish).

Kadayıfçılar S, Erdoğan D (1988). Meliorasyon Makinaları. Ankara, Turkey: Ankara Üniversitesi Ziraat Fakültesi Yayınları (in Turkish).

Keskin R, Erdoğan D (1992). Tarımsal Mekanizasyon. 2nd ed. Ankara, Turkey: Ankara Üniversitesi Ziraat Fakültesi Yayınları (in Turkish).

KİBGS (2008). Karadeniz İhracatçı Birlikleri Genel Sekreterliği Kayıtları. KİBGS: Giresun, Turkey (in Turkish).

Kılıç O (1997). Samsun İli Çarşamba ve Terme İlçelerinin ova köylerinde fındık üretimine yer veren tarım işletmelerinin ekonomik analizi ve fındığa alternatif üretim planlarının araştırılması. PhD, Ankara University, Ankara, Turkey (in Turkish).

Tekgüler A, Yıldız T, Sauk H (2015). Determination of spring rigidity and fruit detachment force in Yomra variety hazelnut trees. Agricultural Mechanization in Asia, Africa & Latin America 46: 13–16.

Thompson MM, Lagerstedt HB, Mehlenbacher SA (1996). Hazelnuts. In: Janick J, Moore JN, editors. Fruit Breeding, Volume III. Nuts. New York, NY, USA: John Wiley and Sons, pp. 125–184.

USDA (2014). USDA Foreign Agricultural Service, Global Agricultural Information (GAIN) Network, 2014 Turkey Tree Nuts Annual, GAIN Report Number: TR 4037. Washington, DC, USA: USDA.

Yıldız T (2000). Traktörle çalıştırılabilir-yerden toplama üniteli bir fındık hasat makinasının tasarımı. PhD, Ankara University, Ankara, Turkey (in Turkish).

Yıldız T, Tekgüler A (2012). Eksantrik tipli silkeleyiciyle fındık hasadında iş başarılarının belirlenmesi. In: 27. Tarımsal Mekanizasyon Ulusal Kongresi Bildiri Kitabı, 5–7 September 2012, Samsun, Turkey, pp. 332–339 (in Turkish).

Yıldız T, Tekgüler A (2014). 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). Journal of Agricultural Sciences 20: 38–47.

Zimbalatti G, Benalia S, Bernardi B, Proto AR, Smorto D (2012). Hazelnuts mechanical harvesting in Calabria: preliminary trials on work productivity. In: "Safety, Health and Welfare in Agriculture and in Agro-food Systems" International Conference, 3–6 September 2012, Ragusa, Italy, pp. 104–109.